9th Central European Conference 2017

Fibre - Grade Polymers, Chemical Fibres and Special Textiles

September 11th-13th 2017, Liberec, Czech Republic

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ISSN: 1335-0617

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ISSN 2350-3696
UDK 677+689(05)

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Editor: Veronika Tunáková

ISBN 978-80-7494-356-0

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SQUARING THE CIRCULAR ECONOMY: TEXTILE REDESIGN

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Abstract: *Today's linear economy, in existence since the start of Industrial Revolution, typically utilizes resources to make products that are soon discarded mostly in landfill i.e. "take, make and dispose". The model is based on the assumption that resources are abundant, available, easy to source and cheap to dispose of. Fashion, perhaps more than any other industry in the world, embraces obsolescence as a primary goal. The recent 'Fast Fashion' phenomenon exemplifies this goal; in producing low-cost clothing in high volumes it is, by its very nature, a fast-response system that encourages disposability. Unfortunately, this model is unsustainable. It is an undisputable fact that resources on this planet are ultimately finite. This is leading to forecasted resource scarcity, sharp increase in raw material prices, reduction in material grade quality, and price volatility. The consequences are far reaching and include hazardous environmental impact of textile fiber production, both upstream and downstream, high energy and water usage (in the production of fibers and the laundry use-phase), the use of toxic chemicals, the release of chemicals in waste water (wet pre-treatment, dyeing, finishing and laundry) and the inefficient disposal of solid textile waste that arises in the manufacturing/production stage and at end-of-life. This strategy of resource consumption, a surprisingly wasteful model of value creation, is leading to decline in prosperity. We must develop innovative concepts towards high resource productivity with zero waste as a potential solution that will move the industry toward a sustainable future.*

A more resource savvy strategy for textiles, which currently has a dismal recycling record of about 12%, is the concept of a Circular Economy. Here, the biological and technical/mineral nutrients of modern society continuously circulate with a high rate of raw material utilization. The materials are recycled infinitely without losing value. Circular systems keep the added value in products for as long as possible and eliminate waste. Therefore, in a circular textiles industry, a garment that has reached the end of its life is kept within the economy, so that they can be productively used again and again and hence create further value.

A circular textile industry based on high value recycling into new textiles will enable the continuation of fiber consumption without depleting our natural resources or negatively impacting the ecosystems that we are dependent on, thus providing resource security and long term price stability for resources within the context of a thriving environment.

Thus, textile as an industrial sector, must seek to rebuild capital - financial, manufactured, human, social or natural. Under this system, the production of goods operates like systems in nature, where the waste and demise of materials becomes the food and source of growth for something new. It is not just sustainability, recycle, reuse and recovery on steroids but a smarter, more regenerative and restorative way to create use and dispose of products that designs out waste – a critical component to delink increase in growth from resource utilization. In absence of this countries will face a bleak and uncertain future with dependence on resources from overseas. Instead, we need to develop technologies towards self-sufficiency in energy and water and keep materials flowing required for consumption. This will ensure the reduction in virgin resources and will treat waste as a valuable input rather than a burden for welfare of society and the environment. The paper will address the main issues of how we got here, how to eliminate waste, breakthroughs required, the key drivers and enablers, the critical role of design, and the business models for a successful outcome. Case studies of companies currently using this strategy will be illustrated.

Keywords: *Textiles, circular economy, key drivers, circular thermodynamics, recycling*

TEXTILE SENSORS IN TEXTILE REINFORCED COMPOSITES

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Abstract: *Composite materials in transport industry such as automotive, railway and aerospace are required to be developed with respect to the technical performance, weight reduction, fuel consumption and adapted prices for the market. Conductive yarns as sensors are usually integrated in textile structures by weaving, knitting or braiding technology. However, their integration in structures is a complex process. Recently, interest has focused on the possibility to develop sensors based on conductive polymers. In this work, new poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) textile sensors were developed by using a novel roll to roll coating method and integrated during weaving of 2D fabric. Electromechanical measurements of finally developed composites were performed. Textile sensors showed possibility to follow the tensile loading and damage detection in the composites in situ.*

Keywords: *smart textile, textile sensor, textile reinforced composite, electromechanical measurements*

1 INTRODUCTION

Composite materials in transport industry such as automotive, railway and aerospace are required to be developed with respect to the technical performance, weight reduction, fuel consumption and adapted prices for the market. A number of metallic parts can be replaced by textile reinforced composites and each step of their production must be monitored to ensure the high quality level products [1]. Smart textile approach in order to realize fibrous sensors compatible with composite technology is a very promising solution for *in situ* health monitoring of composite parts [1,2] Conductive yarns as sensors are usually integrated in textile structures by weaving, knitting or braiding technology. However, their integration in structures is a complex process [2-5]. Recently, interest has focused on the possibility to develop sensors based on conductive polymers.

Conductive polymers are defined as organic polymers able to conduct electricity, exhibiting a conductive or a semiconductive behavior. They combine some of the mechanical features of plastics with the electrical properties typical for metals. The most attractive in a group of these polymers are polyaniline (PANI), polypyrrole (PPy) and poly(3,4-ethylenedioxythiophene) (PEDOT). They show high electrical conductivity and environmental stability, they are synthesized easily, but have poor mechanical properties. The solubility problem of PEDOT was circumvented with poly(styrenesulfonate) (PSS), a water-dispersible polyelectrolyte used as a charge balancing counterion during oxidative polymerization of the 3,4-ethylenedioxythiophene (EDOT) monomer. This yielded poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS) polymer complex. The properties of this complex can be adjusted with the addition of organic co-solvents, surfactants, wetting agents, to the aqueous coating mixture to improve the coatability of the polymer on hydrophobic substrates and mechanical properties. Secondary dopants can be added in small amounts (glycerol, N-methylpyrrolidone, ethylene glycol) [3].

In a previous work [2], PEDOT:PSS textile sensors worked after its production and integration in 2D weaving structures (electrical resistance values ~100 kΩ). Sensors validation after consolidation of 2D fabrics needed to be improved by giving positive electrical resistance responses and opportunities for usage in textile structures *in situ* during tensile loading.

2 MATERIALS AND METHODS

2.1 Textile sensors and composites production

New textile sensors were developed from E-glass/polypropylene (GF/PP) commingled yarn, *PD Fiberglass*, by using a novel *roll to roll* coating method and laboratory device developed in GEMTEX laboratory, ENSAIT, France. According to percolation threshold study, two conductive coatings of aqueous dispersion, 8% PEDOT:PSS CLEVIOS F ET/Latex Appretan 96100, were applied to neat commingled yarn between protective coatings of acrylic esters, Latex Appretan 96100 dispersion [6].

Two textile sensors per coupons (three cases) were integrated during weaving of 2D fabric at the ARM computer controlled hand weaving loom, 4-end satin with repetition, warp density, 4 ends/cm and weft density, 6 ends/cm, fabric thickness ~2.660 cm (coupons cutting by scissor) (Fig. 1).

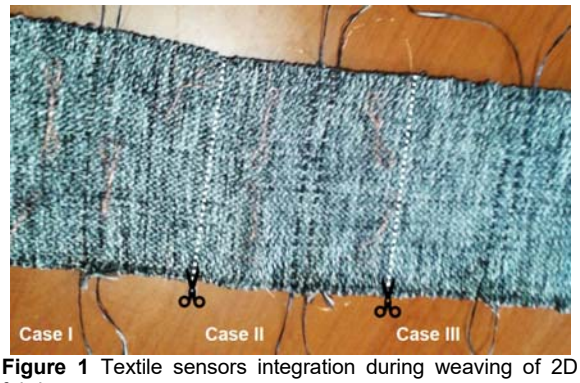

Figure 1 Textile sensors integration during weaving of 2D fabric

Table 1 Conditions of thermal consolidation of 2D fabric with integrated textile sensors

Three layered 2D fabric	GF/PP
Integrated textile sensors	GF/PP
Temperature (°C)	185
Pressure (bar)	30-40 or 40-50
Time of cooling at 100°C (min)	2-3

Textile sensors have to show resistance to high temperature and pressure to obtain *in situ* structural health monitoring of textile reinforced 2D thermoplastic composites during tensile loading. Three layers of 2D weaving fabrics with the middle layer with integrated textile sensors were consolidated at the heating press (Dolouets, France) during 5 min under strict conditions presented in Table 1. Dimensions of developed composites were 8 x 21 x 1.5 cm^3.

2.2 Electrical resistance and electromechanical measurements

Electrical resistance of sensors was measured after their development, before, and after consolidation of 2D textile preforms by using a Keithley® KUSB data acquisition digital I/O counter/time and resistance box connected with a computer (QuickDAQ software).
The tensile measurements of three layered developed textile reinforced 2D thermoplastic composites were performed according to the test standards DIN EN ISO 527-1 and DIN EN ISO 527-4 on the Instron 5900 testing machine. The tensile experiments were performed with a speed of 2 mm/min, and 115 mm difference between clamps. Electrical resistance measurements of two textile sensors per coupon have been done simultaneously by using a Keithley® KUSB data acquisition digital I/O counter/time as well and two resistance boxes connected with a computer (QuickDAQ software) (Fig. 2).

3 RESULTS AND DISCUSSION

3.1 Electrical resistance of textile sensors

Electrical resistance of textile sensors is in range between 610-660 Ω measured after their development and 640-865 Ω before consolidation of 2D textile preforms. Depending on the sensors integration in 2D fabric and consolidation conditions electrical resistance was changed significantly from 24-42 Ω and 320 Ω-10 MΩ as mean values of three cases.

3.2 Electromechanical measurements of composites

Textile sensors showed possibility to follow the tensile loading and damage detection in the composites. According to electromechanical measurements of textile reinforced composites with integrated textile sensors gauge factor was determined from a polynomial equation of degree 2. Fractures of composites were accompanied by cracking sounds and slight changes in the electrical resistance variations versus elongation curves. Several interruptions due to beginning of the delamination and cracks inside the composite were noticed in some cases as well.

Figure 2 Textile reinforced composite with integrated textile sensors during electromechanical measurement

***ACKNOWLEDGEMENT**: The paper is a part of the results of the EU project "MAPICC 3D" within the call NMP-FP7-2010-3.4-1, numbered with 263159 entitled: One-shot Manufacturing on large scale of 3D up graded panels and stiffeners for lightweight thermoplastic textile composite structures. The authors would like to thank the European Commission for funding this project.*

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CAN COMPOSITE PARTS COMPETE WITH OTHER MATERIAL CHOICES IN THE HEAVY DUTY AUTOMOTIVE INDUSTRY, FROM AN ENVIRONMENTAL PERSPECTIVE?

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Abstract: *Environmental aspects for the heavy duty (HD) automotive industry is reviewed and discussed with regard to decrease of the total environmental impact from vehicles. Life Cycle Assessment (LCA) is discussed as a method for assessing the environmental impact for a product's life cycle from the cradle to the grave. Examples of the pros and cons for light-weight materials like aluminium, lightweight steel, thermosets and thermoplastic composites are listed. The assessment of the environmental impact of light-weight materials is complex and the conclusion is that composite materials can compete with other materials under certain conditions.*

Keywords: *lightweight materials, composites, heavy-duty automotive industry, Life Cycle Assessment (LCA)*

1 INTRODUCTION

In the middle of the 90s, researchers were working with methods for the assessment of the environmental impact for the lifecycle of products and processes [1]-[2]. In the beginning, lack of data on raw materials and processes was the largest obstacle, as well as the need for setting up well-defined system boundaries to enable comparisons [3].

The automotive industry was early to make assessments and to tailor-make a simplified valuation method into a tool to enable potential reduction of the environmental impact when new parts or models were developed [4].

Today, the situation is different, a number of software have been developed and input data on raw materials and processes are more readily available in databases, but still only for the more common materials. Hence, it is possible to use LCA for decision-making as long as the alternative parts or processes have the same system boundaries and similar quality of the input data.

The first LCA:s made by the automotive industry pointed out that the use phase had the highest environmental impact, due to the fuel consumption during the lifetime of the vehicle [5][6]. Hence, the reduction of emissions of carbon dioxide from the use phase was in focus for many years [7].

The aim of this paper is to explain some of the complexity when assessing environmental impact of products and processes in the heavy duty (HD) automotive industry (distribution to long-haul trucks).

2 METHOD

General conclusions for the HD automotive industry is discussed, based on general experiences and examples of previous LCA:s [5]-[6],[8]-[10].

3 RESULTS AND DISCUSSIONS

3.1 Examples of ways to decrease the environmental impact from HD vehicles

A lot of effort has been put into the reduction of emissions of carbon dioxide, from fuels, over the years [5][7]. In parallel, research on the development of alternative fuels, e. g from renewable sources, as well as on lightweight materials, which reduces the actual fuel consumption, has been on-going. Hence, there are many aspects that should to be taken into consideration when research has moved into the area of hybrid technology and electromobility. The use of resources will become more important as the emissions of carbon dioxide decreases.

3.1.1 Decrease emissions of carbon dioxide

Decrease of emissions of carbon dioxide has been in focus for a long time. The most important solutions are the development of alternative fuels and drivelines. The decrease of the total weight of the vehicle is also a factor that influences the emission of carbon dioxides due to lower fuel consumption.

3.1.2 Decrease weight of vehicle

One of the solutions to achieve a decrease in weight is to use lightweight materials, like composites or lightweight metals. Lower vehicle weight makes room for more goods to be transported by the same vehicle. A distribution truck will benefit more from a decrease of weight, due to the many starts and stops that are made during the day, than a long-haul truck when all other parameters are kept at the same level. Lightweight materials for HD vehicles include composites and light weight metals and the choice depends on the technical requirements of the parts and the corresponding physical and chemical properties of the lightweight materials.

3.2 Environmental assessment

LCA methodology has been developed and used for more than 20 years. However, it is still common that comparisons of alternative materials for products are made at the end of the development cycle, when all choices have already been made, based on other requirements. If LCA could be used earlier in the development cycle, potential gains could be made in the forms of improved technical solutions, introduction of other material with lower impact, etc.
Common methods for evaluation of LCA:s, for the automotive industry, are on three levels as seen in Table 1.

Table 1 Common assessment categories for the automotive industry [1]. "Emissions", i. e. carbon dioxide (CO_2) emissions, are normally a measured quantity. "Equivalents", is used to make the different impacts of the emissions equal, by using a factor for its importance. Then, the "equalized" emissions are added together. "Valuation", an estimation of the value for society and what they would pay to remedy the effects of i. e. mining of resources.

Methods	Level 1-3		
	Emissions	***Equivalents***	***Valuation***
Carbon dioxide	X		
- Global Warming Potential (GWP) - Acidification (AP) - Photochemical Ozone Potential (POCP)		X	
Environmental Priority Strategies (EPS) [2][4]			X

3.3 Lightweight material choices

There are two main classes of lightweight materials, metals and composites. Normally, the choice is based on technical requirements of the product and cost. In that sense, what would the environmental perspective add? The materials all have pros and cons over the life cycle, which might not be taken under consideration as it is outside the responsibility of the product developer (see Table 2). For a completely sustainable product, all life cycle stages must be environmentally sound.

Table 2 Examples of pros and cons for lightweight materials over the lifecycle. NOTE The list is not exhaustive.

Materials	Environmental perspective	
	Pros	***Cons***
Aluminium	Well-known material, Durable, Material recyclable, down-cycling may be avoided	Energy consumption high for virgin material
Lightweight steel	Well-known material, Material recyclable , down-cycling may be avoided	Corrosion protection May contain important alloying elements that may get lost during recycling
Thermosets	Almost any desired shape possible Sandwich structures of various materials possible	Expensive moulds Long lead-times Manual handling Hazardous chemicals Down-cycling to filler material Product need to be changed, if crashed Painted surfaces (A-class quality) may be difficult
Thermoplastic composites	Recycling possible by remelting Lead-times may be shortened by creation of 3D-knitted/woven shapes [10]	Expensive moulds Product need to be changed, if crashed Painted surfaces (A-class quality) may be difficult

4 CONCLUSIONS

In some cases, the composite could challenge the metal alternatives, but it depends on many factors like i. e.

- Durability
- Costs
- Laws and regulations regarding Substances of Very High Concern (SVHC)
- Expected lead-times at production
- Expected maintenance, does the whole product need to be changed if there is an incident?
- Recyclability of the product with regard to volumes of scrap, recyclability method and revenue from selling the scrap.

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THE REVIEW OF THE TECHNOLOGIES OF CHEMOSENSORY NONWOVEN FABRICS

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Abstract: *The paper presents the different techniques of the manufacturing of smart nonwoven fabrics possessing the sensory properties. Two main methods of functionalization of nonwoven fabrics are discussed i.e. manufacturing the nonwoven fabrics directly from polymers solutions or polymer melts and printing of nonwoven substrates. The common solution of discussed technologies is the application of electrically conductive nano-additives in a form of carbon nanotubes to impart the chemo-sensory properties of developed nonwoven fabrics.*

Keywords: *melt-blown; electrospinning; sensors of vapours; textile sensors; carbon nanotubes*

1 INTRODUCTION

At the turn of the last few decades, a growing interest in technologies aimed at development of smart textile products can be noticed. Preparation of smart textiles is performed by making them functional by an incorporation into fibres specific, active materials, or by surface modification of textiles for example using printing methods [1-5]. In this work the electrical sensory properties of carbon nanotubes were used to functionalize nonwoven fabrics.

Melt-blowing techniques, and electrospinning technology is often used for the production of filter materials for respiratory protection against toxic molecules. Therefore the manufacturing of nonwoven fabrics for filtration materials which are sensitive to vapours can provide innovative approaches, which will deliver signals about concentration of toxic vapours in the air. The new generation of smart half-masks for the protection of respiratory tracks can be manufactured with the use of the newly developed nonwoven fabrics.

2 MATERIALS AND METHODOLOGY

2.1 Preparation of a nonwoven fabric of poly(lactic acid) by a melt blown technique with the addition of carbon nanotubes

While selecting an appropriate polymer for the construction of the sensor for chemical vapour the Hildebrandt and Flory - Huggins theory should be followed. According to this theory, in the case when a compound is influenced by solvent the solubility parameters of the polymer and solvent used should be similar to observe the influence of the solvent on the polymer (swelling, dissolution). Based on the analysis of the Flory - Huggins solubility parameters, [2], the poly (lactic acid) (PLA) was selected for manufacturing the polymeric sensor produced with melt blown technique. The special masterbatches of PLA with incorporated multi-walled carbon nanotubes (MWCNT) were produced. For 4060D PLA polymer, conductive nonwoven fabrics containing 2% MWCNT was obtained [2]. Nanotubes used were characterized by purity at 90%, and the dimensions of 9.5 nm in diameter and 1.5 μm in length. Polymer selected was characterized by a molar mass of up to 87 000 Da and D-isomer content of 12% [2].

2.2 The nonwoven fabric prepared by electrospinning of poly (ethylene oxide) with the addition of carbon nanotubes

For the production of nonwoven fabrics by electrospinning polymer solution technique, poly (ethylene oxide) was selected (PEO), with the addition of multi-wall carbon nanotubes (MWCNT) [3]. Polymer used has a molar mass of 400 000 Da. In order to produce nonwoven fabrics with electrospinning technique, a solution of poly (ethylene oxide) in distilled water at a concentration of 5 wt. % was prepared and a homogenous 3% suspension of MWCNT with respect to the polymer volume was obtained. For manufacturing the electrospun nonwoven fabrics the electrostatic field was developed supplying the voltage of 15kV. The distance between the capillary and the drum was 20 cm [3].

2.3 The nonwoven fabrics prepared by printing method

For the preparation of the printing pastes, graphene pellets (GNP) were introduced at 1 %wt. to an aqueous dispersion of carbon nanotubes (Aquake AQ0301). The composite paste was placed in an ultrasonic tank SONIC 3 for 15 min, and then, aliphatic urethane acrylate, Beryl 2002, was added along with the Secure DP250 photo initiator, after which the system was mixed for 30 min using a magnetic stirrer RZR1. Prepared pastes were applied on a polypropylene (Maplin HP462R) spun-bonded nonwoven fabric. The printing process was realized by means of a screen printing machine with an automatic squeegee, MS-300FRO. Sheets of A4 were printed using a screen with a 49 mesh/cm^2. The obtained prints were fixed using the cross-linking process by exposing the sample to an IR emitter, type 1384 IR1 250 W Lamp for 30 min.

2.4 Methods of nonwoven fabrics assessment

Sensory tests for the determination of presence of solvent vapours in measured atmosphere were carried out using a laboratory measurement system constructed at the

Department of Material, Commodity Sciences and Textile Metrology [2-5]. The system allows for measurements of the humidity and temperature of the atmosphere prevailing in the system and introduction liquid vapour at a given concentration to the measuring chamber. Sensory sensitivity of produced nonwoven fabrics was investigated with the apparatus for measuring the electrical conductivity of flat samples of nonwoven fabrics incorporated to the measuring chamber. The sensory properties of the produced nonwoven fabrics were investigated for the vapours of organic liquids of polar and non-polar character, at a concentration of 200 ppm. To characterize the sensory properties of the samples for toxic vapour substances the sensory factor S was defined by the formula $S = (R_i - R_0)/R_0$, where: R_0 - initial sample resistance, Ω, R_i - final resistance of the sample, Ω.

3 RESULTS AND DISCUSSION

Table 1 summarizes the results of the sensory assignments for the presence of vapours of polar and non-polar solvents in evaluated atmosphere. The requirements for sensitivity threshold for solvent vapours were selected on the basis of the data informing about the toxic effects on the human body and was established at the level of 200 ppm.

Table 1 Sensory test results for the presence of solvent vapour for produced nonwoven fabrics [2,3,5]

Solvent	**Sensory factor, S, %**			
	98% PLA 4060D / 2% MWCNT	**97% PEO / 3% MWCNT**	**Aquake AQ0301/ cross-linking compound**	**Aquake AQ0301/ 1% GNPs /cross-linking compound**
	Melt-blown	Electro-spinning	Printing	Printing
Methanol	15	98	49	59
Acetone	40	67	17	21
Toluene	35	106	-	-
Benzene	60	102	-	-

Sensory phenomenon occurred in all types of produced nonwovens. Comparing the results presented in Table 1 it can be concluded that the nonwoven fabric manufactured with electrospinning a polymer solution containing additive nanotubes (97% PEO / 3% MWCNTs) has the highest sensitivity for vapour sensing for all the solvents (at 200 ppm concentration) relative to other melt blown and printed nonwoven fabrics. The results of the conducted experiments indicate the significant influence of fibres' thickness on the chemosensory properties of developed fabrics. Reduction of the fibres' thickness causes an increase in the specific fibre surface area, which entails a larger surface diffusion of solvent molecules to the fibres. Due to diffusion of solvent molecules the percolation path could be destroyed due to the separation of nanotubes what results in increase of the final electrical resistance of the sample. The results obtained with the nonwoven fabrics 98% PLA 4060D / 2% MWCNT show that the response of the sensor to vapours of methanol is relatively low (15%), while benzene, acetone and toluene, respectively, reaches a value of 60%, 40% and 35%. The relative changes in electrical resistance S coincide with the Flory-Huggins parameter κPLA \ benzene <κPLA \ acetone <κPLA \ toluene <κPLA \ methanol. Analyzing the test results of printed nonwoven fabrics it can be seen that the addition of 1% graphene improves the sensitivity of the product to vapor tested.

4 CONCLUSIONS

The obtained results show that the electrospinning and melt blown technique for nonwoven fabrics formation composed of a composite system made of a polymer matrix reinforced with MWCNT (98% PLA 4060D / 2% MWCNT, 97% PEO / 3% MWCNT) as well as of the printed nonwoven fabrics with the paste composed of MWCNT and MWCNT/ GNPs may be used to produce nonwoven fabrics whose resistance changes under the influence of solvent vapours.

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BIOENGINEERING SMART FUNCTIONAL TEXTILES

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Abstract: *The trend of ageing population has been identified as one of key global societal challenges. Healthcare systems in many countries are under growing substantial budget pressure to meet the future needs. To address this grand challenge, there is an urgent need to develop advanced textile materials to achieve smart multifunctional performances to create innovative ultimate personalized e-healthcare technologies. This could be achieved by developing advanced techniques to engineer advanced materials (e.g. graphene and other 2D nano materials) into and/or onto textile fibers, which will be interfaced with human body and internet mobile devices and cloud computational modeling and simulation of physiological and biomechanical behaviors of human body, as well as its interactions with clothing and external environment. Thus, smooth real time healthcare monitoring, advices and risk/emergency warnings to patients and their medical doctors could be provided. To achieve the goals, there are a number of key scientific and technical challenges to be addressed, including: (1) Establish scientific understanding and engineering principle to fabricate advanced nano-scale functional materials into flexible and strong smart textile fibres with sensing, energy harvesting, energy storage and/or actuation functions; (2) Develop advanced manufacturing techniques to produce advanced wearable smart textile materials (fabrics) using the smart fibres; (3) Develop science of design and engineering principles of system integration of smart fabrics with micro-electronics to produce smart devices; (4) Derive technical solutions to integrate smart devices with wireless data communication technologies to transfer data to cloud servers; (5) Develop cloud-based database, data analysis techniques, as well as computational modelling and simulation of human biological behavior, material functional performance and their interactions with external environments to establish digital biological health avatar for individuals; (6) Develop technical solutions to provide real-time medical professional guidance and feedback to individuals and/or healthcare workers. Careful consideration of the ethics, risks and regulation of such technology is vital from its inception, as the success of this work will challenge both individual patients' health and wellbeing and the organization of timely medical intervention to save lives and reduce healthcare expenses. In this lecture, the scientific foundations are reviewed and the principles are illustrated by examples.*

Keywords: *Bioengineering, societal challenges, healthcare, advanced materials, nanotechnologies, functional, smart, textiles, electronics, wearable, IoT, information and communication technologies*

1 TEXTILE BIOENGINEERING

Textiles play critical roles in maintaining health and survival of human populations over thousands of years. Healthcare and disease prevention have been a major concern of human beings through the history of human civilization. Biological health and psychological happiness are the critical indexes reflecting quality of human lives, in which textiles and clothing plays very important roles. Clothing is one of the most intimate objects associated with the daily life of individual human beings, as it covers most part our body in most of the time. Consciously or unconsciously, our physiological/ biological status and psychological/emotional feelings are closely associated with the clothing we wear. With the advance of science and technology, textile devices become more and more important in treatment of diseases by means of drug delivery, regenerative medicine, tissue engineering and artificial implants. Naturally, engineering textiles and devices for biological and psychological health become an integrated part of the concept of textile bioengineering.

Textile bioengineering (TBE) is rooted in physics, mathematics, chemistry, polymer sciences, biology, computational sciences, and engineering disciplines in polymer, fibers, textile and clothing disciplines. It is the application of a systematic, quantitative and integrative way of thinking about and approaching the solutions in problems of how fibers and textiles can be engineered to the benefits of biology, physiology, medicine, behavior and health of human populations [1].

2 BIOENGINEERING SMART TEXTILES

In recent years, a new era of smart e-textile wearable has emerged with focus on medicine and healthcare, for which a range of key scientific and technical challenges need to be addressed, including: (1) establish scientific understanding and engineering principle to fabricate advanced nano-scale functional materials such as graphene into flexible and strong smart textile fibres with sensing, energy harvesting, energy storage and/or actualization functions; (2) develop advanced manufacturing techniques to produce advanced wearable smart textile materials; (3) develop science of design and engineering principles of system integration of smart fabrics with micro-electronics to produce smart devices; (4) derive technical solutions to integrate smart devices with wireless data communication technologies to transfer data to cloud servers; (5) develop cloud-based database, data analysis techniques, as well as computational modelling and simulation of human biological behaviour, material functional performance and their interactions with external environments to establish digital biological health avatar for individuals; (6) develop technical solutions to provide real-time medical professional guidance and feedback to individuals and/or healthcare workers. Careful consideration of the ethics, risks and regulation of such technology is vital from its inception, as the success of this work will change both individual patients' healthcare and wellbeing and the organization of timely medical

intervention to save lives and reduce healthcare expenses.

A distinctive feature of the smart e-textiles (SET) is to develop advanced innovative technological solutions for transforming community health & care to achieve ultimate personalized e-healthcare by using real-time information to support self-management of health and wellbeing, and to facilitate timely interventions, which will be achieved by drawing a number of cross-cutting capabilities as shown in Figure 1, including:

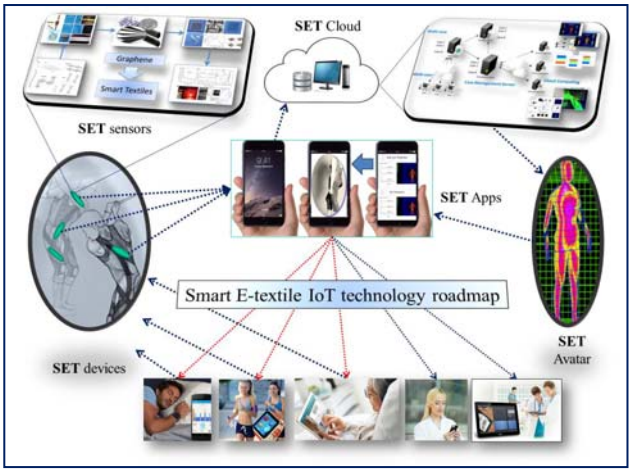

Figure 1 Smart e-textiles (SET) for digital healthcare

•Advanced materials: To advance research in engineering Graphene and other functional 2D materials into smart textile fibres with sensing, energy harvesting, energy storage and/or actualization functions;
•Disruptive technologies for sensing and analysis: To advance research in engineering smart fibres wearable smart textile sensors and fabrics;
•Future manufacturing technology: To advance research on engineering science and techniques to manufacture smart functional graphene fibres, yarns, fabrics and functional textiles;
•Medical devices design and innovation: To advance research in designing and engineering wearable smart functional textile devices (smart beddings, garments, hats, socks, shoes, medical devices, protective devices…) to continuously monitor patient's health signals in walking, sitting, sleeping and any other physical activities such as exercising and falling down;
•Novel computational & mathematical sciences: To advance research in cloud-based database, data analysis techniques, as well as computational modelling and simulation of human thermo-physiological and biomechanical system behaviors and their dynamic interactions with textile materials and external environments to establish digital biological health avatar for individuals;
•Big data and digital economy: To advance research in individual physiological health data monitoring, data communication and analysis, computational modelling of human physiological behavior and its interaction with clothing materials and living environment to create personalized digital health avatar to provide real-time health advices, guidance and facilitate timely medical interventions.

This will facilitate using real time information to support self-management of healthcare and wellbeing, and to enable timely interventions, which involves interdisciplinary collaborations and effort from physics, chemistry, materials science, and a range of engineering disciplines from textile, electronic to information technology and software engineering, more importantly interfaced with life sciences, healthcare and medicine.

Extensive researches have been carried to develop smart e-textiles by means of nano scale modification of fiber surfaces [2-6]. The e-fibers and e-yarns have been used to fabricate smart e-textile wearables for healthcare [7-10].

3 INTIGRATIVE TEXTILE BIOENGINEERING

It has shown from above discussions that textile bioengineering involves a substantial wide range of knowledge and skills developed or to be developed in different disciplines. Development of generally valid paradigms and techniques based on combinatorial approaches for the design, synthesis, characterization, processing, and end-use evaluation of complex and novel materials and apparel products will become an engine of innovation with particular emphasis on comfort, biological heath, protection and disease prevention and treatment for human populations.

The development of integrative and combinational approaches shall include a number of aspects: (i) Cross-functional integration: the functional requirements in thermal biology, biomechanics, sensory comfort, biomedical and healthcare needs to be taken into account together with consideration of fashion, usability, easy-care and costs in the product design and engineering processes; (ii) Cross-disciplinary integration: to design and engineer textiles with any specific biological functional performance, we need to integrate knowledge and skills to carry multidisciplinary research activities from molecular synthesis, nano materials engineering, polymer-fiber-textile and clothing engineering, characterization, apparel design, end-use evaluation by physiological studies, psychological evaluations and clinic trials; (iii) Cross-industry, cross-regions and cross-organization integration: the relevant knowledge, data, information and skills are developed, acquired and stored by experts in different nations/regions, different industries/disciplines and organizations. How to get these resources together to formulate effective engineering systems is a critical challenge for the researchers.

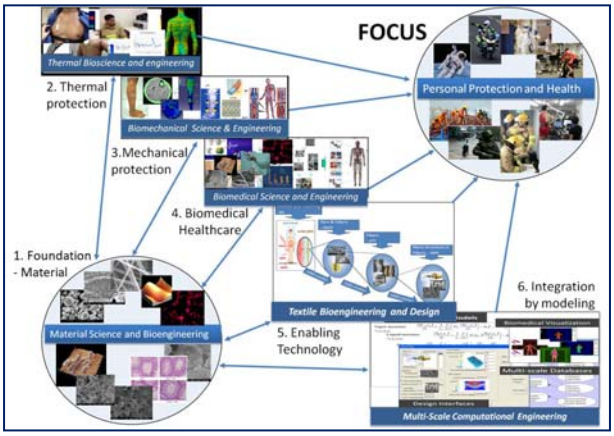

Figure 2 Integrative textile bioengineering

As shown in Figure 2, the success of advancement in material sciences, engineering sciences and technologies, biological and medical sciences has led to an explosion of information, but progress in integrating information has

lagged. We need to make connections among facts, but this is hampered by the data and knowledge distributed in different disciplines, and inherent complexities and problems of interaction and coupling effects of physical/mechanical processes with the neurophysiological, physiological and psychological processes. Mathematical models provide a rational approach for integrating this ocean of data, as well as providing deep insight into the multi-physical-biological-psychological processes. The integrative capacity of models will be needed in translation efforts to bring knowledge gained from material studies to the physiological and psychological level needed for engineering of biofunctional textiles. Modeling should not be an afterthought, but as a critical step in the design and engineering processes that start form the specification of biological and functional requirements of textile products down to the specific functional requirements of materials. Mathematical modeling is the glue holding together various experimental data, information, theories and techniques developed in different disciplines.

The databases must be transformed into models of different functions and processes for different engineering purposes. Accomplishing this requires harnessing the knowledge of all relevant disciplines, including computer science, mathematics, polymer, fiber, textile and clothing engineering, bioengineering, biological and medical sciences. The models range from empirical correlation of databases to mechanistic and systemic descriptions of complex physical and biological processes. Comprehensive informatics-based descriptions of models need to be developed and tested in concert with basic physical, biological and psychological research to uncover the rules of non-linear, interactive and systemic regulations.

Advanced algorithms and computational techniques for predicting and exploring intrinsic and emergent properties of these modeled processes are needed. All relevant fields involve acquiring, processing and analyzing information. They share the need to manage massive, distributed, networked data sets that are compiled from heterogeneous sources. These databases serve a heterogeneous set of users, with roles in research, engineering, production, consumption and education.

The need for such integration leads to initiation and organization of multidisciplinary research programmes with participants from medical professions, physiologists and scientists in chemistry, physics, computational mathematics, mechanical engineering and computing technology to textile technologists and fashion designers [1-21]. For instance, the fundamental research in modeling and simulating the heat and moisture in textiles and fabric mechanics has established a sound foundation to develop advanced computing technology for integrated engineering design of functional biomedical textiles [22-47]. By integrating the computing technologies for structural design, thermal functional design and biomechanical design and sensory engineering, we are able to reveal the outlook, comfort, thermal functional and biomedical performance of the devices before it is actually made. Using the mathematical models with advanced computational techniques, we are able to simulate the dynamic heat and moisture transfer processes in the human body, clothing and environment, the dynamic neurophysiological responses and thermoregulatory responses of the body, the dynamic mechanical interactions between the body and clothing, pressure and stress distributions on the skin surface and in the tissues, as well as the perception of discomfort sensations [48-58]. The simulation results can be visualized and characterized to show the dynamic temperature and moisture distribution profiles in human body, clothing and environment and stress distributions in clothing and on the body, as well as blood flow, blood pressure and temperature distributions in the body. Thus, we are able to illustrate how changes in physical activities, environmental conditions, and different design of clothing and use of different functional materials will influence the thermal biological processes and biomechanical changes of the body, as well as thermal and mechanical comfort of the wearer [59-62]. Such integrated computing aided design technologies have been developed as advanced engineering design tool for fiber, textile and clothing industries, as well as healthcare and medical industries.

4 FUTURE PERSPECTIVES

Textile Bioengineering has emerged as a new frontier cross-disciplinary research field, which involves multiscale engineering of advanced fibers and textile structures for biomedical applications. TBE is a design-led materials research and innovation with focusing on human life sciences to address the key societal challenges in healthcare and wellbeing, particularly for ageing populations. TBE has established a theoretical framework that leads the establishment of scientific understanding and engineering principle to fabricate advanced nano-scale functional materials such as grapheme into flexible and strong smart textile fibres with sensing, energy harvesting, energy storage and/or actualization functions; development of advanced manufacturing techniques to produce advanced wearable smart textile materials; development of science of design and engineering principles of system integration of smart fabrics with micro-electronics to produce smart devices; generation of technical solutions to integrate smart devices with wireless data communication technologies to transfer data to cloud servers; development of cloud-based database, data analysis techniques, as well as computational modelling and simulation of human biological behavior, material functional performance and their interactions with external environments to establish digital biological health avatar for individuals; creation of novel technical solutions to provide real-time medical professional guidance and feedback to individuals and/or healthcare workers. Extensive researches have been carried out in this field and significant progresses have been made, which lead to a promising approach for healthcare and wellbeing and the organization of timely medical intervention to save lives and reduce healthcare expenses.

ACKNOWLEDGEMENTS

The author would like to thank the support of the EU Horizon 2020 and University of Manchester through projects with project with codes of 644268, 761122, AA14512 and R1119938.

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ORAL PRESENTATIONS

FIBRILIZED CEREAL STRAW AS A NEW TEXTILE RAW MATERIAL

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Abstract: *The properties of cereal straw were the inspiration for research into its fibrosis and its use in textile technology. The fibrous cereal straw by modifying its shape and profile will be able to be used as a new textile raw material for the production of ecological technical products. The technology of cereal straw consists of several partial operations such as: preparation of straw for washing (cut off about 20 cm of upper straw with the ears), straw cleaning (removal of pectin and impurities), calendering (flattening of the straw and kneading), enriching on special equipment, refining of fibrous straw (mechanical or enzymatic). The use of fibrous straw for the production of technical textile products will be original and innovative on a global scale.*

Keywords: *cereal straw, fibrilizing of straw, device for fibrilizing, cottoning, texturing, technical products.*

1. INTRODUCTION

The useful properties of cereal straw have become an inspiration for the Institute of Natural Fibres and Medicinal Plants to modify its form while preserving its properties [1-6]. The essence of technology [3] consists in the fact that cereal straw is subjected to various partial operations resulting in its disintegration into the fibrous mass. Straw-made fibres are further refined to produce a product that can be processed on typical textile machines.
The problem of the fibrilizng of cereal straw is also subject to patents [1], [2]. According to the patent [1] the cereal straw is cut into sections of 5-10 cm. It is then washed, softened, purified and mechanically processed into a fibrous product.
According to the patent [2], the chopped cereal straw is characterized by the process in which the that cereal straw is subjected to hot water in the temperature range of 40 to 70 ° C with steam stabilization. The hydrothermally treated cereal shreds are spinning between discs of disc flap when feeding fresh water at a temperature range of 40 to 60 ° C. The resulting mass is added to the wood mass in a ratio of 1:1, and from the resulting new mass are formed sheets of plates.
The method of cereal straw fibrilization that is presented in the patent [3] is significantly different from the patents [1] and [2].

2. TEST MATERIAL AND DEVICES

The research material was a cereal straw (rye) after cutting off the end of the completion of spikes. The length of the cut portion of the straw was approx. 20 cm. Cereal straw without ears was subjected to an ultrasonic washing in the machine made by company "POLSONIC" - sonic14. Fibrilizing process was carried-out on a specially prepared laboratory device equipped with belt card clothing (fibrilizing).

3. PROCESS OF FIBRILIZING OF CEREAL STRAW

The fibrilizing process consists of a series of partial operations including: preparing straw for processing, removal of straw pectin and impurities, calendering straw and mechanical fibrilizing.

3.1. Preparation of straw for processing and removing the pectin's and impurities

It includes the removing of straw ears and their residues as well as the cutting of straw into sections (Fig. 1) corresponding to the length of the ultrasonic washing machine.
Straw segments are placed in an ultrasonic washing machine (Fig. 2) and processed in the washing bath containing the soda and soap. The washing temperature is 60-80 0C. The washing time amounts to 30 min. After washing, the material is washed twice, once in the water of temperature 60-80 0C and once again in cold water.

Fig. 1 The samples of cereal straw

Fig. 2 Washing device Sonic 14 (1) and (2) container with the straw

3.3. Straw calendering

The straw removed from the ultrasonic washing undergoes the removing of water without drying and is subjected to the calendaring that removes the excess moisture from the material, flattens the straws and degradates of so-called bends, i.e. connections of the sections of circular cross-section

3.4. Mechanical cottoning

It involves exposing a thin layer of straw (after calendering) to the action of tape card clothing on a special device (Fig. 3). The result is a splitting of the straws into single fibres, which are characterized by significant flexibility (Fig. 4).

4. FINISHING OF PRODUCED FIBRILIZED STRAW COTTONING

4.1. Enzymatic cottoning

It consists in the treatment of cottoning produced in a mechanical way by the solution of the enzyme preparation called "Pektopol". Cottoning takes place in a water bath comprising in one dm3 the volume of 2 g of preparation KDK and 15 g / kg fibres of "Pektopol". The bath temperature is 55 0C and time processing is 60 min.

Fig. 3 Laboratory device for

Fig. 4 Samples o0f cereal straw after

Fig. 5 Fibrilized straw, twisted in a rope straw

Fig. 6 Sample of fibrilized after texturing

4.2. Texturing

The wet cottoning made by mechanical or enzymatic process is twisted into the rope (Fig. 5). After drying at ambient temperature or preferably in a drying chamber the rope spins up and loosens the fibres contained therein (Fig. 6).

4.3. Wetting

Textured fibre from the fibrilized straw is subjected to the wetting by spraying with the solution of a typical moisturizing agent (grease) in an amount of up to 15% by weight of the fibre and followed by the storage in a sealed container for a period of approx. 24 hours.

5. TECHNICAL AND ECONOMIC BENEFIITS

The source of technical and economic benefits resulting from the use of the technology of fibrilizing is the low price of wheat straw. Relatively expensive fibrilizing operations are still lower than the cost of purchasing and processing of comparable coconut fibres. An important aspect of the issue is also possibility of its application in the processes of acquisition and processing of cottoning from fibrilized straw the machines and equipment used in the processing of domestic natural fibres. National limitations of flax and hemp cultivation cause that a significant number of machines and equipment for their processing remains unused.

The economic effects of fibrilizing technology, consists in:

- reduction of the price of raw materials to manufacture products with the participation of coconut fibres,
- limiting of the imports of coconut fibres, make productive of significant amounts of cereal straw currently destined for the combustion
- new products involving fibrilized cereal straw: warming mats, disinfection's mats,
- mats for production of mattresses in the furniture industry.

6. CONCLUSIONS

1. Original method of cereal straw fibrilizing was developed. Fibrilized cereal straw due to its properties could be used in significant quantities in the textile industry, mainly in technical products (warming mats, disinfectants, mattresses, etc.).
2. The method of the fibrilizing of cereal straw and manufactured products with its content will be original in the world and represents a significant improvement in the field of innovative technologies.
3. Developed technology of the fibrilizing of cereal straw as well as its use in technical textiles can solve the problem of rational and economic use of natural raw material.

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IMPROVED BIOBASED FIBRES FOR DIFFERENT TEXTILE APPILCATIONS: CLOTHING AND AUTOMOTIVE SECTOR

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Abstract: *Poly(lactic acid) is acknowledged to be more environmentally-friendly polymer than polyethylene terephthalate. The fundamental polymer chemistry of poly(lactic acid) allows control of certain fiber properties and makes the fiber suitable for a wide variety of textile applications. However, its thermal resistance (it softens at a temperature around 55°C) limits its use in applications like clothing or car interior.*

Keywords: *poly(lactic acid), fibre, crosslinking, crystallinity, thermal resistance*

1 INTRODUCTION

Poly(lactic acid) (PLA), the first melt-processable synthetic fibre produced from annually renewable resources, combines ecological advantages with excellent performance in textile. PLA successfully bridges the gap between synthetic and natural fibres and finds a wide range of uses, but despite their large market share, commercial PLA grades still do not fulfil all the mechanical and thermal requirements for some applications.

2 APPROACH & RESULTS

Regarding thermal resistance, PLA shows a limited range of service temperature, up to 55-65°C. This condition limits its use in clothing applications as temperatures for ironing and garment processing should be lower than these of cotton and polyester (PES) [1], and in automotive interior ones due to the thermal resistance requirements to meet the standards of this sector. In this context AIMPLAS has been working in different European research projects (BIOFIBROCAR and FIBFAB) to overcome this disadvantage by following different approaches for the development of a compound that fulfil the desired properties:

- Chemical modifications by using reactive extrusion process.
- Enhance crystallization degree by using stereocomplex and other PLA grades with nucleating agents and special process parameters.

With reactive extrusion, by using a crosslinking agent to activate the reaction and a plasticizer it has been possible to improve thermal resistance of PLA achieving an increase in Vicat temperature of around 35°C. But it is noteworthy the characteristic smell remaining in the obtained fibres besides some irritating fumes noted during the spinning process, both coming from the decomposition products originated during the peroxide reaction.

The second approach used gave significant good results (see Table 1). It is proven that a high crystallization degree has positive effect on thermal resistance of PLA [2] [3]. Vicat temperatures above 100°C and MFR values in the suitable range for melt spinning process have been obtained.

Table 1 Enhanced crystallinity compounds characterization

Composition	Properties		
	Vicat Temperature (°C)	***Crystallinity degree (%)***	***MFR (g/10min) at 190°C***
PLA 6201D	57.2 (0.4)	25.4	19.7 (0.09)
PLA 6201D + 5% sc-PLA	59.5 (0.5)	26.3	3.82 (0.08)
PLA 6201D + 10% sc-PLA	66.4 (1.4)	28.4	0.90 (0.04)
PLA 6201D + 20% crystalline PLA + talc	102.6 (0.3)	56.4	15.2 (0.5)
PLA 6201D + 40% crystalline PLA + talc	104.9 (0.7)	58.4	18.5 (0.5)
Crystalline PLA + talc	109.9 (1.1)	59.2	36.6 (1.5)

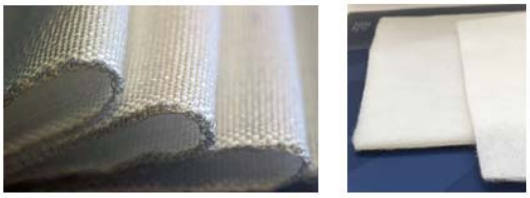

Figure 1 Fabric and nonwoven obtained with new PLA based fibres

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POLYSACCHARADIES POROUS STRUCTURES FOR APPLICATIONS IN REGENERATIVE MEDICINE

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Abstract: *The work has investigated the possibility of producing highly porous composite materials based on polysaccharide, which is an alginate. As the matrix of the composite, sodium alginate was used, which in later stages was converted to calcium or copper alginate. The filling phase – a "functional" - was composed of various types of calcium alginate fibers modified with nanofillers. The effect of incubation of porous materials in Ringer's solution was determined and the possibility of developing on the surface of the material the apatite structures was investigated. Moreover, the sorption properties of porous materials were investigated.*

Keywords: *alginians, porous strcutures, freeze-drying process, SEM*

1 INTRODUCTION

One of the materials used very often in regenerative medicine are various types of porous structures (foams, foam-like materials). At the same time, the increasing amount of scientific work on the modification of this type of polymer, ceramic or metallic structure proves the attractiveness of applicability of such materials in many branches of modern medicine. By analysing the porous structures obtained, it is necessary to adduce to the main assumptions for the characterization of such materials proposed by IUPAC - the International Union of Pure and Applied Chemistry, which assumes that porous material is a solid characterized by pores, channels, cracks, crevices, the depth of which is bigger than the width of the solid. On the other hand, when considering the pore size itself, it is possible to distinguish microporous materials - when the pore diameter is less than 2 nm, mesoporous materials with a diameter in the range of 2 nm to 50 nm and macroporous materials when the pore diameter is above 50 nm. It should be emphasized that the use of foams in today's medicine must take into account both the chemical structure of the material, the utility and the reaction in the environment of the natural tissue, and also the size of the cells that will penetrate inside the porous material. One of the most popular ceramics present in today's medical applications is calcium phosphate based materials, mainly hydroxyapatite [1-5]. In addition to highly-porous ceramic and metallic materials, various types of solutions are often used, using both natural polymers and synthetic polymers. Various types of polysaccharides, collagen, gelatine, lactic acid copolymers, polyvinyl alcohol or polycaprolactone and others are used for this purpose. Among the methods currently used [36,37], the following can be distinguished:

- Casting from solution with the porogen;
- Phase separation: thermal induced phase separation (TIPS) and phase inversion in the liquid-phase separation (immersion precipitation)
- Solid Freeform Fabrications (Solid Prototypes)

In this aspect, the concept of hybrid/composite materials was created combining the modified fibrous structures with a polymer matrix. As a result, it is possible to deliver and differentiate in time the release of bioactive substances that support tissue regeneration.

2 MATERIALS AND METHODS

2.1 Materials

Protanal LF 10/60 sodium alginate (FMC Biopolymer - Norway) was used for the production of fibres and porous structures. As fibre modifiers, the nano-additives such as calcium triphosphate, hydroxyapatite and Fe_3O_4 were used. The characteristics of the alginate fibres used are as follows:

- Calcium alginate multifilament containing hydroxyapatite nanoadditive with a specific strength of 22 cN/tex;
- Calcium alginate multifilament containing calcium β-triphosphate nanoadditive with a specific strength of 20 cN/tex;
- calcium alginate multifilament containing Fe_3O_4 nanoadditive with a specific strength of 21 cN/tex and carbon nanotubes with a strength of 18cN/tex;

2.2 Methods.

The method used to obtain the porous composite materials was the freeze-drying method, referred as the TIPS method. The process was to prepare a solution of sodium alginate in distilled water at a concentration of 6% followed by the addition and mechanical stirring of the short fibres constituting as the modifying phase. The fibre share was calculated on the basis of the weight of the polymer used in the solution. On the other hand, using a nonwoven as a modifying phase, this process was carried out by inundation with a solution of sodium alginate. The solutions prepared was then poured into suitable molds and subjected to a rapid reduction of the temperature to -32 ° C to produce a crystallization of the solvent (water). As a result of the migration of the solvent, the polymer structure becomes thickened and polymer clusters formation, which at a later stage becomes the skeleton of

the scaffold. After the freezing process, the systems were lyophilized at -80°C using a 40°C shelf temperature. The entire process took place under reduced pressure to a level of 0.05 mbar. After the freeze-drying process, the materials based on sodium alginate modified with fibres are obtained. These systems are highly hydrophilic materials, unstable in aqueous medium. As a result, in order to increase their usefulness as materials used in regenerative medicine, the process of Na^+ ion exchange has been carried out for Ca^{2+} and Cu^{2+} divalent metal ions. The analysis of the microscopic structure of the obtained materials was based on SEM+EDX studies. At the same time the structure and surface of the above mentioned materials were analysed after the incubation process in various solutions.

3 RESULTS AND DISSCUSION

The SEM image studies have shown that the appropriate interphase is formed between the modifying component (fibres) and the polymeric matrix, which is a calcium alginate (Figure 1). An important element of this type of systems is also the appropriate sorption properties. The materials obtained are characterized by high sorption properties in both 65% and 100% relative humidity. For all tested systems, sorption values are 14-21% (sorption at 65% RH) and 40-53% (sorption at 100% RH). At the same time, the level of retention of the received materials is very high and is above 150%. An important element determining the usefulness of materials in regenerative medicine, and especially in orthopedics and bone tissue surgery, is the ability to create an appropriate response to the presence of material in the body. The basic parameter for material suitability in the above-mentioned applications is the apatite precipitation occurrence on the biomaterial surface. The photos show the influence of the incubation process on the surface changes of the materials tested (Figure 2).

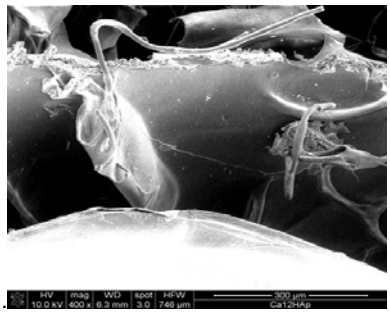

Figure 1 The image of highly-porous structure modified with alginate fibres

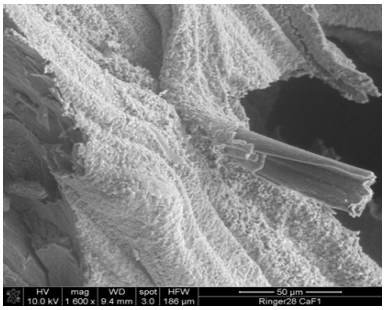

Figure 2 The image of highly-porous structure modified with alginate fibres after the incubation in Ringer solution

4 SUMMARY

The research has shown the possibility of forming porous structures in combination with different types of fibres. Polysaccharide materials exhibit the ability to precipitate the apatite structures that are necessary for the regeneration of bone tissue.

***ACKNOWLEDGEMENT**: The research was funded by the Rector's Fund for the statutory research and carried out in the Department of Materials and Commodity Sciences and Textile Metrology.*

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THE EFFECTS OF ENZYME TREATMENT ON THE PHYSICAL PROPERTIES OF GREEN COCONUT FIBER

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Abstract: *The objective of this study was to determine the effects of physical properties on the green coconut fibers extraction used mechanical method of different levels of acid cellulase enzyme. Fibers from green coconut as referred to as an agricultural waste were prepared and extracted its fibers by stream explosion. The studied found that fibers immersed in 0.01% of enzyme concentration were smooth textures and were able to be extracted easily. Also the physical properties of these fibers were smaller (average of 108 denier). The ultimate tensile strength of unprocessed fibers (original) was at an average of 0.40 gf/den of ultimate tensile strength and 15.97% elongation at break. Therefore, using enzyme in the extraction process produces finer and smaller fibers.*

Keyword: *green coconut fiber, enzyme, agricultural waste, mechanical extraction, stream explosion*

1 INTRODUCTION

Coconut is a member of the palm family with its scientific name of Cocos nucifera L. It is a key agricultural crop in tropical areas [1]. The main content of coconut fiber is cellulose, hemi-cellulose, and lignin. The lignin content in coconut fibers is very high [2] According to the study of properties of young coconut fiber separated by use of NaOCl, NaOCl / NaOH, or H2O2, separating young coconut fiber by using H2O2 showed the best results in terms of strength / durability and elimination of fatty acids and fiber separated by NaOCl had slightly glossy texture [3]. Chemical catalysis using sodium sulfide, sodium hydroxide and sodium carbonate results the approximately 36% less of linear density, approximately 35% less in diameter and 72% less of durability in which fibers are being softer. This is noted as an improvement on fiber's structure [4]. Therefore, fiber quality improvement using enzyme is considered as one valuable method to produce quality green coconut fibers from agricultural waste.

2 MATERIALS AND METHODS

2.1 Material

Extracted green coconut (in figure 1) using mechanical method of stream explosion by Electric boiler Model: LDRO.05-2.5 at medium level of stream pressure at 17 Bar, 207 ºC for 5 minutes.

(a) (b)

Figure 1 (a) four mounts coconut (b) green coconut waste

2.2 Treatment and experiment

1 . Acid cellulase in open-lid tanks with 2 different levels of enzyme concentration at 0.05% and 0.01% at room temperature for 6 hours.

2 . Study on green coconut fibers using scanning electron microscope (SEM).

3 . Standardized textile tests on three categories of green coconut fibers' physical properties as followed;

3 . 1 Fiber length test using ASTM D5 3 3 2 -9 2 Standard Test Method for Fiber Length and Length Distribution of Cotton Fibers.

3.2 Linear density test using ASTM D 1577-07 Standard Test Methods for Linear Density of Textile

Fibers and determined using a Scanning Electronic Microscope.

3.3 Tensile test using ASTM D 3822-01 standard Test Method for Tensile Properties of Single Textile Fibers.

3 QUALITY IMPROVEMENT USING ACID CELLULASE ENZYME ON GREEN COCONUT FIBERS

3.1 Characteristics of green coconut fiber

Quality improvement using acid cellulase enzyme on green coconut fibers were shows in figure 2 and 3.

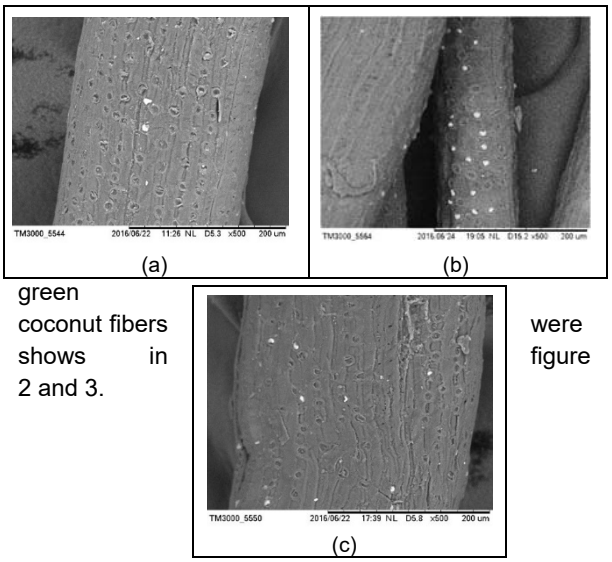

Figure 2 Green coconut fiber's long section (x500) (a) untreated fiber (original) treated in 0.05% enzyme and (c) treated in 0.01% enzyme

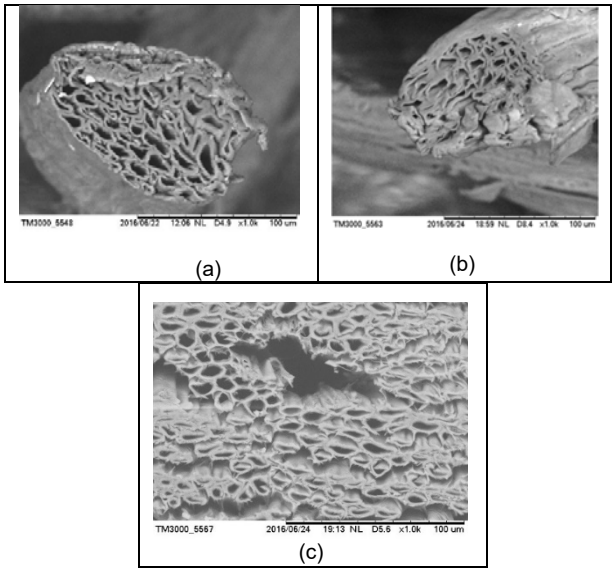

Figure 3 Green coconut fiber cross section (x1.0k) (a) unprocessed fiber (original) treated in 0.05% enzyme and (c) treated in 0.1% enzyme

From figure 2 long section and figure 3 cross section, the studied found that quality improved fibers treated in 0.01% (c) enzyme produced smooth texture fibers and much easier to extract fibers than other fibers in different enzyme concentration.

3.2 Physical properties of green coconut fiber

Table 1 Quality improvement using acid cellulase enzyme of green coconut fibers

Treatment	Denier (denier)	ength (cm)	Tensile strength (gf/den)	Elongation at break (%)
Untreatment	123	5-15	0.40	15.97
enzyme 0.05%	120	4-15	0.39	14.56
enzyme 0.01%	108	4.15	0.38	12.45

According to Table 1, Fiber treated in 0.1% enzyme produced the smallest fibers at an average of 108 denier. In terms of tensile strength, untreated fiber (original) has the highest tensile strength and elongation at break at an average of 0.40 gf/den (15.97%). By treatment acid cellulose enzyme, the enzyme changes fiber's size to smaller and produces finer texture respectively. Yet it did not affect fiber's physical property in length. Moreover, non-alkali palm fiber, extracted palm fiber using sodium hydroxide and those fashioned by succinic anhydride are all given the smoother and more durable fibers [5].

4 CONCLUSIONS

By using mechanical method of stream explosion, the results were extracted green coconut fibers that produced short fibers, brown in color and has smooth texture. As seen from electron microscope, the external texture of fibers is rough, uneven and porous while the acid cellulase process produced the finest or smallest fibers as the result.

Acknowledgement

To thank the Thailand Textile Institute for research funding in 2016 and Rajamangala University of Technology of Thanyaburi for support the generous equipment for the preparation of this research.

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SPINNING AND CHARACTERISATION OF SEGMENTED PIE BICOMPONENT FIBRES FROM POLYOLEFIN AND NYLON 6 WITH TIO_2

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Abstract: *Segmented pie bicomponent fibres have been attracting a lot of attentions across the innumerable textile applications owning to their advanced multifunctional properties. The immense advantages of the split segmented pie bicomponent fibres are that they can be spun and processed as larger fibers, then split into ultra-fine pie shape fibres at conventional melt spinning process rates. The spinning of Nylon6 segmented with polyethylene with 1% TiO_2 in both components and Nylon6 segmented with polypropylene with 1% TiO_2 in both components as the experimental bicomponent fibres were carried out using a lab scale two-extruders system. The reason to use nylon and polyolefin with TiO_2 is that these kinds of materials are widely available, inexpensive and compatible to the bicomponent fibre spinning process. The fibres were prepared by varying winding speeds from 300 metre/minute, 500 metre/minute, and 700 metre/minute. The produced fibres were examined for their appearances and surface characteristics (before and after split) using optical microscope, and for the three-dimensional structural analysis using Scanning Electron Microscope (SEM), and Transmission Electron Microscope (TEM). The Differential Scanning Calorimeter (DSC) was used for studying their thermal characteristics; the amount of absorbed and released energy when heated and cooled as well as their transformation temperatures. The determinations of crystalline to amorphous transition temperatures in the compound filaments were also performed. Their fundamental mechanical properties were carried out to determine the tensile properties of the fibres. The purposes of this work were to study and characterise the splitting behaviour of the two combinations of the materials, as their physical parameters are the critical factors in their end-use applications as filter media with photocatalytic property.*

Keywords: *segmented pie bicomponent fibre, ultra-fine fibre, polyolefin, nylon6, TiO_2*

DEVELOPMENT AND APPLICATION OF ACTIVATED CARBON WEB FOR EMI SHIELDING AND OHMIC HEATING

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Abstract: *In this work porous and electrically conductive activated (AC) webs were produced by using acrylic fibrous waste then following carding and needle punching. The physical activation of acrylic webs was performed by using high temperature muffle furnace at different temperatures (800, 1000 and 1200* °C*). These activated carbon webs were characterized by using EDX and X-ray diffraction analysis. Further the utility of prepared AC webs was checked for EMI shielding application.* For single layers of 1200 °C web, the electromagnetic shielding effectiveness of 63.26 dB, 66.75 dB, and 75.44 dB was found for respective frequencies of 600 MHz, 1 GHz, and 1.5 GHz. This behavior was attributed to the increased multiple internal reflections and stronger absorption of electromagnetic radiations in 1200 °C activated carbon web. *At the end these webs were checked for ohmic heating application by using thermal camera. The web prepared at 800* °C showed higher temperature 185 °C after 60 seconds of exposure at 0.5 voltage.

Keywords: Textile recycling, Acrylic fibrous wastes, Activated carbon, Electromagnetic shielding (EM).

1 INTRODUCTION

For eco-friendly advancement in the field of EMI shielding, the focus is now shifting towards lightweight materials having good adsorption and less reflection for EM radiations [1, 2]. This concept has replaced metal based shielding materials which are good shielding materials from reflection point of view. In this changed scenario graphene and carbon nano-structures emerged as strong alternatives to metal based shielding materials [3, 4]. Carbon based shielding foam are dominant choice due to their light weight and good shielding ability. However as the concentration of conductive particles is increased it caused undesirable effect on the foam ability of polymers for the creation of porous structure. Although researchers are trying to develop carbon based porous structure with good EMI shielding effectiveness, however it is still a big challenge. This work presented the simple and novel method for preparation of porous and electrically conductive activated carbon nonwoven web.

2 EXPERIMENTAL WORK

The acrylic fibrous waste was obtained from Grund Industries, Czech Republic in form of short lengths generated during mechanical processing of bath mats. The short segments of acrylic fibers were removed from bath mats using mechanical cutting method. The compact dense structure of nonwoven web having thickness 11.6 mm and density 2.78 g/cm3 was prepared by combined action of carding and needle punching machine. The web was initially stabilized at 250 °C with heating rate of 35 C h^{-1} and under predetermined tension. Further, the stabilized web was carbonized at 800 °C, 1000 °C and 1200 °C with heating rate of 300 °C h^{-1} and without any holding time. The controlled physical activation was carried out by carbonization under the layer of charcoal. The novel part of this study is single stage carbonization and physical activation in presence of air.

3 RESULTS AND DISCUSSION

The physical characteristics of activated carbon webs prepared at 800 °C, 1000 °C and 1200 °C of temperature, under 300 °C h^{-1} heating rate and without any holding time are shown in table 1.

Table 1 Effect of carbonization temperature on physical properties of high loft AC web

Temp. (°C)	Yield (%)	Shrinkage	Flexibility	Dusting
800	61.7	Good	Good	Good
1000	57.6	Good	Average	Average
1200	45	Average	Poor	Poor

As the temperature kept on increasing the resulting yield decreased due to more carbonization at high temperature which caused adverse effects on shrinkage, flexibility and dusting as well. Energy disperse x-ray spectroscopy was performed to know the relative proportion of different elements present in the activated carbon webs. The increase in carbon content and reduction in oxygen content was found with increase in carbonization temperature from 800 °C to 1200 °C. The activated carbon web produced at 1200 °C exhibited 92.49% carbon content and 6.61% oxygen content. This behavior was attributed to removal of hydrogen, sulfur, nitrogen and other elements due to

decomposition at higher temperature. In order to know the development of crystallinity with increase in carbonization temperature, the XRD analysis was carried out. Figure 1 shows the XRD pattern of different activated carbon samples produced at 800 °C, 1000 °C and 1200 °C temperature.

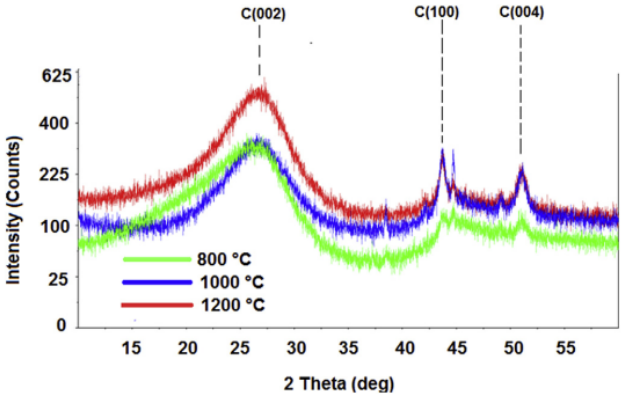

Fig 1 Effect of carbonization temperature on crystallinity of activated carbon web.

Figure 2 show the mean values of electromagnetic shielding effectiveness for single layers of activated carbon samples in frequencies of 600 MHz, 1 GHz and 1.5 GHz. The increase in shielding effectiveness with increase in carbonization temperature was observed. The single layer of 800 °C activated carbon web revealed the lowest electromagnetic shielding effectiveness of about 5 dB in frequency range of 600 MHze1.5 GHz. On the other hand, the 1200 °C activated carbon web exhibited the shielding ability of 63.26 dB, 66.75 dB and 75.44 dB for respective frequencies of 600 MHz, 1 GHz and 1.5 GHz.

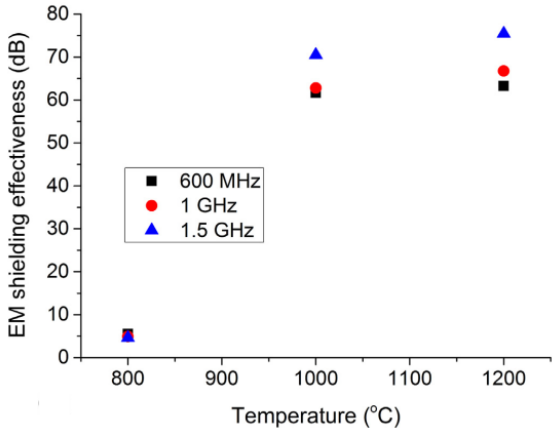

Fig 2 Effect of frequency on EM shielding effectiveness of AC webs

Joule heating also known as ohmic heating and resistive heating, is the process by which the passage of electric current through a conductor produces heat. Joule heating of activated carbon webs prepared at 800, 1000 and 1200 °C were checked at 0.5 voltage. After 60 seconds of exposure the web prepared at 800 °C showed a temperature rise of 185 °C. As the conductivity of AC webs kept on increasing the resulting ohmic heating kept on decreasing due to low resistance in the flow of electrons.

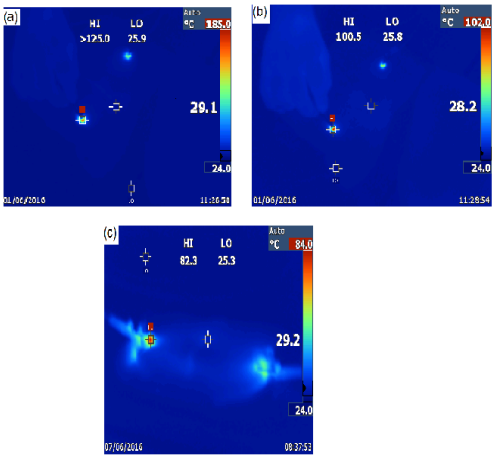

Fig 3 effect of applied voltage on ohmic heating of AC carbon webs

Acknowledgement

This work was supported under the student grant scheme (SGS-21198) by Technical University of Liberec, Czech Republic.

4 CONCLUSION

The acrylic web was successfully converted into porous and electrically conductive AC web through physical activation at 800 °C, 1000 °C and 1200 °C. The utility of these webs was checked for EMI shielding and ohmic heating application. It was found that as temperature of carbonization increased the protection against shielding increases. However results of ohmic heating are otherwise due to more resistance offered by the webs at low temperature carbonization.

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THE IMPLEMENTATION OF CHITOSAN INTO COTTON FABRIC

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Abstract: *Chitosan, produced by chitin hydrolysis, has been highly evaluated for medical purposes. For the last decade, its application in textiles and biomaterials has significantly growth. It was well implemented in man-made fiber, but in natural ones achieved properties were not durable. Therefore, in this paper two different chitosan were implemented into cellulose material. The following methods of analysis were used for physical-chemical characterization: Fourier transform infrared spectrometry (FTIR), electrokinetic potential (EKA) and thermal gravimetric analysis (TG). For the purpose of durability investigation, the characterization was performed after one washing cycle.*

Keywords: *chitosan, cotton fabric, FTIR, EKA,TGA*

1 INTRODUCTION

Chitosan is the (β-1,4) linked D-glucosamine derivative of the polysaccharide chitin (poly N-acetyl-d-glucosamine) found in the outer shell of crustaceans (e.g. shrimp and crab). Chitosan is usually produced by alkaline hydrolysis of chitin, a process which results in N-deacetylation and depolymerization. Chitosan has been highly evaluated for medical purposes, as antibacterial, wound dressings, drug delivery systems, enhancing immune activities [1-4]. For the last decade, its application in textiles and biomaterials has significantly growth [2-6]. It was well implemented in man-made fiber, but in natural ones achieved properties were not durable. Since the antimicrobial property of chitosan is strongly affected by molecular weight, pH, and degree of deacetylation (DDA), in this paper two different chitosan were implemented into cellulose material, and its characterization was performed for the purpose of durability determination after one washing cycle.

2 MATERIAL AND METHODS

2.1 Material

Peroxide bleached 100 % cotton woven fabric, article "Fedora" by Tekstilna tvornica Trgovišće, Croatia. Mass per unit area 150 gm^{-2}, yarn: warp 55 cm^{-1}, 16 tex; weft 32 cm^{-1}, 20 tex.
Chitosan of different molecular weight and degree of deacetylation (tab.1) was purchased from Mathani Chitosan Pvt. Ltd.

Table 1 Characteristics of chitosan

Chitosan	*DDA*	*Milling time*	*Size [μm]*
C-P2	80	30	1-0,5
C-TRI	90	30	1-0,5

2.2 Procedure

Chitosan implementation was performed in mercerisation process [7]. Mercerisation was performed following the technological process (with 0 % tension) within a bath containing 24 % NaOH, 5 gl^{-1} anionic surfactant Subitol MLF (Bezema) as wetting agent in a liquor ratio of 1:20, for 2 min, at 17 °C. Before hot rinsing the alkali cotton fabrics were treated in a bath containing 5 gl^{-1} of chitosan. Afterwards, fabrics were rinsed with hot water for 40 s, then cold water, neutralised and rinsed until pH 7, then air-dried.
For the treatment durability determination, fabrics were washed at 60 °C with standard ECE detergent without fluorescent whitening agents according to ISO 6330:2012.

2.3 Methods

The samples were analyzed by a FTIR spectrometer (PerkinElmer, software Spectrum 100). 4 scans at a resolution of 4 cm^{-1} were recorded for the each sample between 4000 cm^{-1} and 400 cm^{-1}.
The electrokinetic potential versus the pH was measured by the streaming potential method using a Brookhaven-Paar Electrokinetic Analyser (EKA) with a stamp cell, and calculated according to the Helmholtz-Smoluchowsky equation [8]. The zeta potential and Isoelectric Point (IEP) of the textile fabrics were determined and analysed.
Thermogravimetric (TG) experiments were carried in air atmosphere out using a thermogravimetric analyzer Pyris 1 TGA from Perkin Elmer. All samples of 5 to 6 mg for TGA were analyzed from 50 till 800 °C at the heating rate 10 °C min^{-1} with a continuous air flow at a rate of 30 °C min^{-1}.

3 RESULTS AND DISCUSSION

The selected results of FTIR analysis, Electrokinetic analysis and TG analysis are shown in Fig.1-3.

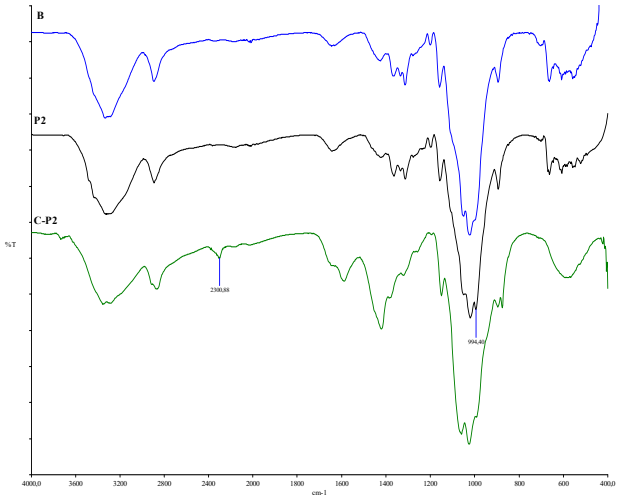

Figure 1 FTIR analysis of chitosan (C-P2), bleached cotton fabric (B), and chitosan implemented fabric (P2)

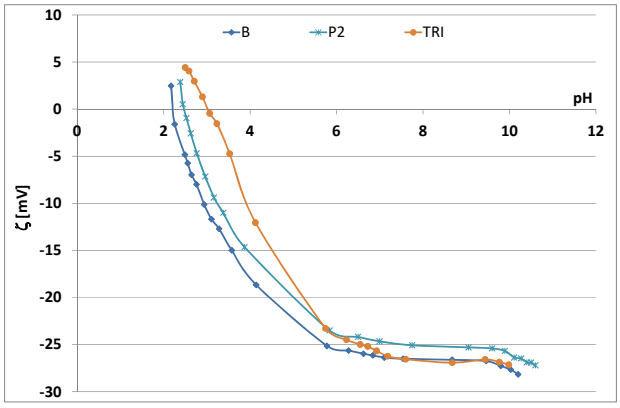

Figure 2 Electrokinetic potential (ζ) vs. pH of 0.001 M KCl of bleached cotton fabric (B), and chitosan implemented fabrics (P2 and TRI)

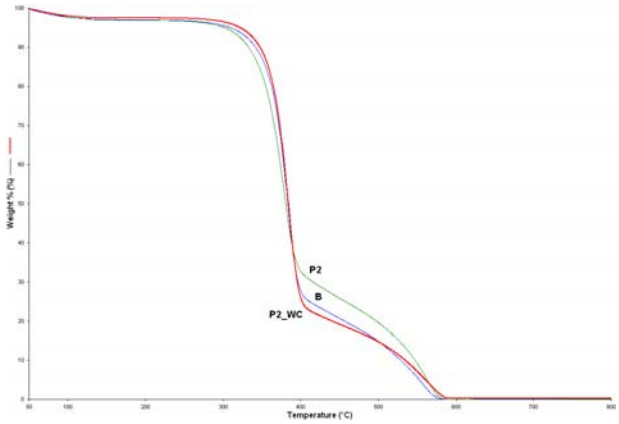

Figure 3 TGA curves of bleached cotton fabric (B), and chitosan implemented fabric (P2) and washed for one washing cycle (P2-WC)

From results shown in Fig.1 it can be seen that such small amount of implemented chitosan is not detectable by FTIR. Therefore, electrokinetic analysis was performed. From the results shown in Fig.2 it can be seen that both implementations went well. For the fabric with implemented chitosan P2 the increment of zeta potential in neutral and alkali medium with slight movement of IEP. This effect is more enhanced for fabric with implemented chitosan TRI. It can be explained by DDA which represents number of the amine or acetyl amine groups on the glycoside unit of chitosan. Since DDA of TRI is 90, it was expected higher zeta potential and IEP. From TG analysis it can be seen that the chitosan is implemented into the fabric. The weight is significantly higher at 500 °C for fabric treated with chitosan P2, and little bit lover after one washing cycle, but still present.

4 CONCLUSION

The electrokinetic and thermogravimetric analyses confirmed that both chitosans were well implemented into cellulosic fabric.
Fabric treated with higher DDA chitosan (TRI) has more positively charged amino groups.
The achieved implementation is stays after one washing cycle.

Acknowledgement: *This research was supported by: University of Zagreb "Functionalisation and characterisation of textile materials for achieving protective properties" (TP3-16), by Croatian Science Foundation under the project 9967 "Advanced textile materials by targeted surface modification". The manuscript was partially financed from funds assigned for 14-148-1-2137 statuary activity by Lodz University of Technology, Department of Material and Commodity Sciences and Textile Metrology, Poland.*

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SATURATION RATE DETERMINATION DURING CAPILLARY RISE USING ELECTRICAL RESISTIVITY

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Abstract: *In this paper, a saturation rate during the capillary rise of a textile fabric was determined. A mathematical model based on the Archie Law, considering the electrical resistivity, saturation rate and fabric tortuosity. In order to determine the saturation exponent a calibration method was introduced. According to this method the spatiotemporal distribution of the saturation rate during the capillary rise is presented.*

Keywords: *Saturation rate, capillary rise, electrical resistivity*

1 INTRODUCTION

The comfort afforded by textile fabrics can be improved by understanding the liquid transport mechanism.In capillary flow through textile fabrics, the constitute yarns are responsible for the main portion of the wicking action [1, 2]. Therefore, many researches have been conducted to study the wicking behaviour in textile structure. Among the extensive research in this field, textile yarns were treated either as porous media [3, 4], the liquid transport through which can be described by Darcy's law, or as capillary tubes, the liquid flow through which can be modelled by Lucas–Washburn kinetics. In the first case, however, the characteristic parameters, such as permeability, are difficult to quantify and are always obtained empirically [5]. In the second case, similarly, the effective radius of the capillary tube, the effective contact angle, etc., are also determined by fitting the experimental data. An extensive literature review shows that although broad research has been carried out in this area, a procedure to determine the saturation during capillary flow through textile based is still lacking.

In this work, the saturation rate during the capillary rise is determined using an electrical resistivity method. A theoretical model was developed based on the law of Archie. An experimental validation showed that our model can determine correctly the spatiotemporal distribution of saturation rate in textile structure.

2 FABRIC SATURATION DETERMINATION USING ELECTRICAL RESISTIVITY

There is an analogy between the laws of fluid mechanics and those of electrical conduction. The difference in pressure in a pipe is in fact the analog of a potential difference across a conductor, while the fluid flow is the analog of the electric current. In both cases, the relationship between pressure/flow difference and potential / current difference depends on the geometry (form and length) of the pipe or conductor.

Archie's law [6] has been the standard method for relating the conductivity of a clean reservoir rock to its porosity and the conductivity of the fluid saturating its pores for over 60 years. Initially an empirical relationship for a narrow range of rocks and porosities, it has found wide application. It has been verified recently by analytical methods for certain special cases [7, 8], and has been extended for use when the surface conduction is significant, such as at low salinities and in clay-bearing lithofacies [9].

One form of the traditional Archie's law can be expressed as [10]:

$$R_{e-m} = \frac{R_{e-water}}{\tau \varepsilon^m S^n} \cdot \quad (1)$$

Where $R_{e\text{-}m}$ is the bulk effective resistivity of the porous material; $R_{e\text{-}Water}$ is the resistivity of the liquid occupying the pores; ε is the porosity, which is assumed to be fully saturated (i.e., identical to the volume fraction of the fluid phase); S is saturation, τ is the tortuosity, m is the cementation exponent and n is the saturation exponent (usually close to 2).

The cementation exponent (m), also called compacity factor and usually in the range 1.3–2.5, is an index of the pores sizes in the porous media [10]. It has been demonstrated by KELLER [11] that the compacity exponent is closely related to the porous compacity level, pores size and distribution.

The use of Archie's law requires the porosity and liquid resistivity determination. Moreover, the exponents (m) and (n) are empirical and determined for each sample. Thus, it is necessary to carry out calibration experiments determining these various parameters.

Other researchers evaluated the saturation rate (S) as a function of the resistivity index (I_R), (second Archie law) defined by:

$$I_R = \frac{R_{e-m}}{R_{e-sat}} = \frac{1}{S^n} \cdot \quad (2)$$

Where, ($R_{e\text{-}sat}$) is the resistivity of the saturated material.

Bu plotting $\ln\left(\frac{R_{e-m}}{R_{e-sat}}\right)$ as a function of saturation rates the constant (n) is determined. The exponent of "Archie saturation" (n) is also close to 2 but can reach 10[12].

3 CALIBRATION METHODOLOGY

A calibration is carried out for each sample in order to evaluate the saturation rates by measurement of electrical resistivity for each saturation rate. Thus, a sample (dimensions 5 cm × 5 cm) with dried mass (m_d) is impregnated in water and then transferred to a support. The mass of the sample is continuously recorded by an

electrical balance in order to determine the saturation rate.

The non-conductive grid allows the sample to be dried through both sides. Each sample is placed freely on the drying support and not tensioned to avoid deformations that can modify the size of the pores. During drying, wet mass (m_w) decreases. The saturation rate (S (%)) is calculated as follows:

$$S(\%) = \frac{m_w - m_d}{m_d} \times 100 \,. \qquad (3)$$

Thus, the calibration procedure consists in measuring the resistivity as a function of the different saturation rates.

FIG. 1 illustrates the sample calibration for the saturation exponent (n) determining. It is noticed that the regression line of the curve is linear with a regression coefficient (R^2 = 0.984) and (n = 2.5351).

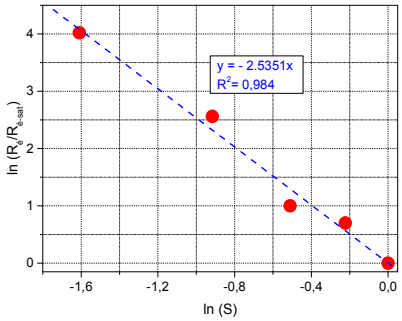

Figure 1 Calibration a sample for determining the saturation exponent (n)

4 SATURATION RATE DETERMINATION DURING CAPILLARY RISE

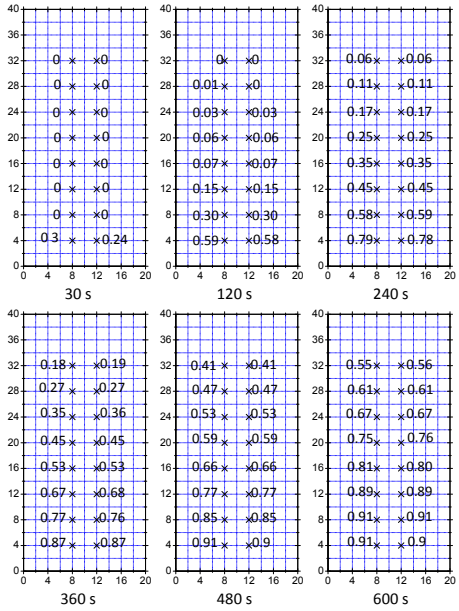

Figure 2 Spatiotemporal distribution of saturation rate in the case of a capillary rise test at 4 cm steps

A series of experiments on a plain knitted structure was conducted with distilled water as wicking liquid. The experimental apparatus for vertical capillary rise [13].

The experiments were conducted in a standard atmosphere of 20± 2 ◦C and 65± 2% relative humidity, and the samples were conditioned for 24 hours before testing.

FIG. 2 shows the Spatiotemporal distribution of saturation in width and height of a capillary rise test. For the same height, the saturation rate is identical which implies the structure is the same according to the width. According the FIG.2, not surprisingly, the penetration velocity of liquid in early stage is much higher than in subsequent stages. With time passing, the advancement of liquid becomes slower and slower until equilibrium is established. Figure 3 Spatiotemporal distribution of saturation rate in the case of a capillary rise test at 4 cm steps

5 CONCLUSIONS

The saturation rate during capillary rise is investigated. Using a modified Archie Law, the saturation was determined based on the electrical resistivity of wetted textile fabric. He calibration method was carried out for each sample to determine the saturation exponent (n) before testing.

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BALL BURST TEST OF SILICA NONWOVEN MATERIAL

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Abstract: *Development of synthetic skin cover is of a great interest in the field of reconstructive and aesthetic surgery. Human skin open wounds are serious from the treatment point of view. The healing is usually followed by several chronic complications and this fact predetermines this disease to undesirable clinical experience. In this study a ball burst test of nonwoven silica textile material was performed. In the first step a finite element analyses were performed. In the second step an experimental setup was done. The Young's modulus was estimated to 0.74 MPa and the Poisson's ratio to 0.28. The mean burst strength was 12.9 ± 3.3 kPa. It was shown that standardized ball burst experiment is suitable for getting mechanical behavior of silica nonwoven material. It gives even better results, in terms of data scatter, than e.g. uniaxial tests.*

Keywords: *nonwoven, burst test, finite element method, silica material*

1 INTRODUCTION

Human skin open wounds are serious from the treatment point of view. The healing is usually followed by several chronic complications and this fact predetermines this disease to undesirable clinical experience. The wound repairs is usually done by different techniques depending on type of wound (burn, melanoma..etc.). One of the promising ways seems to be in using nonwoven silica textile materials [1]. This material supposed to have specific characteristics allowing them to deliver high-performance across a wide range of applications. Specific functions include: absorbency, liquid repellency, resilience, stretch, softness, strength, flame retardancy, wash ability, cushioning, filtering, bacterial barrier, and sterility. From the morphological point of view, the network of silica fibers is in plane chaotically arranged through all volume, fig. 1.

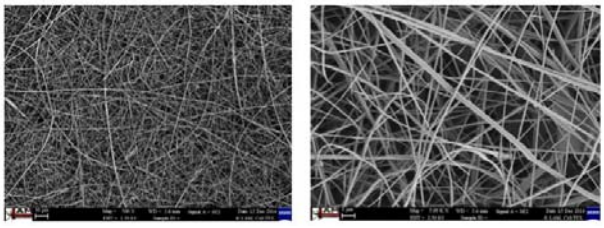

Figure 1 Silica nanofibers structure

There is a few information regarding its mechanical behavior. Supposing to use this new material as a medical device, it´s mechanical behavior is need to know. The aim of this contribution is determined the mechanical behavior of selected silica nonwoven.

2 MATERIALS AND METHODS

Due to extremely fragile behavior of the tested material a ball burst test was select to use. In the first step a finite element analysis was used to predict its behavior. In the second step an experiment was performed.

2.1 Finite element analysis

The finite element model was created in the software MSC.Marc 2016.0 (*MSC.Software, Czech Republic*). Regarding to different stiffness of tested material and experimental devices setup, a rigid – flexible contact approach was selected. The nonwoven samples are meshed by solid eight node elements. The final model consists of 209 461 elements with 4 elements on radial axis. The clamps and loading punch is supposed to be rigid, fig. 2.

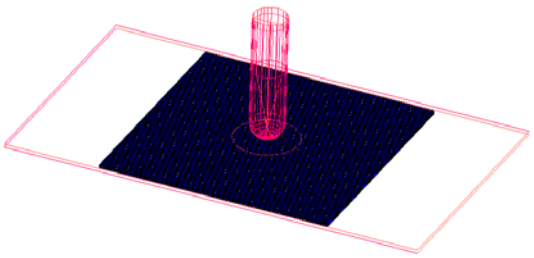

Figure 2 Finite element model of a ball burst test

The loading history was following

a) Pull down the clamps towards each other (0.05 mm displacement), so that testing sample is fully constrained.
b) Pull down the rigid punch (1.2 mm displacement), so that the tested sample is loaded in perpendicular axis.

The material model of silica nonwoven was supposed to be isotropic model. The Young's modulus was 0.74 MPa and the Poisson's ratio 0.28. The material properties were updated at each solution according experimental results. A segment-to-segment contact constrains with Coulomb's bilinear friction model was defined. The friction coefficient was set to 0.1.

Overall burst strength was calculating according to normative standard and true stress distribution on a loaded sample was observed.

2.2 Experimental setup

For the evaluation and update of FE results, a series of experiments were performed. For a ball burst test ten samples of rectangular dimensions (20 x 50 mm) were used. In the first step a thickness of all samples was measured on an optical microscope. The ball burst tests were performed at the two–column testing machine with 100 N load cell, Testometric (*Testometric Co., Ltd., UK*). The velocity of loading was set at 10 mm/min for all the cases. The samples were loaded up to visual failure state of samples. Strength displacement curves were calculated and overall burst strength as well according to normative standard.

3 RESULTS

3.1 Finite element analysis

The stress concentration on a testing sample is at the vertex area of the punch sample contact. The burst test was calculating as a reaction force of the punch divided by area of the sample (loaded zone only). The resulted value is 14.8 kPa. On the other hand the true stress in the loaded zone of the sample reaches from 1 to 15.6 kPa, fig. 3.

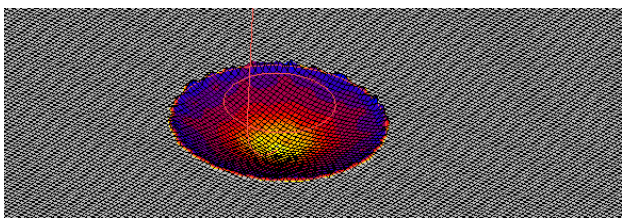

Figure 3 Distribution of true stress at the loaded zone. The maximal value is 15.6 kPa.

The true stress distribution across the loading zone of the sample is seen on figure 4.

3.2 Experimental results

The mean measured thickness of samples was 481.9 ± 86.7 µm. All of the samples were loaded up to the material failure and the mean burst strength was 12.9 ± 3.3 kPa. The failure occurred at around the vertex of the ball sample contact.

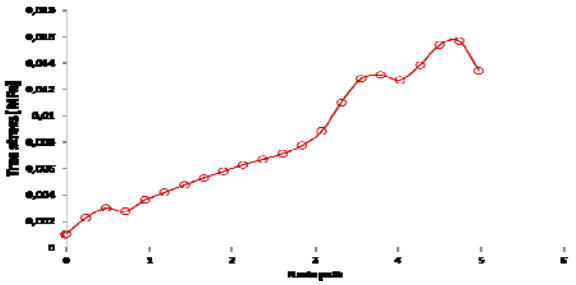

Figure 4 Distribution of true stress at the loaded zone.

4 CONCLUSION

Development of synthetic skin cover is of a great interest in the field of reconstructive and aesthetic surgery. There are available commercial synthetic skins substitutes, as Integra® or Biobrane®. Nevertheless there are various limitations in its use, mostly it is the size and price. The development of nonwoven silica textile material for this use cannot be done without understanding its mechanical behavior.

The results from ball burst experiment shows extremely low scatter in measured data. This agreeable finding doesn´t correspond to our experience with other mechanical tests of nonwovens material, where high scatter of measured data is reached. The finite element simulation shows non-homogenous distribution of true stress in the loaded zone.

It was shown that standardized ball burst experiment is suitable for getting mechanical behavior of silica nonwoven material. It gives even better results, in terms of data scatter, than e.g. uniaxial tests [2]. On the other hand finding from finite element results shows some lack of knowledge in interpretation of results from this test. This finding has to be studied in the future work.

***ACKNOWLEDGEMENT**: We gratefully thank you to Mrs. Sarka Reznickova for her help during experimental set-up.*

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MOISTURE SORPTION BEHAVIOUR OF DEVELOPING COTTON FIBRES

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Abstract: *Dynamic vapour sorption is used to gain valuable information concerning the structure of cotton fibres during their development. Moisture sorption isotherms for cotton fibres are obtained through dynamic vapour sorption analyser during their development stages. The amount of absorbed water is found to be closely related to the chemical composition of the fibre. This study provides valuable insights into the driving principles of the moisture sorption process of cotton fibres may aid to develop ways to improve the moisture management properties in general.*

Keywords: *moisture sorption, cotton, dynamic vapour sorption*

1 INTRODUCTION

Water content in the fibre has a profound effect on almost all the mechanical properties (tensile strength, stiffness, ultimate elongation, etc.) as well as the physical (electric and thermal conductivity, isolation against UV radiation solubility, etc.) and chemical ones (chemical reactivity, resistance to microbes, etc.) [1]. Thus, a study on the moisture sorption is also of high interest for developing cotton fibres.
In the present study, the sorption behaviour of cotton fibres harvested at different stages in their development process is examined using dynamic vapour sorption (DVS). The moisture sorption profiles are studied for the developing cotton fibres. The aim is to provide valuable insights in the moisture sorption mechanisms of the cotton fibre during the development process.

2 MATERIALS AND METHODS

2.1 Materials

The different cotton fibres were produced by Bayer Crop Science N.V. (Ghent, Belgium). Cotton cultivar ST457 (Gossypium hirsutum) was grown in a green-house at 23°C and 15 kLux, with a 16 h/8 h day/night cycle). Flowers were tagged at anthesis and a few bolls were harvested at 15, 21, 36, and 80 days post anthesis (DPA).

2.2 Methods

Dynamic vapour sorption measurements were conducted in a Q-5000SA instrument (TA-instruments, Zellik, Belgium). All measurements were performed at 23±0.1°C. Deliquescent salts (sodium bromide and potassium chloride) were used to verify the humidity of the instrument. The humidity was increased stepwise, with steps of 10 % RH from 5 till 95 %. The desorption isotherm, from 95 till 5 % was recorded as well.

3 RESULTS AND DISCUSSIONS

The sorption curves for the developing cotton fibres (15, 21, 36 DPA) and a complete mature fibre (80 DPA) as are shown in Fig.1.

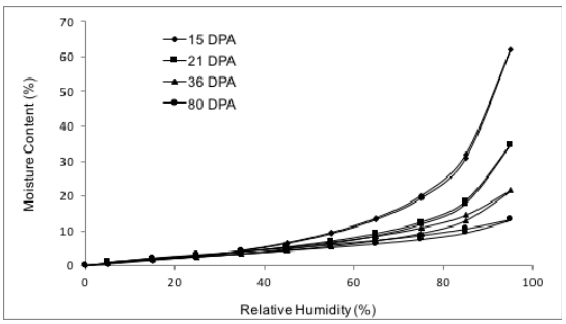

Figure 1 Moisture content (%) as a function of the relative humidity (%) for developing cotton fibres and a mature fibre

Fig.1. reveals considerable differences in sorption capacity during the fibre development. In the early stages the moisture sorption is extremely high compared to the one of the fully mature cotton fibres. An equilibrium moisture concentration (EMC) value of about 60 % is observed for the lowest DPA-value. During the fibre development, a strong linear decrease in EMC is noted. This can be attributed to the structural and compositional changes in cotton fibres during their maturation process. At the early stages only primary cell wall is present in the fibres. Once the elongation phase of the fibre is passed, the amount of cellulose increases quickly in line with the decrease in sorption capacity.

4 CONCLUSIONS

DVS can be used to gain valuable information concerning the structure of cotton fibres during their development. Generally, it can be concluded that the amount of absorbed water is closely related to the chemical composition of the fibre.

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DYNAMIC-MECHANICAL ANALYSIS OF YARN

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Abstract: *The main aim of this work is study of twist influence on yarn dynamic modulus and loss tangent under cyclic loading. For this study group of polyester staple yarns with the same fineness and in the range from the lowest possible to the highest possible twist was produced and tested. Parameter C based on loss tangent of yarn at the same level of twist and loss tangent of parallel fiber bundle, measured by dynamic-mechanical analysis (DMA) under different frequencies, was proposed. It was found, that this parameter is decreasing with increasing of twist and it correlates with orientation factors of Pan [1] and White [2] and slipping factor of Hearle [3],[4].*

Keywords: *dynamic mechanical analysis, loss tangent, complex modulus, yarn packing density, yarn twist*

1 INTRODUCTION

It is well known that fineness and twist (twist factor) have huge influence on the mechanical properties of short staple fiber yarns. One of the main factors is friction between the fibers, which is connected with the yarn packing density. Due to increasing of twist the packing density is increased as well to the limit value approximately 0.7 to 0.8 [1,2].
Second important factor is the orientation of fibers in the yarn. The increasing twist leads to the decreasing of orientation factor and therefore yarn strength is reduced [1,2]. In 1907 Gegauff [3] proposed a simple analysis to correlate the fiber helix angle (β) in yarn with the yarn modulus. Based on yarn helical model the tangent of surface fiber helix angle is directly connected with number of twist and yarn diameter. According Gegauff ratio between yarn and fiber modulus represents orientation factor as $\cos^2(\beta)$. White et. all [4] proposed more complex analysis based on the continuum mechanics for derivation of orientation factor. Pan [5] suggest orientation factor as a function of fiber helix angle and yarn Poisson ratio. Considering the slippage of fibers in yarn Hearle obtained orientations and slipping factors [6].
From ratio of the acoustic dynamic modulus of yarns at the some twist level and acoustic dynamic modulus of parallel fiber bundle, it is possible to calculate the approximate orientation factor, too [2].
Based on idea of Murayama [7,8] new parameter connecting with inter-fiber slipping and fiber orientation investigated by loss tangent of yarn and parallel fiber bundle was proposed and measured by DMA. Influence of twist on this parameter and connection with mention above orientation and slipping factors were studied.

2 THEORETICAL PART

Under cyclic loading, the strain and the resultant stress of a polymeric material is not in the same phase due to the viscoelastic behavior of polymers. This phase difference of stress and strain results in two parts of modulus, i.e. a real part E′ and an imaginary part E″, expressed as

$$E' = \sigma_0 \cos\delta / \varepsilon_0 \quad \text{and} \quad E'' = \sigma_0 \sin\delta / \varepsilon_0, \tag{1}$$

where σ_0 is the amplitude of stress, ε_0 is the amplitude of strain, δ is the phase angle. The ratio of these two parts of modulus is called the loss tangent, which is defined as

$$\mathrm{tg}\delta = E'' / E'. \tag{2}$$

The real part of the modulus *(E')* is called the storage modulus and it is related to the elastic energy stored in the polymer system. The imaginary part of the modulus (E″) is called the loss modulus, which is associated with the energy loss due to intermolecular friction.
For calculation of the energy loss doe to inter-fiber friction following equation Murayama [5] was proposed

$$\eta^* = \eta + \eta_{eq} = \eta + 4f / A\omega), \tag{3}$$

where η^* is the apparent viscosity of the fibrous structure, η is the apparent viscosity of the fiber, η_{eq} is the equivalent friction viscosity, A is the magnitude of the periodic loading, ω is the angular frequency of the loading, f is the coefficient of friction and k is the real modulus of the fiber. By testing single fibers and the fiber assembly at different frequencies, it is possible to determine the frictional energy loss due to inter-fiber friction. When a single fiber is tested under cyclic loading, the energy loss due to inter-fiber friction does not exist. The loss tangent of the filament can also be calculated from Eq. (2) except that η^* should be replaced with η_f, which is the viscosity of the fiber. The relation between η and η_f is expressed as

$$\eta = C\eta_f. \tag{4}$$

Murayama [7,8] indicated this parameter C as “Bond Strength Parameter, which is dependent on the geometry of the fabric and bond strength between the neighboring fibers. For C = 1 the bonding is perfect.
In the case of a fiber bundle, the difference between a single fiber and a fiber bundle will be insignificant if the fibers in the bundle are all separated and deformed uniformly with the same strain. C values for a single fiber and a fiber bundle would be different if the fibers in the bundle are not loaded to the same extent as the single fiber tested under the same condition. Therefore factors that affect the loading condition of the fibers in the bundle will influence the C value. These factors include bundle twist, fiber organization in the bundle and surface properties of the fiber [7,8].
Yarn is created by twisting of fiber bundle. We assume parallel fiber bundle with some value of fiber number.

Based of results described in [7], [8] the following equation for parameter *C* was proposed

$$C = \frac{tg\delta\left(\begin{matrix}yarn\\ \varpi_1\end{matrix}\right) - tg\delta\left(\begin{matrix}yarn\\ \varpi_2\end{matrix}\right)}{tg\delta\left(\begin{matrix}bundle\\ \varpi_1\end{matrix}\right) - tg\delta\left(\begin{matrix}bundle\\ \varpi_2\end{matrix}\right)}. \quad (6)$$

Parameter C is function of loss tangents of yarn (at the same level of twist) and parallel fiber bundle (zero twist) measured by different frequencies (ϖ_1, ϖ_2).

3 EXPERIMENTAL PART

For this experiment six polyester yarns of fineness 25 tex with different twist were spun. Testing device DXO4T was used for this experiment. The following testing conditions were set: sinus loading process, minimal force 2N, maximal force 10N, gauge length 10mm, constant temperature 25°C, frequency from 1 to 50Hz, time of measurement approx. 20min. Since the gauge length is shorter than the length of the fibers (38mm), it can be assumed that both ends of the fibers will be clamped in the jaws and the yarn will behave as a bundle of fibers with different twist levels. For all yarns five samples were measured and estimate of mean value and its 95% confidence interval for complex modulus and its two parts and loss tangent were calculated see Fig.1.

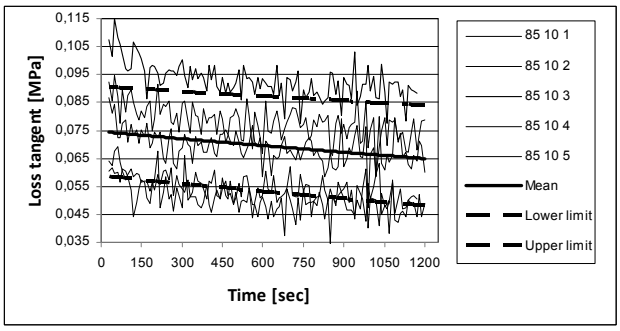

Figure 1 Time dependency of loss angle for yarn with twist coefficient 85m^{-1}ktex$^{2/3}$ and frequency 10Hz (lower and upper limit of 95% confidence interval of loss tangent mean value)

Influence of frequency on complex modulus and loss tangent was investigated. Loss tangent of bundle at the level zero twist was interpolated. For calculation of parameter C by Eq. (6) frequency 10 and 20Hz was selected see Fig.2.

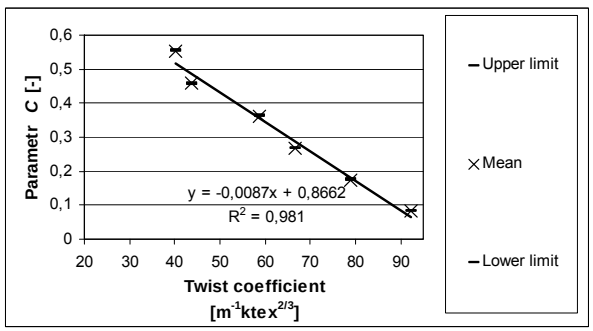

Figure 2 Parametr *C* as function of yarn twist coefficient

Orientation factors according Pan [5], White [4] and slipping factor of Hearle [6] were evaluated. These factors with parameter C were correlated see Fig.3.

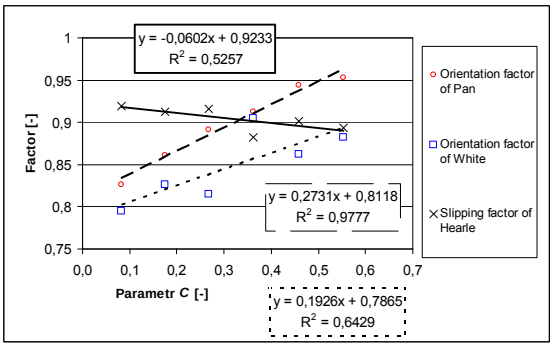

Figure 3 Orientation factors and slipping factor as function of parameter *C*

4 RESULTS AND DISCUSSION

Time dependency of loss tangent is slowly decreasing. Higher level of frequency means higher loss tangent. Loss tangent as function of twist is slowly decreases and then stabilizes. The results are consistent with work [9]. Parameter C is decreasing linear function of twist coefficient see Fig.2. Parameter C is in strong correlation with Pan and White orientation factor. Orientation factors are increasing with parameter C. On the other side slipping factor of Hearle is decreasing function of parameter C *see Fig. (3)*.

5 CONCLUSION

Methods for measurement complex modulus and loss tangent by DMA were investigated. Influence of frequency and twist on the complex modulus, on its real and imaginary part, and loss tangent was described. Corrected parameter C according Murayama was proposed. This parameter is dependent on yarn technological parameters, which influencing yarn structural parameters especially fiber orientation, packing density and number of inter-fiber contacts. Packing density of yarns, diameter and other properties were measured, too. Continuing of this study can help better to describe the mechanism of inter-fibrous friction and improve the prediction of the mechanical-physical yarns properties.

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EVALUATION OF SURFACE WATER ABSORBENCY OF TERRY FABRICS

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Abstract: *After hygienic body cleansing the towel is used in order to wipe the skin and this is the moment when the towel in the close contact with human body skin. Generally, the towels, which are used in our bathrooms, have to meet the following requirements: a high absorption capacity, moisture wicking, softness and fineness. Other requirements that should be characterized in relation to terry towels are: non-allergy, antibacterial effects, antimycotic effects, odour resistance, fast drying up and easy maintenance. In relation to the towels assortment, the process or course of the water transfer does not exhibit the same features in comparison with the clothing fabrics where the water is transferred from the skin through clothes and then it gets quickly to the ambient environment. In the case of the towels, the transfer of water is divided into two specific phases. In the first phase, the water is quickly transferred from the skin to the towel. Taking into account the specific time interval after the first phase, the second phase occurs. In relation to this second phase, the moisture evaporates from terry towel to the environment and long-term desiccating process occurs. Based on the predetermined investigation procedures and steps, the following evaluation is introduced in this paper:*

- *evaluation of the first phase of surface water absorbency in relation to the terry towel,*
- *evaluation of the second phase, which stands for the time interval of the terry towel desiccating process, which is based on the water evaporation to the environment.*

The main objective of the paper was to specify the influence of the material composition and the influence of the basic parameters of terry fabrics on their surface water absorbency as well as the time of desiccating process. The measurements were repeated after every washing (max. number of washing procedures = 5 times). The new method was designed and tested in relation to measurement of surface water absorbency, while the given method was based on the simulation of the practical application of the terry fabrics in order to determine their surface water absorbency during the hygienic body cleansing. Fabrics, which were used for investigation as samples, were made of cotton, regenerated cellulose, tencel fibres, and their mixtures. Assortment of terry fabrics was used for preparation of individual samples [4], for which a detailed structural analysis of the following characteristics was made: the number of threads in the fabric [3], the thickness of the fabric [2], area density of fabric and fineness of thread [5] (Table 1).

Tab.1 Properties of (loop) terry fabrics

Sample n. and material	Properties		
	Mass per unit area [g.m^{-2}]	***Thickness [mm]***	***Fineness [tex] (weft / warp / terry warp)***
1./ 100% cotton	400	2.22	35/56/35
2./ 100% cotton	450	2.23	38/61/35
3./100% cotton	500	2.39	38/60/34
4./ 100% cotton	600	3.21	38/57/55
5./ 100% microcotton	400	2.63	48/60/44
6./ 70% cotton30% tencel	450	2.05	40/60/37
7./ 60%cotton40% regenerated cellulose	450	2.05	40/57/37
8./ 55%cotton45% regenerated cellulose	450	2.16	41/63/37
9./ 50%cotton50% regenerated cellulose	450	2.56	37/57/38

The main objective of this work was to measure the surface water absorbency of the terry fabrics. Relating to surface absorbency ability of terry towels, the tests were performed under the strict conditions determined for tested samples. Two measurement points or areas were designated for the each one sample. At first, the given tested sample was fixed in the holder device and then, 50 ml of distilled water was poured into the funnel, from which the given water flowed down onto the surface of the terry fabric. To preserve the same conditions for all tested samples relating to water speed, the speed of the water flow was determined to be constant and it was 8s.The testing procedure was connected with determination or detection of the overflowed distilled water which was not absorbed by terry fabric. The overflowing water was collected in the collection box and then poured into a measuring cylinder. Subsequently, the value of overflowed water was subtracted from the original amount of distilled water (volume) and this calculation led to the result of the testing procedure and it was the determination of average value of surface water absorbency of the terry fabric in the predetermined area. After the each measurement of the mentioned properties, the washing process of towels was carried out. Terry fabric samples were washed for 5 times at all. Washing conditions were determined as follows: temperature of the wash bath was 60 °C, the ratio of solution to the sample was 50: 1, the number of rinses in cold water was 2 and washing time was 60 min.The second phase of the test was as follows: the tested samples were washed in detergent under according to the predetermined conditions and they were left to desiccate in air at relative humidity of 60 ± 1% and ambient temperature of 21 ± 1 ° C [8]. In relation to the defined time intervals, samples were

weighed on the analytical balance. The weighting of the samples was repeated until the value of the weight of the dried sample was the same as it was before the test. Tab. 2 shows the total desiccating time of individual terry fabric samples.

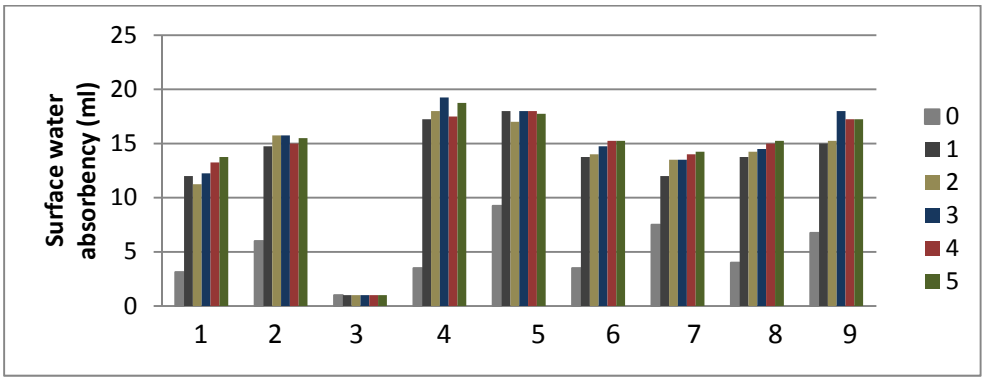

Fig.1 The average values of the surface water absorbency of terry towels – reference samples (before washing) and after the individual washing processes (from the first to the fifth first to fifth)

Tab.2 Time of terry fabrics desiccating

Sample (n.)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Time of desiccating process [h]	42	48	48	48	42	54	54	54	60

The work was focused on s evaluation of loop terry towel (fabric). The surface water absorbency of predetermined areas or sites of terry fabrics was observed and evaluated and it was in relation to material and structural composition. The main objective was to simulate the surface water absorbency regarding to terry towels. The results of the measurements show that samples designated as n. 4 and n. 5 have the best surface water absorbency. In the case of these samples, there is very good transport of moisture from the skin and therefore, they are a good representatives of wet sorption while this sorption is based on the structure of terry fabric. The impact of material composition and structural parameters of terry towel fabrics on surface water absorbency was also evaluated. Based on the obtained results, it is important to point out that material composition did not have any significant impact on changes of observed properties. Relating to findings, it can be concluded that the addition of tencel and regenerated cellulose to the cotton mixture does not any impact on the increase of the surface water absorbency. In comparison with the cotton, the mentioned components exhibit better antimycotic and antibacterial properties as well as better odour resistance. Repeated washing process and subsequent measurement of surface water absorbency of towels led to increase of the surface water absorbency after each one washing process. Moreover, the measured values are stabilized after the fifth washing. Interesting results were obtained in relation to sample designated as n. 3, because there were not any changes observed after the repeated washing process (the given sample exhibited the same values of surface water absorbency after each washing and measurement) and it can be attributed to high surface tension, which caused by significant deterioration of surface water absorbency leading to malfunctioning of terry towel fabrics. In relation to the second phase standing for the evaluation of the desiccating process of towel samples, the given terry fabric samples, which contain cotton combined with other more absorptive component, exhibit much longer time interval of desiccating.

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COLOR MEASUREMENT OF PRINTED FABRICS USING HYPERSPECRAL IMAGING SYSTEM

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Abstract: *Although colorimetric values of solid colors can be measured using a spectrophotometer, colors in a printed fabric cannot be measured by a spectrophotometer due to the restrictions of the measurement principles. Hyperspectral imaging systems are capable of measuring spectra of the sample from every different spatial location which are further used for calculating colorimetric values of these pixels. Therefore, hyperspectral imaging technology with hyperspectral image processing is candidate to be used for colorfastness tests of printed fabrics where spectrophotometers cannot be used. In this study it is aimed to detect different color regions in a printed fabric and obtain the reflectance spectra of corresponding regions. Different classifying methods are tried to detect the color regions and mean spectra of the regions are obtained. The performance of the methods is discussed.*

Keywords: *multi-colored fabric, printing, clustering, color segmentation*

1 INTRODUCTION

One of the most important quality parameters of a printed fabric is its colorfastness performance, which is often evaluated subjectively by comparing colors on the fabric before and after subjected to standard tests [3].
Although evaluation of the colorfastness tests of a solid-color fabric can also be performed objectively using spectrophotometers, a printed fabric that contains multiple colors must be evaluated only by subjective methods due to the restrictions of spectrophotometers. The most important restriction of a spectrophotometer is its incapability of obtaining true reflectance spectra of multicolor fabric samples with sizes smaller than its aperture [5,6]..
Today, the rapid progress of digital imaging technology hyperspectral imaging systems become available in the market which can provide not only the spectral information but also the spatial information of a measured sample [1]. The capability of hyperspectral imaging systems to measure reflective spectra of corresponding spatial information leads them to be used for color measurement of very small regions in multicolor printed fabrics and samples of small sizes.

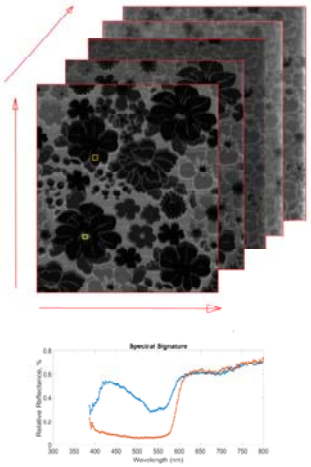

Figure 1 Printed fabric sample and spectral signature of two different regions

To evaluate colorfastness of printed fabrics a simple procedure is proposed. First step is to obtain the spectra of different colors in a printed fabric before it is subjected to a test. The second step is to classify the color regions of the processed fabric sample using classification methods and obtain the mean spectra of the corresponding regions. The last step is to compare the spectra obtained before and after the process to evaluate the color change.
Hyperspectral imaging system can give spectra of every pixel and every pixel can be used for comparisons. But using spectra of only one pixel can lead to errors, Therefore it is needed to use mean spectra of a uniform region of similar colors. In this study different classification methods are tried in order to detect color regions which are similar to the reflective spectrum of untreated fabric samples

2 MATERIALS AND METHOD

2.1 Hyperspectral Imaging System

In this research a hyperspectral spectral camera (PIKA L, Resonon Inc.,Bozeman, USA) with the lens mounted 15 cm above the printed fabric sample is used. The main specifications of the spectral camera are as follows: The Spectral Range (nm) 400 – 1000, Spectral Resolution (nm) 2.1, Spectral Channels 281, Spatial Channels 900

Figure 2 Hyperspectral imaging camera (PIKA L, Resonon Inc.,Bozeman, USA)

2.2 Printed Fabric Samples

12 different printed fabrics in 4 different groups are used for experimental studies. Every group has same design with different colors. Six of the samples are shown in the Figure 3. Data processes are conducted with MATLAB 2016a and SpectrononPro™.

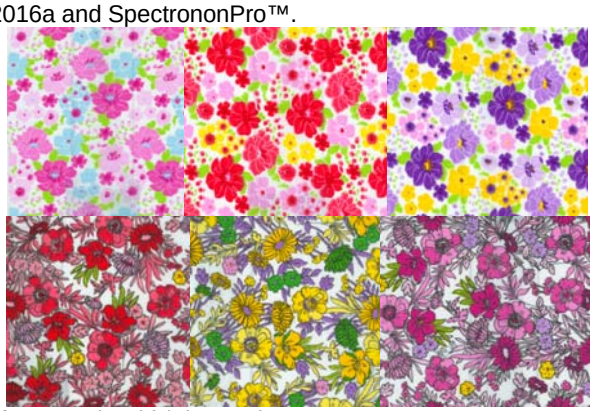

Figure 3 Printed fabric samples

3 RESULTS AND DISCUSSION

There are different classification methods used for generating classification maps of different clusters within hyperspectral data. Some of the classification algorithms Spectral Angle Mapper (SAM), Euclidean Distance use spectrum of target objects as inputs which are obtained from untreated fabrics. The statistics-based classifiers Logistical Regression, Quadratic Discriminate, Support Vector require data cubes of the classification target [1, 2, 4].

Samples of main spectrum of the color regions from the printed fabric is shown in Figure 4 obtained from the fabric sample shown in Figure 5. The segmented regions and the fabric samples are shown in Figures 5 and 6

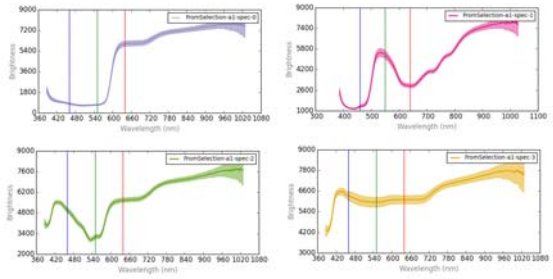

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Figure 4 Reflectance spectrum of four different regions

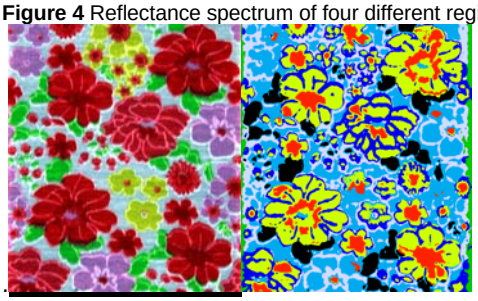

Figure 5 Printed fabric sample and segmented color regions

Figure 6 Printed fabric sample and segmented color regions

4 CONLCUSION

In this study it is shown that hyperspectral imaging technology with hyperspectral image processing is appropriate to be used for measuring reflective spectra of different color regions of printed fabrics where spectrophotometers cannot be used For this purpose different classifying methods are tried in order to detect the color regions. After obtaining the regions mean spectra of the regions are calculated.

ACKNOWLEDGEMENT: *This work was supported by Research Fund of Erciyes University. Project Number: FYL-2016-6720.*

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THE STUDY OF CONSUMER PROPERTIES OF DUAL-LAYER WEFT KNITTED FABRIC USING ECO-RAW MATERIALS

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Abstract: *In today's world, more and more people pay attention to various aspects that can maintain and improve their health and quality of their life. So nowadays such interest in expanding the range of ecological knitwear for functional purposes produced using natural raw materials is increasing again.*
The structure and the proposed fueling data to develop an integrated knitted fabric, which is due to the use for the formation of a one coat of dual-layer fabric with hemp and nettle yarn can be used as a functional textile material for the underwear manufacturing with therapeutic and preventive action, including underwear for wounded soldiers during their treatment and rehabilitation.
The designed structure is a two-layer fabric with the forged connections between layers in the main thread. In forging load canvas connectors are arranged in a checkerboard pattern. In the areas of connecting load the non-cross-cutting holes are formed. They provide ventilation and rapid water removal from under the clothes.
The studies determined the impact of eco-type materials in integrated layers of a dual-layer fabric to replace the linear dimensional jersey, relaxation characteristics, level of capillarity and fluid change level in time.

Keywords: eco-textiles, environmentally friendly knitwear, yarn, hemp, nettle, multifunctional knitwear.

1 INTRODUCTION

A variety of chemical composition, physical and mechanical properties provide knitted materials with pre-defined properties. In our laboratories were conducted a series of experiments to study the different physical and mechanical properties of knitted fabrics with natural yarns and changing of their properties when combined with modern, artificially produced components for creating multifunctional jersey.
Along with widely known types of natural materials like cotton and wool, the products from lesser-known, but still insufficiently studied types of environmentally friendly materials are getting more and more attention – such as yarn from eucalyptus, banana, coconut, soy, bamboo, corn, hemp and nettle. Such materials have positive preventative and sometimes even therapeutic effect on people, along with antibacterial and antiseptic properties. In terms of eco-tactile materials they don't irritate the skin and don't electrify.

2 MATERIAL

Hypoallergenic properties of mentioned yarn are achieved through plant material in the absence of toxic chemicals used to control weeds, pests and diseases of crops. The cost of growing hemp and nettle is relatively low and the therapeutic and environmental effects are very attractive.
Nowadays the products from hemp yarn are becoming common enough. Along with high consumer properties they are hypoallergenic and create temperature and energy balance, have antiseptic, wound healing and antiallergic function. Due to the porous structure of hemp fiber retains heat better and absorbs moisture (giving body to breathe during the heat). Contact with the endocrine glands has a beneficial effect on the nervous and cardiovascular system. Hemp fiber can reflect ultraviolet radiation. Medical scientists found out that the treatment of small wounds and scars with fibers from hemp accelerates healing processes three times faster. This is because hemp fiber maintains up to 20% of oil, which is an effective healing instrument [1].
Unfortunately hemp fiber is tough enough and isn't uniform in thickness. The large debris only compounds the situation. These factors are reduced by repeated yarn rewinding through waxing where it becomes more uniform. The moisturizing is needed to improve of hemp knitting yarn ability.
Along with this the little-known raw nettle also has effective medicinal properties. It is proved that nettle products help with many ailments: headaches and joint pain. Nettle products improve blood circulation, have a calming effect on the nervous system and beneficial effect on sleep to overall health and even the mood (give the light joy, feeling of peace and confidence appears), causing pleasant sensations. It helps to cope with depression, loss of strength and fatigue. Also positively affecting the acupressure points, that harmonizing the work of internal organs. It has a warming effect, thus contributing to the elimination of stagnant and inflammatory processes in the body. Therefore nettle zones and overlays are popular for quick relief from pain.
Raw nettle is treated the same way as flax. Nettle yarn production technology is not complicated, but is very time consuming [2].
The abovementioned suggests the high hygiene properties of knitted fabrics made from hemp and nettle yarn. High-medical properties of eco-materials and hemp nettle determine the importance of further expansion of their use, including the production of underwear for therapeutic and preventive usage. Along with this equally important are changes in linear dimensions after washing, relaxation properties and capillarity.

3 EXPERIMENTAL

Despite all the positive features hemp and nettle fibers are very irregular in thickness and rather tough.
This exactly complicates the widespread use of these types of materials in the knitting industry. The large debris of materials makes it almost impossible to process hemp and nettle on knitting equipment. Though, these factors are reduced through repeated rewinding yarn on winding equipment. Also, moisturizing can improve the process. All of these points on the need for research of processing conditions to identify parameters that ensure the normal course of loop formation process.
The technology was developed to produce dual-layer fabric with forge-connected layers in main thread on double-bar knitting machine. As the raw material for one of two layers of fabric it is suggested to use hemp or nettle yarn that provides curative properties of knitted fabric.
To form another layer it is suggested using anti-allergenic polyester filament with high resolution capillary that provides elasticity, maintaining the shape and temperature control, and increases the final appeal of these products to consumers. In addition, this raw material is inert to the development of pathogenic organisms because of its hydrophobic abilities. It does not absorb odors and ensures easy removal of dirt during washing.
Graphic recording double-layer weave structure of dual-layer weft knitted fabric is presented in "Fig. 1 ".

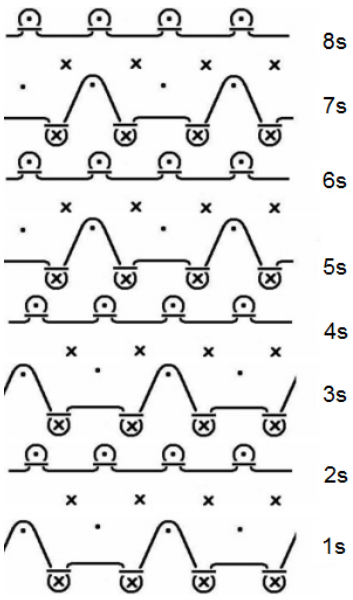

Figure 1 Graphic weave record

To produce samples it is suggested to use a 16th class double-bar knitting machine with interlock needles. To improve its ability the knitting hemp and nettle yarn materials need to be rewind three times. Yarn rewinding has eliminated debris and uneven thickness. Before knitting the yarn is moisturized in order to reduce bending rigidity.
Table 1 below shows the data for functional canvases.

Table 1 Filling data

Sample number	Filling data for loop forming systems
1	1, 3, 5, 7 s – Hemp yarn 25X2 tex
	2, 4, 6, 8 s – Polyester thread 16, tex
2	1, 3, 5, 7 s – Nettle yarn 31X2 tex
	2, 4, 6, 8 s – Polyester thread 16, tex

4 RESULTS

During the research were identified the effects of eco-type materials to replace the linear dimension samples of integrated knitted fabric, were determined relaxation characteristics. The results allow predicting the behavior of knitted fabric at operational loads. Research of capillarity makes it possible to determine the influence of eco-type materials at the level of capillarity prototypes and the nature of the changes in the fluid raising on functional layers of dual-layer knitted fabric.

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THERMO-PHYSIOMOGICAL COMFORT OF BRUSHING WOVEN FABRICS

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Abstract: *The effect of brushing on thermophysiological comfort properties of three basic weaving structures was studied: plain, twill and sateen.The thermophysiological comfort was evaluated based on thermal conductivity, resistance and absorptivityusing the Alambeta instrument. Also water vapour and air permeability were evaluated using respectively the Permetest and the FX3300 instruments to characterise the fabric breathability. The brushing treatment was carried out manually of 1% and 3% of weight loss. A sample without brushing is considered as reference. Results show that brushing affects thickness, thermal properties, air permeability and water vapour permeability. Water vapour transmission decreased but thermal resistance increased.*

Keywords: *brushing woven fabrics, thermal comfort properties, water vapour permeability*

1 INTRODUCTION

Comfort may be defined as a pleasant state of psychological, physiological and physical harmony between a human being and environment [1]. Designers of clothing can take care of psychological and physical aspects of comfort by suitable selection of colour, design, texture, style, garment fit, etc. However, suitable fabrics from the comfort point of view must be developed by textile technologists by proper selection of fiber content, yarn and fabric structure and finishing as they effect physiological comfort level through thermal transmission and moisture permeability.

Fabric brushing or surface raising is a mechanical finishing process. It is an effective way to increase the ability of the fabric to retain heat or provide a thermal barrier. This process makes fabrics fluffy and warm, with a soft handle.

Brushed fabrics are commonly used to make pants or trousers, jackets (sports), shirts, brushed Denim and even for sleeping garments and bed sheets.

For underwear applications, the fabric must be hydrophilic to move away moisture for the skin interface and spread the limit on the largest possible area to favor evaporation. Often to help this phenomenon, a "brushed" fabric is used causing a considerable increase in surface area thus enhancing the comfort level.

Therefore, the study of thermo-physiological comfort properties of brushing woven fabrics may be an important topic for scientific research.

In this context, we will investigate the effect of brushing and weave structure on thermo-physiological comfort.

2 EXPERIMENTAL

2.1 Materialse

For the purpose of this research, three woven fabric samples in 3 basic weave structures (plain, twill and sateen) were manufactured.

All fabrics were woven using 50 % cotton/ 50% polyester, warp density 24 ends/cm and 33.5 tex for the warp component. The weft density is 24 picks per cm and 18.8 tex of Polyester. All woven fabric samples were made using flexible rapier weaving machine; GamMax from Picanol under the same technological conditions.

Before testing, all samples were scoured (bath containing 1.5% of caustic soda, 0.2% of surfactant and 0.1% of sequestrant agent at 100°C for 20 minutes was employed).

Also, all samples were conditioned and tested in the environmental conditions. Lab temperature was maintained between 20-22°C and relative humidity was around 25-28 %.

2.2 Methods

Our samples were manually brushed using brushing paper. We tried to get uniform brushing aspect. we get a reduction of weight of 1 % and 3 %.

In this work the thermo-physiological comfort parameters (thermal conductivity, thermal resistance, thermal absorptivity, water vapor permeability and air permeability) of the fabrics were measured..

- Thermal conductivity is a property of materials that expresses the heat flux that will flow through the material if a certain temperature gradient exists over the material.
- Thermal resistance is an indication of how well a material insulates.
- Thermal absorptivity determines the contact temperature of two materials.
- Relative water vapor permeability is the rate of water vapor transmission through a material.
- Air permeability is the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material.

An Alambeta instrument was used to measure thermal resistance, thermal absorptivity and sample thickness and to calculate all the statistical parameters of the measurement. Objective measurement of the warm-cool feeling of fabrics, so called thermal absorptivity (Ws1/2/m2.K), is possible [2]. The contact pressure was 200 Pa in all cases, and the CV values of all the samples were lower than 5%.

Relative water vapour permeability was measured on a Permetest instrument by a similar procedure to that given by Standard ISO 11092 [3]. The number of measurements

was 5 for Alambeta and 3 for Permetest. All the measurements were done in controlled laboratory conditions.
TEXTEST Air permeability Tester (FX3300) is used to measure the air permeability at 100 Pa air pressure. An average of 5 readings for each sample is reported.

3 RESULTS AND DISCUSSION

3.1 Air permeability

According to figure 1, the Twill and Sateen weaving structure have the highest air permeability value. These results can be explained by fabric porosity. As it is known that these weaving structure are more porous than Plain structure and with the increment of porosity the air permeability values increase as expected.
Even after brushing, the same phenomenon is seen.

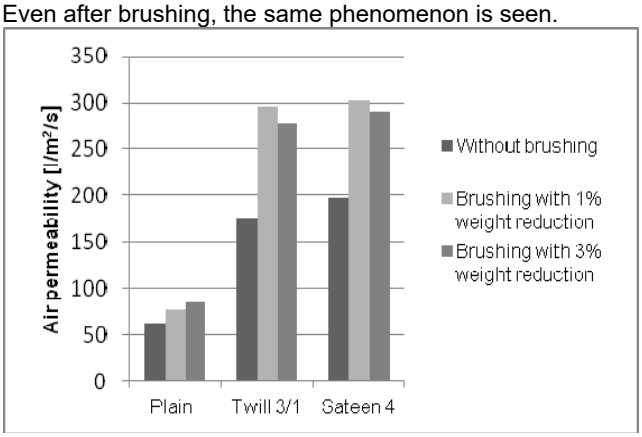

Figure 1: Air permeability of Plain, Twill 3/1 and Sateen 4

3.2 Thermal conductivity

Thermal conductivity is an intensive and specific property of materials that indicates its ability to conduct heat. According to figure 2 and without brushing, sateen structure has the highest thermal conductivity

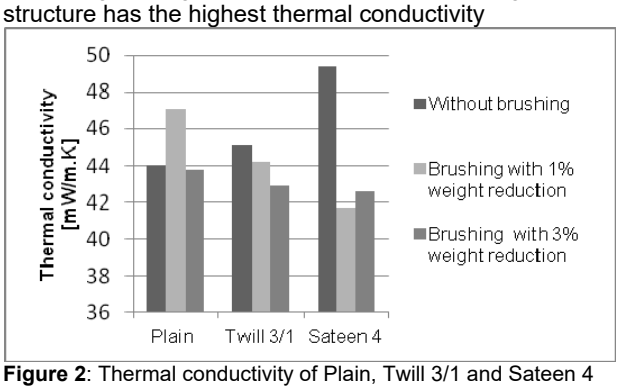

Figure 2: Thermal conductivity of Plain, Twill 3/1 and Sateen 4

3.3 Thermal resistance

Thermal resistance is a measure of the body's ability to prevent heat from flowing through it. Under a certain condition of climate, if the thermal resistance of clothing is small, the heat energy will gradually reduce with a sense of coolness [4].
For each structure, the brushing treatment increases the insulation of fabrics as the thickness is also increasing.
After brushing, the Sateen and Twill structure have the highest thermal resistance and this could be explained by the fact that these structure are loose and easily to brush compared to Plain structure.

3.4 Thermal absorptivity

Thermal absorptivity is the objective measurement of the warm-cool feeling of fabrics [2]. A warm-cool feeling is the first sensation. When a human touches a garment that has a different temperature than the skin, heat exchange occurs between the hand and the fabric. If the thermal absorptivity of clothing is high, it gives a cooler feeling at first contact [5].
After brushing, thermal absorptivity decreases and we obtain warmer fabrics. The plain weaving structure has the highest thermal absorptivity and, at the same time, the coolest feeling at the moment of contact of the fabric with human skin.

3.5 Relative water vapour permeability

Relative water vapour permeability is the percentage of water vapour transmitted through the fabric sample compared with the percentage of water vapour transmitted through an equivalent thickness of air.
It can be seen from figure 5 that, before brushing, all structures have almost the same value of relative water vapour permeability. After brushing, Plain weaving structure has higher relative water vapour values than Twill and Sateen fabrics. It could be explained by the fact that Plain weaving structure is compact (with high warp density) that the brushing doesn't effect

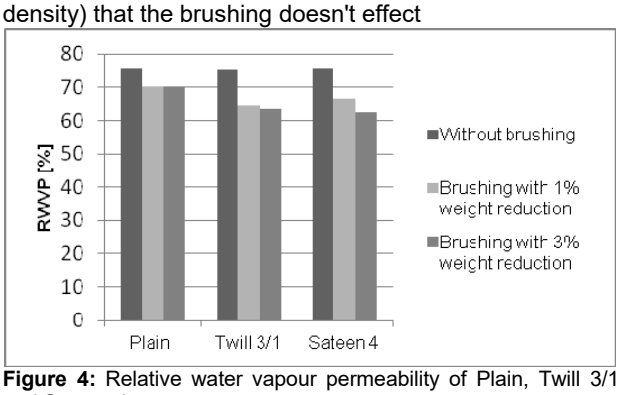

Figure 4: Relative water vapour permeability of Plain, Twill 3/1 and Sateen 4

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STUDY OF THERMAL COMFORT OF SINGLE JERSEY FABRIC BY UTILIZATION OF RECYCLED WOOL WITH POLYESTER

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Abstract: *This research explores the utilization of recycled waste with polyester by giving useful product and environment sustainability. The paper studies the influence of different blends ratio of recycled Wool and Polyester on the thermal comfort and mechanical properties of their knitted fabrics. The aim of this research is to determine tenacity, elongation, thermal resistance, air permeability, moisture management, of the wool-polyester knitted fabrics. Three blends of recycled wool and polyester (70/30, 60/40, 50/50) were used to make Ring spun yarns of 8 single. From these yarns, single jersey fabric was made by using hand flat knitting machine. To check thermal and mechanical properties, Tensorapid, Uster tester 5, Moisture management tester, Air permeability tester, Sweating guarded hot plate were used. Thermal resistance of Wool-Polyester (70/30) was found highest and Wool-Polyester (50/50) showed maximum air permeability among all blends. The research concludes that by increasing recycled wool, thermal resistance will increase and air permeability will decrease, providing warmth to body. Besides Polyester enhances the mechanical properties of the fabric. These findings are helpful to design particular winter clothing along with good mechanical properties.*

Keywords: *Wool, thermal resistance, winter clothing.*

1 INTRODUCTION

In 2005, a survey held in U.K. revealed that more than one million tons of textile are thrown away every year. Any synthetic material present in the waste does not decompose and makes environment polluted and unsustainable. Woolen garments are decomposable but they produce methane causing global warming. But the modern textile industry has potential to recycle and recover the textile waste providing economic and environmental benefits. Recycling of textile waste reduces the need for landfill space, consumption of the virgin resources and contributing less pollution to the environment. The broad objective of this study is to make sustainable environment by recycling of textile waste [1].

In this age, people's demand for fabric is not merely based on dimensional and mechanical properties but they also want thermal comfort properties. So the modern textile industry introduces clothing with great thermal comfort and desired mechanical properties by making blends of different fibers [2].

Wool is animal fiber that is made from the skin of sheep. It is also known as protein fiber. Wool has a range of diameters that make it multifunctional and versatile fiber. Wool is used especially in sweaters and coats for clothing purpose because it is comfortable and warm. The scales on wool fiber makes it good insulator of air Two thirds of wool is used in the manufacture of garments, including sweaters, dresses, coats, suits and "active sportswear". Wool can also be blend with other fibers to enhance its properties. When it is blended with natural and synthetic fibers, they improve drape and crease resistance. So these wool blends can be used where better drape is required.

Old woolen stuff is broken through different methods to make woolen fibers again, these woolen fibers are known as recycled wool. Old woolen stuff basically falls into the category of postconsumer textile waste that usually refers to any product that a person no longer needs and decides to discard due to wear or damage. These usually include used or worn clothing, bed linens, curtains, towels, sheets and blankets, clean rags and sewing remnants, table cloths belts, hand bags, paired shoes and socks [3].

Polyester fiber is synthetic fiber having great strength, luster and abrasion resistant. It has 35% crystalline region and 65% amorphous region. The longitudinal appearance of the fiber is very regular and featureless because of the near circular cross section. In fact, the magnified appearance of polyester can be linked to that of a glass rod. Polyester can be blended with natural fiber to achieve comprehensive properties of the product. [4]

Knitted fabric is vastly used in apparel due to its comfort and soft properties. Comfort is absence of displeasure and discomfort [5]. "Comfort in clothing can be defined as a pleasant state of psychological, physiological and physical harmony between a human being and the environment" [6, 7]. Comfort can be sensorial or thermal. Thermal comfort of clothing depends on kind of fibre, spinning process, amount of twist per inch, fabric thickness, finishes, fabric cover factor. [8,9]. Thermal comfort of clothing imparts sustainability in our life. It makes possible people to survive and strive under wide range of temperature ranging -40c to +40c [10].

Thermal conductivity means how much a material conduct heat. It depends on kind of fibre. The materials don't conduct heat are called thermal resistant material. For winter clothing thermal resistance should be high to obtain thermal comfort. On the other side, in summer thermal conductivity should be high.

Air permeability is the air flow rate passing through perpendicularly known area under a prescribed pressure differential between two surfaces of material. it is effected by, Fabric construction, fibre nature [11].

This study finds the impact of different blends ratio of wool and polyester on the thermal comfort and mechanical properties of their fabric. Three blends of recycled wool

and polyester (70/30, 60/40, 50/50) were focused to make Ring spun yarns of 8 single and then their knitted fabric on Hand flat knitting machine.

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EXPERIMENTAL STUDY OF THERMAL PROPERTIES OF KNITTED FABRICS

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Abstract: *In this paper, the thermal properties of cotton, micro-modal and polyamide based single jersey structures were statistically investigated. The thermal properties of samples were measured using hot Disk device. The thermal conductivity and the thermal absorptivity were measured. The results of the tests were evaluated statistically and the importance levels of the relationship between the measured parameters were determined. It was observed that polyamide knitted fabrics with lower weight per unit area have lower thermal conductivity, which procure better thermal comfort.*

Keywords: *knitted fabrics, thermal conductivity, thermal absorptivity, hot disk, thermal comfort*

1 INTRODUCTION

Thermal properties of textile fabrics are of great interest and relevance for textile researchers , since they determine several of the major characteristics related to the wearer's overall comfort perception [1], having significant effects on the skin mean temperature also [2]. The heat transfer through clothes takes place by means of three distinct processes: conduction, convection and radiation. In the conduction mechanism, heat propagates through short range interactions of molecules and/or electrons, while convection involves heat transfer by means of the combined mechanisms of fluid mixing and conduction, and heat radiates away in the form of electromagnetic waves, mainly in the infrared (IR) region [3]. For what concerns us here, it is generally accepted that heat transfer by conduction is more significant than other mechanisms.
Thermal conductivity is fundamental to determine the heat transfer through fabrics. For textile materials, still air in the fabric structure is the most important factor for conductivity value, as still air has the lowest thermal conductivity value when compared to all fibers (λair = 0.025). Therefore, air transports a low quantity of energy by conduction and thermal conductivity decreases as well [4].
Thermal absorptivity is the objective measurement of the warm-cool feeling of fabrics and is a surface related characteristic. If the thermal absorptivity is high, it gives a cooler feeling at first contact with the skin. The surface character of the fabric greatly influences this sensation
The transient plane source (TPS) thermal characterization technique is becoming an important tool for the determination of the thermal properties of a variety of materials [5] due to its robust design, rapid characterization time and for its ability to simultaneously measure the thermal conductivity and thermal diffusivity of complex materials, such as nanocomposites.

2 EXPERIMENTAL SETUP

2.1 Materials and structural properties

In this study, six jersey knitted samples designed for sportswear applications were used. The fiber contents, material weights and thickness are listed in Table 1.

Sample code	Fibre content	Weight per unit area (g/m2)	Thickness (mm)
A	PA 6-6	237	1.02
B	PA 6-6	123	0.68
C	PA 6-6	72	0.53
D	PA 6-6	112	0.74

2.2 The method of thermal properties measurement

As well known, any thermal property of a given fabric depends on the thermal conductivity l, the latter being a function of the thermal power Q transmitted through the testing sample, of its surface and thickness, and of the temperature difference ΔT across its thickness.
The thermal comfort properties such as thermal resistance R, absorption b and diffusion a are derived from the measured thermal conductivity λ and are computed as follows:

$$a = \lambda / \rho c \quad (1.1)$$

And

$$b = \sqrt{\lambda \rho c} \quad (1.2)$$

Where ρ [kg/m^3] is the density of the sample (calculated by dividing the surface density by thickness) and c [J/(kgK)] its specific heat.

The thermal conductivity λ of fabric samples were measured by the Hot Disk_ Method Thermal Analyser (TPS-2500). The hot-disk method uses a thin disk-shaped sensor (hot-disk sensor) to measure the thermal conductivity. The measurement time was kept at 10 s, and the output power to the hot-disk sensor was 10mW. The sensor radius was 2.001 mm. At least five measurements were performed for each material to ensure the repeatability of the measurements results.During the measurement, the hot-disk sensor was sandwiched between the two sample fabrics, according to ISO 22007 2 (He, 2005; ISO, 2008; Salaün et al., 2010).

3 EXPERIMENTAL RESULTS

The effect of fiber type and mass per unit area on the thermal conductivity and absorptivity was investigated

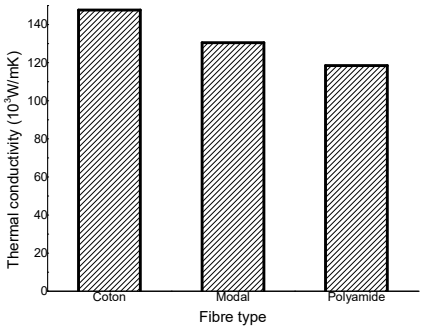

Figure 1 : Effect of fiber type on thermal conductivity

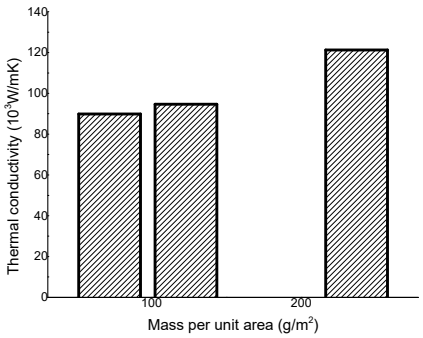

Figure 2 : Effect of mass per unit area on thermal conductivity

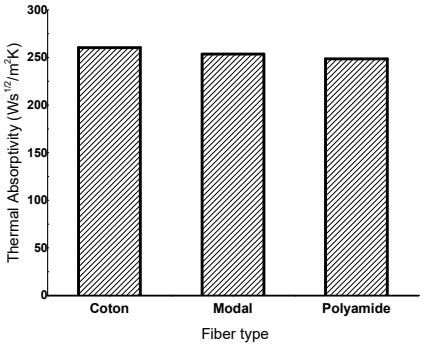

Figure 3 : Effect of fiber type on thermal absorptivity

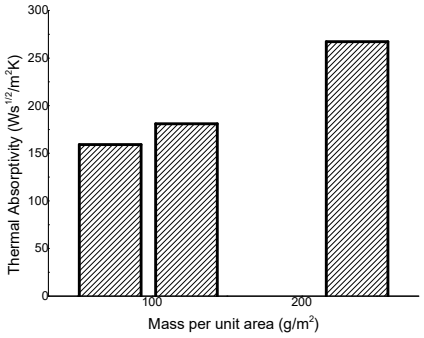

Figure 4 : Effect of mass per unit area on thermal absorptivity

The figures show a correlation between the structural parameters of the samples tested and their thermal properties

Knitted fabrics made from cotton fibers have higher thermal conductivity. In fact, micro porosity is higher for natural fibers, which reduces thermal insulation.

It was observed that polyamide knitted fabrics with lower weight per unit area have lower thermal conductivity, which procure better thermal comfort.

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EXPERIMENTAL INVESTIGATION INTO THE THERMAL PROPERTIES OF KNITTED FABRICS USING TRANSIENT PLANE SOURCE METHOD

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Abstract: *In this paper, the thermal properties of cotton, micro-modal and polyamide 6-6 based single jersey structures were statistically investigated. The thermal conductivity and diffusivity of samples were measured using hot Disk device. The thermal absorptivity expressing the warm-cool feeling of fabrics was derived from the measured parameters. The results of the tests were evaluated and the importance levels of the relationship between the measured parameters and the fibre content and mass per unit area were determined. It was observed that polyamide knitted fabrics with lower weight per unit area have lower thermal conductivity, which procure better thermal comfort.*

Keywords: *knitted fabrics, thermal conductivity, thermal absorptivity, hot disk, thermal comfort*

1 INTRODUCTION

Thermal properties of textile fabrics are of great interest and relevance for textile researchers , since they determine several of the major characteristics related to the wearer's overall comfort perception [1], having significant effects on the skin mean temperature also [2]. The heat transfer through clothes takes place by means of three distinct processes: conduction, convection and radiation. In the conduction mechanism, heat propagates through short range interactions of molecules and/or electrons, while convection involves heat transfer by means of the combined mechanisms of fluid mixing and conduction, and heat radiates away in the form of electromagnetic waves, mainly in the infrared (IR) region [3]. For what concerns us here, it is generally accepted that heat transfer by conduction is more significant than other mechanisms.

Thermal conductivity is fundamental to determine the heat transfer through fabrics. For textile materials, still air in the fabric structure is the most important factor for conductivity value, as still air has the lowest thermal conductivity value when compared to all fibers (λ_{air} = 0.025 $W \cdot m^{-1} \cdot K^{-1}$). Therefore, air transports a low quantity of energy by conduction and thermal conductivity decreases as well [4].

Thermal absorptivity is the objective measurement of the warm-cool feeling of fabrics and is a surface related characteristic. If the thermal absorptivity is high, it gives a cooler feeling at first contact with the skin. The surface character of the fabric greatly influences this sensation

The transient plane source (TPS) thermal characterization technique is becoming an important tool for the determination of the thermal properties of a variety of materials [5] due to its robust design, rapid characterization time and for its ability to simultaneously measure the thermal conductivity and thermal diffusivity of complex materials, such as nanocomposites and fibrous materials.

2 EXPERIMENTAL SETUP

2.1 Materials and structural properties

In this study, six jersey knitted samples designed for sportswear applications were used. The fiber contents, material weights and thickness are listed in Table 1.

Sample code	Fiber content	Weight per unit area (g/m2)	Thickness (mm)
A	Cotton	177	0.67
B	Micro modal	160	0.69
C	PA 6-6	175	0.56
D	PA 6-6	237	1.02
E	PA 6-6	123	0.68
F	PA 6-6	72	0.53

2.2 The method of thermal properties measurement

As well known, any thermal property of a given fabric depends on the thermal conductivity (λ), the latter being a function of the thermal power Q transmitted through the testing sample, of its surface and thickness, and of the temperature difference ΔT across its thickness.

The thermal comfort properties such as thermal resistance R, absorption (b) and diffusion (a) are derived from the measured thermal conductivity (λ) and are computed as follows:

$$a = \lambda / \rho c \qquad (1.1)$$

And

$$b = \sqrt{\lambda \rho c} \quad (1.2)$$

Where ρ (kg/m^3) is the density of the fiber and c (JKg^{-1}K^{-1}) its specific heat.

The thermal conductivity λ of fabric samples were measured by the Hot Disk_ Method Thermal Analyzer (TPS-2500). The hot-disk method uses a thin disk-shaped sensor (hot-disk sensor) to measure the thermal conductivity. The measurement time was kept at 10 s, and the output power to the hot-disk sensor was 10mW. The sensor radius was 2.001 mm. At least five measurements were performed for each material to ensure the repeatability of the measurements results. During the measurement, the hot-disk sensor was sandwiched between the fabric, according to ISO 22007 2.

3 EXPERIMENTAL RESULTS

The effect of fiber type and mass per unit area on the thermal conductivity and absorptivity was investigated

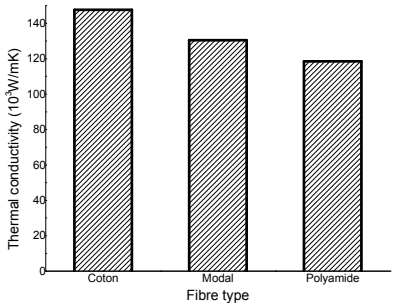

Figure 1 : Effect of fiber type on thermal conductivity

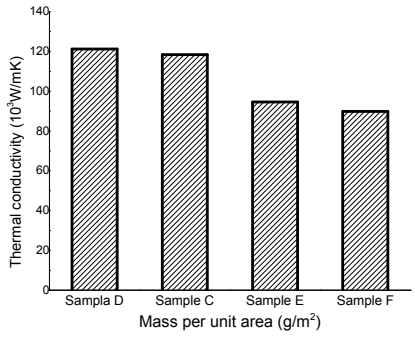

Figure 2 : Effect of mass per unit area on thermal conductivity

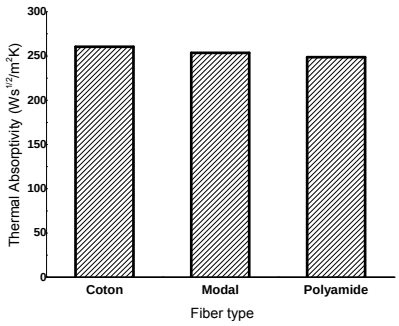

Figure 3 : Effect of fiber type on thermal absorptivity

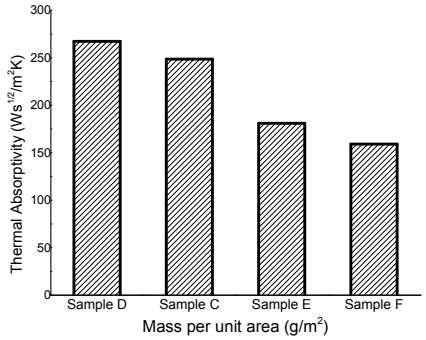

Figure 4 : Effect of mass per unit area on thermal absorptivity

The figures show that knitted fabrics made from cotton fibers have higher thermal conductivity than micro modal and polyamide. The lower thermal conductivity of fabrics made from polyamide fibers could be ascribed to the lowest thickness which expresses higher macro porosity.

Figure 3 show that heavier fabrics have higher thermal conductivity. This situation can be explained by the amount of entrapped air in the fabric structure. The amount of fiber in the unit area increases and the amount of air layer decreases as the weight increases. As is known, thermal conductivity values of fibers are higher than the thermal conductivity of entrapped air.

Polyamide fibers give a warmer feeling at first touch due to lower thermal absorptivity values and lower fabric weight give more warm feeling.

4 CONCLUSION

The thermal comfort properties of six different knitted structures made from cotton, regenerated cellulosic fiber and polyamide 6-6 have been studied and analyzed. It was observed that polyamide knitted fabrics with lower weight per unit area have lower thermal conductivity, which procure better thermal comfort.

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THE FABRIC FOR THAI ART FOLDING OF BANANA LEAVES ON CLOTHING

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Abstract: *Thailand has a uniquely long-standing tradition of arts and crafts. Thai art folding of banana leaves, probably the best-known such as food wrappers and precious handicrafts has been practiced to make colorful decorations for festivals. As time passed, roles of using parts of banana have been reduced but there has been an attempt to help conserve it only some art and craftsmanship. This research will study and analyze about Thai art folding of banana leaves, the folding technic from art and design, product and fashion for diversity of folding. Furthermore, Fabric is the key of this research to know the type of fabric suitable for folding. Thus, the experiment and practice show the fabric qualification by selected 9 properties included 1. Good stability 2. Good draping 3. Heat resistance 4. Smoothness 5. Balance 6. Wrinkle 7. Strong with the wearable fabric are 1. Natural Fabric 1.1) Cotton 1.2) Linen 1.3) Muslin 1.4) Jute 1.5) Ramie 2.Man-made fabric 2.1) Polyester 2.2) Nylon 2.3) Organza 2.4) Organdy 2.5) Satin 3. Blended Fabric 3.1) Cotton Spandex 3.2) Linen Viscose. The result is Polyester, Organdy and Organza respectively suitable for folding. In conclusion, the purpose of this research compiles the theory, technique, and method of Thai art folding of banana leaves. Moreover, the many types of folding technique from Thai art folding of banana leaves for clothing construction that can be a guideline and modified in the next stage for designers who interested in craftsmanship, culture, and tradition. Then, to create the guideline from the Thai art folding of banana leaves. Finally, the wearable art by using the clothing construction guideline from the Thai art folding of banana leaves.*

Keywords: *Fabric, folding, wearable art, traditional techniques*

1 INTRODUCTION

Considering plants that have been closely linked to the traditional Thai ways of life, banana can be placed among the top ranks. This is not only because its parts are used in many traditional ceremonies but also due to the high nutritive value of its fruit that has made it a simple home remedy or a quick fix for flagging energy levels. Also, banana is a very useful plant to the Thai household.

Thailand has a uniquely long-standing tradition of arts and crafts. Unlike most of its neighbors, it has never been occupied by a foreign power or engaged in wars of conquest, and it has thus enjoyed a relatively peaceful development since ancient times. Patronized by the court and the temples, the designs and craftsmanship of Thai artisans have flourished (William Warren, 1994: 1). Thai banana leaves folding, probably the best-known example of Thailand's precious handicrafts, has been practiced to make colorful decorations for festivals. Leaves are folded in delicate, triangular and intricate patterns before being presented to Lord Buddha statues at temples. The religious offerings made from banana leaves and flower petals are called "Bai Sri". The art of banana leaf folding is handed down from generation to generation (Artcrumps, 2013).

As time passed, roles of using parts of banana as such materials as food wrappers or children toys, as well as its role in some ceremonies, have been reduced, and mostly replaced by plastics or other easier-to-find materials. However, there has been an attempt to help conserve the art of decoration from parts of banana, especially for traditional ceremonial purposes, as it is considered a fine art from ancient Thai folk wisdom (Blue Lotus, 2004). Also, Thai banana leaf folding is one of the remaining traditional art that still exist and are known by some art and craftsmanship student, so proliferation is the way to inherit and develop the Thai culture (Pattrawut Thongyam:2005).

In conclusion, this research will study and analyze about Thai art folding of banana leaves, the folding technic from art and design, product and fashion for diversity of folding. Furthermore, Fabric is the key of this research to know the type of fabric suitable for folding.

2 MATERIAL AND TOOLS

2.1 Material

1. Natural Fabric
1.1) Cotton 1.2) Linen 1.3) Muslin 1.4) Jute 1.5) Ramie
2.Man-made fabric
2.1) Polyester 2.2) Nylon 2.3) Organza 2.4) Organdy 2.5) Satin
3. Blended Fabric
3.1) Cotton Spandex 3.2) Linen Viscose.

2.2 Tools

1. Sewing machine, Lock stitch type 301
2. Scissors
3. Thread
4. Folding process
   4.1) Hand pleating
   4.2) Hot steam pleating machine
   4.3) Hot rotary machine
5. Textile testing center

3 EXPERIMENT

Hak kor ma is the selection folding technic.

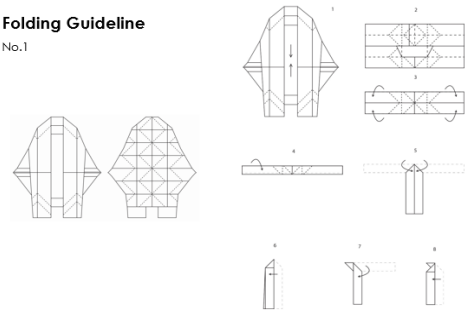

Figure 1 Thai art folding of banana leaves

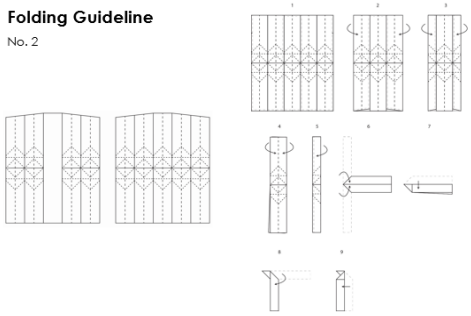

Figure 2 Folding guideline no.2

4 RESULTS

From the experiment have founded the best stability are cotton, polyester, organdy, organza, cotton+spandex, linen, muslin, jute, ramie, nylon, linen+viscose, and satin. The best draping are satin, polyester, nylon, organdy, organza, linen, cotton+spandex, linen+viscose, cotton, muslin, jute, ramie. The best heat resistance are cotton, linen, muslin, cotton+spandex, jute, ramie, polyester, linen+viscose, satin, organdy, organza and nylon. The best smoothness are satin, organdy, organza, cotton, linen, muslin, jute, ramie, polyester, nylon, cotton+spandex, linen+viscose. The balance are cotton, linen, muslin, jute, ramie, polyester, cotton+spandex, linen+viscose, organdy, organza, nylon and satin. The best wrinkle are cotton, polyester, cotton+spandex, muslin, nylon, organdy, organza, satin, linen+vicose, linen, jute and ramie. The best strong are cotton, linen, muslin, jute, ramie, polyester, cotton+spandex, linen+viscose, nylon, organza and satin. Finally, The best result is Organdy, Organza and Polyester respectively suitable for folding and the best folding process is hand-pleating.

There are the test report of Oragandy and Organza according to the must qualities for folding clothing from Foundation for Industrial Development Thailand Textile Institute / Textile Testing Center.

Table 1 Test Report : Organdy

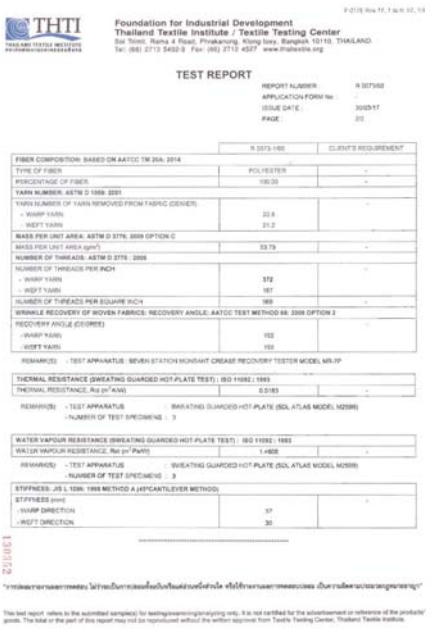

Table 2 Test Report : Organza

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INVESTIGATION OF QUILTED MATERIALS APPLIED IN OUTDOOR CLOTHING

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Abstract: *Quilt fabrics are more and more commonly used in outdoor clothing, especially jackets. Usually they are composed of two or three layers connected together by thread or thermal quilting. Dependably on the quilt structure they are characterized by different thermal insulation properties. In presented work 6 variants of quilts were investigated in the range of their thermal resistance, water-vapor resistance and air permeability. On the basis of the results it was possible to assess the quilt materials from the point of view of their usability for outdoor clothing.*

Keywords: *quilt fabric, quilting, outdoor clothing, thermal insulation, thermal comfort*

1 INTRODUCTION

Clothing is defined as a textile product covering the human body. The clothing product is made of patterns received on the basis of the dimensional characteristics of the human body. Clothing product is a collection of many materials, mainly textile ones, selected in such a way to achieve determined utility functions. The construction and form of clothing depend mainly on the structure and shape of the human body, functions which the product should fulfill, conditions of clothing usage, especially climatic conditions, customs, fashion trends, etc.
Clothing products are classified according to different criteria, for instance the target group, a way of manufacturing, material and particular purpose. Dependably on the degree of complexity the clothing can be classified as one-layer or multilayer product. In multilayer clothing goods there are usually three layers fulfilling different roles:

- outer shell,
- middle layer,
- lining.

In winter clothing, a very important role is played by the middle layer, the basic function of which is to protect the human body against chilling [1]. Different kinds of textile materials are used as the middle thermal insulating layer of multilayer clothing, such as traditional wadding, nonwovens or polar flees. Thera are also innovative, highly advanced thermal insulating materials like Thermore® nonwovens, or membrane systems which ensure excellent thermal insulation connected with the physiological comfort. In recent years the quilt fabrics are commonly used as the middle thermal-insulation layer of outdoor clothing. The quilt fabrics are also applied alone in outdoor clothing manufacturing, especially jackets. Quilting is the process of sewing two or more layers of fabrics together to make a thicker padded material, usually to create a quilt or quilted garment. Usually, typical quilting is done with two or three layers. In two-layer quilt the thermal insulating material is sewn together with the surface material. In three-layer quilt the thermal insulation material, usually PES flees, is placed between two woven fabrics. The quilt can be finished in different ways, for instance: PU or PUV coating, waterproof, breathable, reflective, etc.

The properties of quilt fabrics, especially their thermal insulation influence significantly an ability of clothing made of them to ensure the protection against cold in outdoor microclimate.

2 AIM OF WORK

The aim of work was to investigate the quilt textiles applied in outdoor clothing. Different kinds of quilt fabrics two- and three-layer were measured in the range of their basic physical parameters and properties influencing the thermo-physiological comfort of clothing made of them. Obtained measurement results allowed assessing the investigated quilted materials from the point of view of their usability for outdoor clothing.

3 MATERIALS AND METHODS

In the frame of presented work different kinds of quilt materials were measured in the range of their comfort-related properties. They were:

- 4 variants of two-layer PES quilt,
- 1 variant of three-layer PES quilt,
- 1 variant of three-layer PES/CV quilt.

The set of the investigated quilts is presented in Table 1.

Table 1 The set of the investigated quilts

Symbol	No. of layers	Content	Mass per square meter g m^{-2}	Thickness mm
Q 1	2	PES	149.1	0.78
Q 2	2	PES	217.2	3.22
Q 3	2	PES	129.8	2.42
Q 4	2	PES	120.5	2.00
Q 5	3	PES	172.5	1.56
Q 6	3	PES/CV	191.4	1.30

All variants of two-layer quilts are composed of the PES flees as a thermal insulation layer and PES woven fabric as a surface layer. The three-layer quilt Q 5 (fig. 1) is composed of the PES flees as well as the surface and bottom layer made of the PES woven fabrics. The Q 6

three-layer quilt (fig. 2) is created from the PES flees, surface CV woven fabric and bottom PES net.

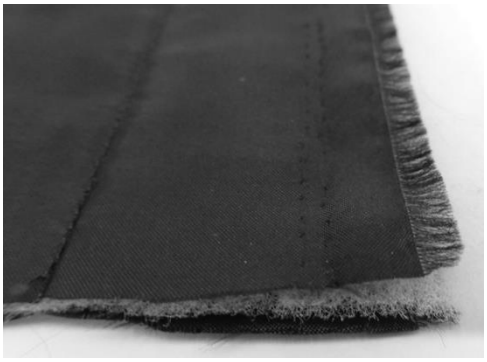

Figure 1 Q 5 three-layer PES quilt

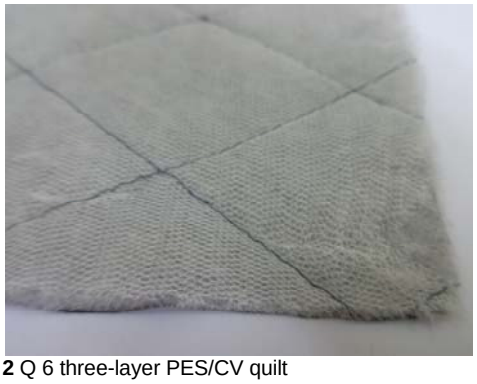

Figure 2 Q 6 three-layer PES/CV quilt

All mentioned above textile materials were measured in the range of their properties influencing the thermo-physiological comfort. Measurement of thermal insulation properties was performed with the Alambeta device according to Internal Standard [2]. Water-vapor resistance was determined by means of the sweating guarded hot-plate test according to ISO standard [3]. Air permeability was measured according to Polish Standard [4].

4 RESULTS

The results from the Alambeta are presented in Table 2. Obtained results show that the investigated quilt fabrics differ between each other in the range of their comfort related properties. Only the thermal conductivity of the investigated quilts is at the same level. It results from the fact that all investigated materials are made of the same kind of fibers – PES fibers. The PES fibers are in the woven fabrics and in flees between the fabrics. The only exception is the material Q 6. It contains the CV woven fabric as a shell. Thermal resistance of the investigated quilts is in the range from 0.026 till 0.12 W^{-1} Km^2. The highest thermal resistance was stated for the Q 2 quilt, the lowest – for the Q 1 quilt. Thermal resistance of the investigated quilts depends significantly on their thickness (fig. 3).
Table 3 presents the results of water-vapor resistance and air permeability.

Table 2 Results from the Alambeta

Sample	Thermal conductivity	Thermal diffusivity	Thermal absorptivity	Thermal resistance
	$W\ m^{-1}K^{-1}$	m^2s^{-1}	$Wm^{-2}\ s^{1/2}\ K^{-1}$	$W^{-1}\ Km^2$
Q 1	0.036	1.40E-07	95.9	0.026
Q 2	0.036	5.25E-07	49.8	0.116
Q 3	0.036	7.05E-07	43.6	0.098
Q 4	0.036	6.10E-07	46.2	0.087
Q 5	0.037	2.55E-07	73.5	0.051
Q 6	0.037	3.84E-07	59.7	0.053

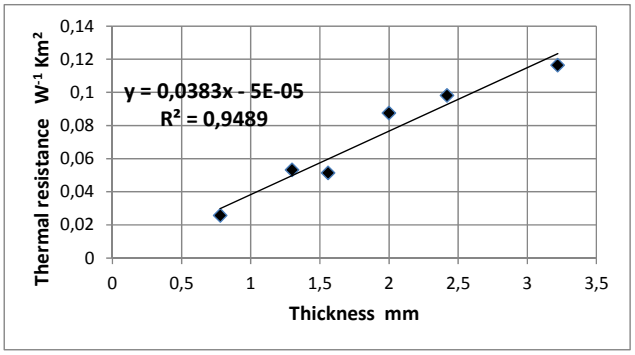

Figure 3 Thermal resistance vs. thickness

Table 3 Water-vapor resistance and air permeability of the investigated quilts

Sample	Water-vapor resistance	Air permeability
	$m^2Pa\ W^{-1}$	$mm\ s^{-1}$
Q 1	4.95	85.4
Q 2	11.94	282.9
Q 3	12.69	84.4
Q 4	8.93	390.2
Q 5	9.05	231.6
Q 6	6.36	227.1

In the case of the water–vapor resistance and air permeability significant differentiation is also observed.
In order to apply the investigated quilts in outdoor clothing it is necessary to analyze the results and to make choice of appropriate quilt dependably of a kind of clothing good and its function.

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STUDY OF CZECH MALE BODY DIMENSION AND EVALUATION OF MEN´S TROUSERS PATTERNMAKING METHODS

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Abstract: *This study deals with the effect of different male somatotypes and different pattern making method on men´s trousers pattern design. First, the research is focused on the analysis of the 200 Czech men anthropometric data in order to define Czech somatotypes. The body sizes of the intended trousers wearers are identified with the help of the grouping of body sizes appropriate to the European population in according to the rules of the standard "EN 13402–3: Measurements and Intervals". Then comparing them with the label states characteristic dimensions of the Czech products of the BUSHMAN brand trousers. Six men´s trousers pattern drafting methods of the Czech and the other European authors are analysed. The result indicates that the trousers patterns are mostly drawn by using a constant numerical value for generating the design dimensions instead of using a regression equation for value calculation. These patternmaking methods are totally inadequate for pattern drafting in order to fit a wide range of men's bodies (male morphology).To solve this problem, this paper examines a proposal for a pattern making method for a men´s trousers. The most suitable method, thanks to the largest number of formulas in form of the regression equation, is the NVS Czech method. This method and the definition of the body size range appropriate to the Czech population will increase the efficiency of construction parameters and thus to automate the pattern grading process of the trousers pattern construction in a wide range.*

Keywords: *Czech male anthropometric data, pattern making method, trousers*

1 INTRODUCTION

The quality of fitting of the garment depends on a relatively high degree of our knowledge of the body dimensions of the target wearers. Instead of having a lot of information of the body proportions, we can simply use the way of determination of a value of one body dimension which is calculated as a percentage of another dimension [1].
The problem of improper fitting may be due to not only the body sizes but also the inappropriate pattern drafting methods.
A number of pattern making methods for men´s trousers have been published. Each of them is involving formulas in the form of either a set of equations, a set of empirical numerical values or indeterminate curves that are based on the practical experience of experts. It is not clear that whether patterns are drafted by using these methods would fit a wide range of population [2].
For this reason, it is meaningful to deal with an effect of the anatomical differences of the body on the pattern designs and to study the body proportions as well as to analysis their properties by means of statistical methods [3].
Using results from the regression analysis of anthropometric data in the design methodologies is very effective [4].
Implementation of the results of a regression analysis of the anthropometric data of the target wearers to a pattern making methods seems to be a very efficient way.

2 EXPERIMENTAL METHOD AND OBJECTIVES

The aim is to find out a suitable pattern design method for a men's trousers block development that would be suitable for contemporary types of Czech male figures. The men's trousers of the BUSHMAN brand was chosen for research. The manufacturer is the Czech company and a target group of customers is the Czech male population.

2.1 The specification of the study objectives

- To provide a thorough understanding of the Czech male body proportions. To define body sizes of the Czech wearers of the BUSHMAN brand trousers.
- To investigate the procedure of Czech and other European traditional pattern construction methods which are used for the development of a men´s trousers pattern block. Emphasis is based on the method evaluation the design line segments are expressed and on what is the way of their value definition. There are three methods to definite it: 1) by regression formula, 2) by numerical value, 2) by drawing.
- To find out a pattern drafting method based on pattern parameters which are defined by calculation to using the most regression equation of the type (1).

$$\overline{ABi} = K_{D1(ABi)} * D_1 + K_{D2(ABi)} * D_2 + A_{ABi} + e_{ABi} \qquad (1)$$

Where:

- $\overline{ABi}$ ... is a dependent variable - computed *i*-design dimension
- $K_{D1(ABi)}$, $K_{D2(ABi)}$ *…are* regression coefficients
- D_1, D_1… is an independent variable – primary body dimension
- A_{ABi}… absolute value
- e_{ABi}… ease allowance

- To define the range of sizes of the intended wearers of BUSHMAN brand trousers according to the rules of the standard "EN 13402–3: "Measurements and Intervals".

3 RESULTS AND DISCCUSION

The basis of the study is the anthropometric data of 200 Czech men aged 18-60. Mainly these are body measurements of lower part of body, which were taken in the survey conducted by TUL Department of Clothing in 2006 [5].
According to criteria of the most sold sizes of the BUSHMAN brand trousers (48, 50, 52 and 54) those data are reduced that contain measurements of lower part of body of the 130 subjects.
Study of the proportion between of a waist and upper hip girth value shows the significant difference. It is more than 10cm. We can see this atypical effect in the case of 54 subjects that accounts 45% of the total number of observed subjects [7]. This finding illustrates the variability of the population under the time which causes a change of male body proportions. This finding should be reflected in a deeper study of these ratios. This disproportion affects the final shape of the upper hip part of trousers pattern block and thus affects the quality of the male trousers fitting.
Six men´s trousers pattern drafting methods of the European authors are analysed. Two Czech methods: NVS and UNIKON plus, Italian method: Fernando Burgo, German method: Müller & Sohn, English method: Winifred Aldrich, Swedish method: Inger Öberg. There are trousers pattern line segments chosen for evaluation, the 13 segments for front part and the 11 for back part of trousers block. The result indicates that the trousers patterns are mostly drawn by using a constant numerical value for generating the design dimensions instead of using a regression equation for pattern construction dimension value calculation. The Czech methods NVS summarised the largest number of formulas in form of regression equation which has 11 parameters. Italian method: Fernando Burgo the least which has 5 parameters.
Thus the Czech patternmaking method NVS seams to be useful for trousers pattern drafting procedure in order to fit a wide range of men's bodies (male morphology). Using those method and the definition of the body size range appropriate to the Czech population will increase the efficiency of construction parameters and thus to automate the grading process of the trousers pattern construction in a wide range.

The Bushman brad size series are built according to the standard EN 13402 size designation rules. There are set of 4 cm interval (difference between the two adjoining body measurements) in rage of the sizes 48, 50 and 52 Verification of the experimental results was made by the drawing the shape of trousers block in size 50 with help of Czech method NVS. Subsequently, the grading increments were determined by using the calculation method. The trousers patterns were graded in whole proposal range.
The approved pattern piece shapes were verified in the trousers manufacturing process. The fitting of the already made trousers was tested on the most popular body type of the Czech male somatotypes – subject of the size (48, 50, 52 and 54) which are defined with the help of the standardized primary and secondary body dimensions.

***ACKNOWLEDGEMENT**: The authors would like to thank the Faculty of Textile Engineering, Technical University of Liberec for the support this paper and also to their student Ján Masaryk for his assistance in the experiment.*

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A PRELIMINARY STUDY OF AN INVERTED ORGANIC SOLAR CELL ON A WOVEN METALLIC FABRIC

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Abstract: *Solar energy is one of the popular energy source among the other renewable energies. Photovoltaic technology is a clean way to generate electricity from sunlight. Flexible photovoltaics enable the portable electronic to power at off-grid conditions. Metal mesh woven fabric was used as a substrate and electrode allowing the light to reach photoactive layer. The photoactive layer and electron transport layer (ETL) were deposited by the means of dip-coating. The metal back electrode was evaporated in a thermal evaporator under vacuum.*

Keywords: *wearable electronics, flexible photovoltaics, solar textiles, organic photovoltaics, component, formatting, style, styling, insert (keywords)*

1 INTRODUCTION

Electronic textiles have been popular in scientific and commercial fields with their flexible and versatile functionalities to make smart clothes [1-3]. It is difficult to obtain a transparent and conductive flexible surface suitable for organic solar cells [4]. Generally, a conductive and transparent thin film deposited on a non-conductive substrate in vacuum and annealed at a high temperature for such applications [5-13].
In this study, a metal mesh woven fabric was used as a conductive substrate for the organic solar cell structure allowing the light illuminate on photoactive layer. ZnO, P3HT:PCBM were consequently deposited on the metal mesh by dip-coating and then a back metal electrode was deposited by thermal evaporation.

2 EXPERIMENTAL

A Ti mesh woven fabric was purchased and cleaned in an ultrasonic bath of acetone, isopropanol and then dried with a nitrogen gas flow. A ZnO solution was dip-coated on the mesh and then annealed in an oven to form electron transport for the organic solar cell mechanism. A P3HT:PCBM solution was dip-coated on ZnO coated metal fabric and then left for drying by hanging in ambient atmosphere. A metal back electrode was evaporated at 10^{-6} Torr vacuum. The cell was illuminated through the mesh structure. The schematical drawing of the solar cell fabricated in this study is given in Figure 1.

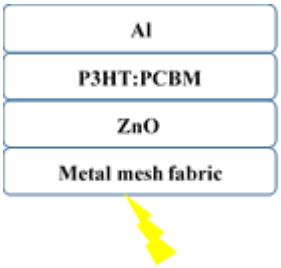

Figure 1. The schematical drawing of the solar cell fabricated in this study.

3 RESULTS

The photovoltaic fabric was illuminated at Sun 1 AM 1.5G at 100 W/m^2 light intensity and power conversion efficiency was calculated. The IV curve of the preliminary studies is given in Figure 2.

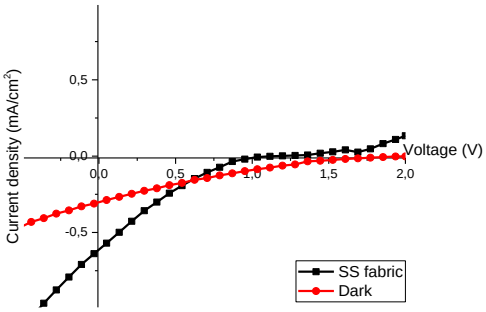

Figure 2. The IV curve of the fabricated photovoltaic fabric.

4 CONCLUSIONS

The preliminary power conversion efficiency obtained from the metal substrates were not as expected due to the short-circuits. Thicker films on the metal wires might solve this problem. Further studies should be performed with thicker films and protective layers. Such special textiles can open a new window for portable electronics.

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GLOSS AND HARDNESS EVALUATION OF WATER-BASED UV CURABLE POLYURETHANE ACRYLATE FILM USED IN TEXTILE PRINTING

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Abstract: In the current study, it is aimed to evaluate the hardness and gloss properties of water-based UV curable polyurethane (PU) acrylate films by using two types of photoinitiators at different ratios. For this purpose, UV curable water-based unpigmented and pigmented formulations were prepared. Formulations were applied on glass plates and UV cured under gallium and mercury (Ga/Hg) lamps at three different energy levels, i.e., 60, 90 and 120 W/cm. After UV curing process, gloss and hardness values of polymeric films were measured. The highest film hardness values implying the highest curing level, was obtained with the formulation A1, including only Omnirad® 819 DW (former Irgacure® 819 DW) which is effective in deep curing, and formulation A3 including Omnirad® 819 DW and Omnirad® 500 (former Irgacure® 500) effective in surface and deep curing at 2:1 ratio, respectively. Among these two formulations, the highest gloss value was obtained with the formulation A3. GaHg lamp combination provided the highest gloss values while highest film hardness values were obtained with GaHg and GaGaHg lamp combinations. Compared to clear films, pigmented films rendered higher gloss values which was more prominent in single lamp (Ga, Hg) cured films.

Keywords: *Water-based, polyurethane acrylate, photoinitiator, UV curing, gloss, hardness.*

1 INTRODUCTION

UV curing technology is a fast, an easy to apply and an environmentally friendly method which can be applied in pigment printing [1].
The UV curing mechanism is explained by the photopolymerization reaction of the binder. The photoinitiators absorb the energy of photons generated by irradiation and initiate the polymerization reaction by forming reactive groups during UV curing [2,3]. These reactive groups lead to the cross linking of the binder which then results in film formation on the surface of the textile material. For the polymerization process of acrylic and styrene systems, different types of photoinitiators possessing good chemical, optical and mechanical properties, have been developed. It has been reported that UV curable formulations should consist of at least 0.3% photoinitiator and at least 10% binder. In comparison with thermal curable formulations, the polymerization is achieved much more rapidly in UV curable formulations [1, 2]. UV radiation doses may be changed to control film hardness and gloss for the evaluation of the polymerization level of the film [4, 5]. In the current study, we aimed to evaluate the gloss and hardness values of UV cured clear and pigmented polyurethane acrylate films by the use of two different photoinitiators at different ratios.

2 EXPERIMENTAL

2.1 Materials

In the preparation of water-based UV curable clear and pigmented formulations, a flexible, water-based, aliphatic PU acrylate binder (Laromer® UA 9059) was used. Bisacyl phosphine (Omnirad® 819 DW) effective for deep curing and α-hydroxyketone (Omnirad® 500) effective for surface curing [6] were used as the photoinitiators. Wetting agent (Exosel 54, Acar Kimya, Turkey), defoamer (Foamaster® 8034, BASF), anionic acrylic copolymer thickener (Orgaclear P 460, Organik Kimya, Turkey), deionized water and ammonia solution (NH_4OH) were also used in the formulation. To obtain pigmented film a red pigment (Irgazin® Red K 3840, BASF) was used in the formulation.

2.2 Method

Water-based UV curable formulations were prepared using different photoinitiator ratios (0:3) of Omnirad® 500 and Omnirad® 819 DW). Films of 120 µm thickness were obtained with a film applicator (Byk Gardner) on glass plates. The pH and the viscosity of the pigmented and clear formulations were adjusted to 8.0-9.0 (with WTW Inolab pH 7110 pH meter) and 20.000- 25.000 cP (at 20 rpm, with spindle 6 with a Brookfield DV-E viscometer), respectively. The clear formulation recipe is given in Table 1. The photoinitiator ratios used in formulations A1-A7 are given in Table 2. Formulation A3 was also prepared with 3% pigment with respect to binder amount. Films were cured in a UV curing equipment (Raycon®, Turkey) with an adjustable belt speed (2-50 m/min), and equipped with Ga (380 V) and Hg (220 V) lamps. UV curing was performed at three different energy levels (60, 90 and 120 W/cm) at a belt speed of 10 m/min under different UV lamp combinations (Hg, Ga, GaHg, GaGaHg). Total applied energy amount was measured with a UV-Integrator Type D radiometer. The chemical changes in the cured films was characterized by FTIR spectroscopy (PerkinElmer FTIR C99089).
The gloss measurements of polymeric films were made according to ASTM D523, “Standard Test Method for Specular Gloss” standard using a Rhopoint, Novo-Gloss^{TM} glossmeter at 60^{o} geometry. After UV curing the

König hardness of polymeric films were evaluated with a Byk Pendulum Hardness Tester.

Table 1 Clear formulation

Materials	Quantity (g)
Deionized water	26
Binder (Laromer® UA 9059)	66
Photoiniators	3.6
Thickener (Orgaclear® P 460)	2.63
Wetting agent	0.49
Defoamer	0.1
Ammonia	0.33
Total	100

Table 2 Photoinitiator ratios used in the formulations

Formulations	Omnirad® 500	Omnirad® 819 DW
A1	-	3
A2	0.5	2.5
A3	1	2
A4	1.5	1.5
A5	2.0	1.0
A6	2.5	0.5
A7	3.0	-

3 RESULTS AND DISCUSSION

3.1 Hardness measurements

The highest film hardness was obtained with the formulation A1, including only Omnirad® 819 DW which is effective in deep curing, and formulation A3 including Omnirad® 819 DW and Omnirad® 500 effective in surface and deep curing at a ratio of 2:1 (Figure 1). In general, the film hardness values decreased with the decrease in the amount of Omnirad® 819 DW photoinitiator (effective in deep curing) in the formulation. The increase in the total applied energy resulted in an increase in the film hardness values of all formulations. Both GaHg and GaGaHg lamp combinations yielded higher film hardness values.

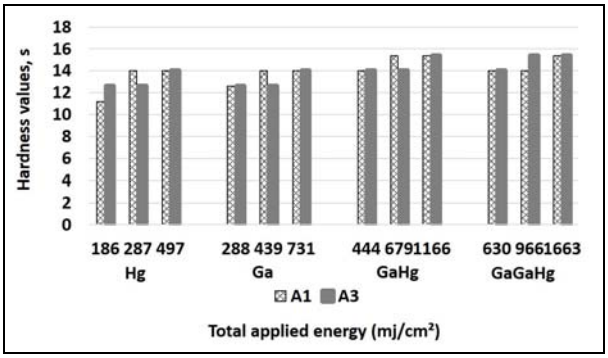

Figure 1 The effect of applied energy on hardness properties in clear formulations A1 and A3

3.2 Gloss measurements

The highest gloss values were obtained in films prepared with A3 formulation cured under GaHg lamp combination (Figure 2). It can be suggested that there is a synergetic effect towards improvement of gloss when two photoinitiators are combined in the same formulation. In accordance, when the amount of photoinitiator Omnirad® 500 increases, the gloss values improved until a certain value. After this value, gloss values tend to decrease.
The effect of the total energy applied in the curing process on the gloss values for both clear and pigmented films is shown in Fig. 3 for A3 formulation. For clear films, the higher gloss values were obtained for GaHg lamp combination but in pigmented films, the higher gloss values were obtained in films cured under Ga lamp. However, hardness results showed that curing with a single Ga lamp provided a low film hardness, indicating a low degree of curing. It is concluded that in order to obtain sufficient film hardness and gloss values, GaHg lamp combination should be preferred in curing.

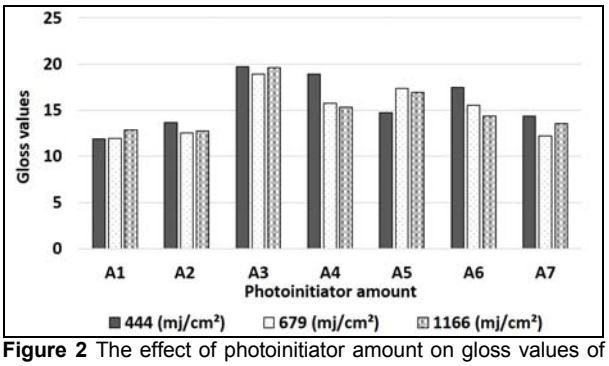

Figure 2 The effect of photoinitiator amount on gloss values of clear films cured under GaHg lamp combination

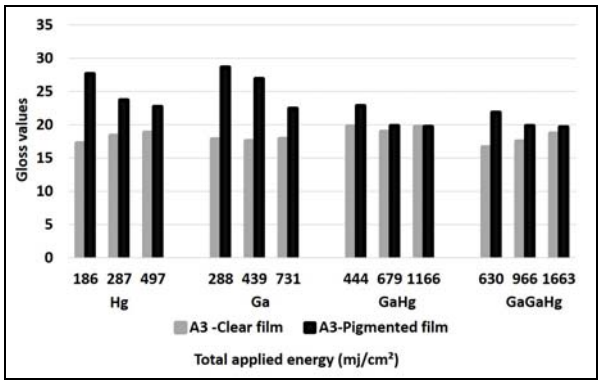

Figure 3 The effect of applied energy on gloss values of clear and pigmented films cured under different lamp combinations

3.3 FTIR spectroscopy

FTIR analysis of the clear films showed that there was a reduction and a disappearance of the twisting peak of -CH_2=CH_2 at 810 cm^{-1} wave number and bending peak at 1.410 cm^{-1} wave number, which suggested the development of the cure.

4 CONCLUSION

According to gloss measurement results, the higher gloss values were obtained with clear A3 formulation which includes Omnirad® 500 and Omnirad® 819 DW, photinititaors at a ratio of 1:2, respectively. The best hardness values were obtained in films prepared with A1 formulation including only Omnirad® 819 DW, cured with GaHg lamp, however the gloss values of this formulation were the lowest among all formulations. Formulation A3 provided optimum gloss and hardness values.

Although the highest hardness values were obtained with the GaGaHg lamp combination, considering the energy efficiency and curing level, GaHg lamp combination could be recommended for curing.

ACKNOWLEDGEMENT:

The authors acknowledge The Scientific and Technological Research Council of Turkey (TUBITAK) for the financial support (Project No. 215M995).

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FUNCTIONAL REACTIVE DYEING OF COTTON BASED ON PHOTOACTIVE PHTHALOCYANINES

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Abstract: *An innovative photoactive phthalocyanine based antimicrobial system used for textile barrier finishing was studied and optimized as a new tool for photo-initiated antimicrobial functionality of textiles. A range of photoactive phthalocyanines containing Zn or Al and reactive groups capable to create a covalent bind with cellulosic fibres was synthesised and applied on the cotton fabric by the reactive dyeing process. The antimicrobial efficiency of the finished fabrics was determined according to a modified standard relevant for health-care textiles evaluation during repeated washing and chemo-thermo-disinfection maintenance cycles. The unique properties of textiles dyed with photoactive phthalocyanine derivatives were confirmed. This type of textile finishing can be used for simultaneous dyeing and preparation of antimicrobial/self-cleaning textile materials with a long-lasting wash-permanent barrier effect as an effective, safe and less environmentally risky alternative of conventional antimicrobial systems. A range of PTCs containing Zn or Al in their structure and reactive groups capable to create a covalent bond with the cellulosic fibre was synthesised in Centre for Organic Chemistry, Pardubice. These derivatives were applied on cotton fabric in INOTEX, Dvůr Králové n. L. as reactive dyestuffs under optimized conditions. Resulting colour-fastnesses were evaluated according to relevant standards. Testing of photoactivity of the finished textiles was conducted in Centre for Organic Chemistry by means of an iodide method. Antimicrobial activity of the finished textiles was evaluated in the National Institute of Public Health, Prague according to the modified standard EN ISO 20743 after dyeing and repeated maintenance cycles prescribed for health care sector: washing at 60 °C (EN ISO 6330, Wascator, 6N, EEC - standard phosphate-free detergent, conducted in INOTEX) and chemo-thermo-disinfection prescribed for health care sector (washing 60-65 °C followed by rinsing with solution of Persteril - peracetic acid 36%, conc. 0,2 ml/l conducted in the Commercial Laundry & Dry Cleaning Company, Náchod, Czech Republic).*

Keywords: *Antimicrobial textiles, photocatalysis, reactive dyeing, textile finishing*

1 INTRODUCTION

Photoactivity of PTC compounds containing certain metals as a central atom is based on production of singlet oxygen $^1O_2$ when exposed to light. This highly reactive form of oxygen is able to kill majority of microorganisms and to destroy some pollutants. The lifetime of the singlet oxygen is only several microseconds and therefore the field of its effect is 20 nm from a surface modified by chosen PTC derivatives. These unique properties of photoactive PTCs systems were used for preparation of antimicrobial/self-cleaning textile materials with long-lasting wash-permanent barrier effect as an effective, safe and less environmentally risky alternative of conventional antimicrobial systems [1, 2].

2 EXPERIMENTAL

2.1 Dyeing

PTC derivatices containing Zn or Al in their structure and reactive groups (VS: vinylsulphone and MCT: monochlorotriazine) creating a covalent bond with cellulosic fibre were synthesised in Centre for Organic Chemistry, Pardubice. These green-bluish dyestuffs were applied on cotton fabric (120 g/m^2, plain weave shirting, desized and scoured) in INOTEX, Dvůr Králové n. L. under optimized conditions by exhaustion process of reactive dyeing (LR 1:20, 60°C). Resulting colour-fastnesses were evaluated according to relevant standards (Table 1).

Table 1 Colourfastnesses of PTS dyed cotton fabric

Colourfastness	Standard	Results
water	EN ISO 105-E01	4/4/4-5
washing 60°C	EN ISO 105-C06	3-4/4/4-5
perspiration alkaline	EN ISO 105-E04	4/3-4/4-5
perspiration acid	EN ISO 105-E04	4/4/4-5
rubbing dry	EN ISO 105-X12	4-5
rubbing wet	EN ISO 105-X12	4
light Q-SUN	EN ISO 105-B02	3D

2.2 Testing of photoactivity

Testing of photoactivity of the finished textiles was conducted in Centre for Organic Chemistry by means of an iodide method with a spectrophotometric determination of the triiodide production (Equation 1).

$$^1O_2 + 2I^- \xrightarrow{H^+} I_2$$
$$I_2 + I^- \longrightarrow I_3^-$$

Equation 1 Triiodide forming at single oxygen presence

A red-light emitting diode (LED) light source was used for the photocatalytic effect initiation. The rate of the singlet oxygen production was determined as a growth rate of I_3^- expressed as a direction k_{obs} of the linear dependency. The results after the dyeing and after repeated maintenance cycles were compared (Table 2).

Table 2 Colouration and singlet oxygen production of PTC dyed cotton in dependence on maintenance cycles No.

Maintenance cycles for health care sector : washing 60°C+ chemothermodisinfection		
No. of cycle	Relative depth of shade /%/	Singlet oxygen production $k_{obs}.10^2$ [min^{-1}]
0	100	0.1051
1	108.30	0.1064
5	100.81	0.1032
10	103.94	0.0960
25	89.99	0.1114

2.3 Testing of antimicrobial efficiency

Antimicrobial activity of the finished textiles was evaluated in the National Institute of Public Health, Prague according to the modified quantitative standard EN ISO 20743. The antimicrobial effect and its permanency were evaluated after dyeing and after repeated washing (60 °C) and chemo-thermo-disinfection cycles as a prescribed maintenance procedure for fabric used in health-care sector. For the antimicrobial efficiency testing following bacteria strains were used: G-negative *Escherichia coli,* CCM 4517 and G-positive *Staphylococcus aureus,* CCM 4516).
The evaluation of antimicrobial activity of textiles according to the standard EN ISO 20743 were performed using the standardized Absorption method (an evaluation method in which the test bacterial suspension is inoculated directly onto samples) in Petri dishes (contact time 18 – 24 h, temperature 37° C). Antibacterial activity (A) was calculated according to Eq. 2:

$$A = (\log C_t - \log C_0) - (\log T_t - \log T_0) = F - G$$

Equation 2 Calculation of antimicrobial efficiency

where $F(C_t - C_0)$ = Growth value on the control sample (untreated)
$G(T_t - T_0)$ = Growth value on the antibacterial sample (PTC finished)

The microbiological tests were conducted using selected light sources necessary for photocatalytic effect initiation under intensity of light radiation 2.1 and 5 J/cm^{-2}. The light sources simulation indoor and outdoor conditions were used.

Results of antimicrobial activity of PTC dyed cotton fabric after finishing and repeated washing at 60°C and chemothermodisinfection cycles are summarised in Table 3 (light source simulating daylight indoor conditions).

Table 3 Antimicrobial activity of PTC dyed cotton

Antimictobial activity – A (log)			
Maintenance cycles	**PTC dyed cotton (3% dyeing)**	***S. aureus***	***E. coli***
Washing	Unwashed	5.5	4.9
	5 x washed at 60 °C	5.6	4.1
	10x washed at 60 °C	3.0	3.5
Washing + Chemo-thermo-disinfection	Unwashed	5.0	6.0
	5 x washed at 60 °C + CHT	5.0	5.5
	10x washed at 60 °C +CHT	5.0	5.4

3 CONCLUSIONS

From the results of antibacterial activity it can be concluded that cotton fabric dyed with a photosensitive PTC derivative has a high antimicrobial effect against both G+ and G- bacteria strains. This effect is stable in repeated washings at 60° C. Moreover the stability of the effect in repeated washing followed by a chemo-thermo-disinfection used in health care sector has been proved This type of barrier finishing/dyeing represents an effective non-toxic and eco-friendly alternative of antimicrobial finishing systems and is suitable for apparel textiles and bed-linens.

Aknowledgement: *The work was supported by the Technology Agency of the Czech Republic – project of Competence Centres TE02000006 ALTERBIO – Centre for alternative friendly high effective polymer antimicrobial agents for industrial applications.*

ACKNOWLEDGEMENT*: The work was supported by the Technology Agency of the Czech Republic – project of Competence Centres TE02000006 ALTERBIO – Centre of alternative friendly high effective polymer antimicrobial agents for industrial applications.*

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SCREEN PRINTING ON SILK FABRIC USING NATURAL INDIGO

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Abstract: *The purpose of this research was to study the printing silk fabric with natural indigo and using modified starch of wild taro (Colocasia esculenta (L.) Schott) corm as thickening agent. The optimal formula of printing silk fabric using natural indigo paste was prepared by mixing 50% natural indigo past, 5% thickening agent, 6% thiourea dioxide, 1% sodium hydroxide and 38% water. The pattern design at printing areas on fabrics showed satisfied printing quality and colour fastness results were good to very good level.*

Keywords: *printing, natural indigo, silk, thickening agent, wild taro*

1 INTRODUCTION

Natural indigo, known in different names in different parts of the world, has been in use since around 7000 BC for dyeing of cotton in attractive and bright blue shades [1]. Plants belonging to the genus Indigofera are most valuable for producing natural indigo. The colouring matter in the plant is present as a glucoside of indoxyl, known as indican, which is hydrolyzed to the indoxyl by enzymatic action and indigo is then obtained by subsequent oxidation. In ancient times, reduction of indigo was carried out by fermentation technique which included use of ripen fruit and stale urine assisted by wood ash or lime as alkali. The solution prepared in this way was left overnight for reduction and solubilization of indigo. Wild taro (*Colocasia esculenta* (L.) Schott), is a vegetatively propagated root crop species of the monocotyledonous family *Araceae* and is grown in almost all tropical regions of the world [2-3]. The aim of this present work was study the printing of silk fabric with natural indigo dye as dyestuff and using new thickening agent from modified starch of wild taro corm. The printing and fastness properties were investigated.

2 EXPERIMENTAL

2.1 Materials and chemicals

A commercially produced plain-weave silk fabric was purchased from market. Fabric was scoured with an aqueous nonionic surfactant solution at a temperature of 50 °C for 30 min, then thoroughly rinsed and air dried at room temperature. Natural indigo paste was purchased from Nakhon Panom province, Thailand. The following chemicals of laboratory grade were used in the experiment: thiourea dioxides ($CH_4N_2O_2S$), sodium hydroxide (NaOH) and hydrogen peroxide (H_2O_2) were supplied by Star Tech Chemical Industrial Co., Ltd. A nonionic soaping agent, was purchased from Boonthawee Chemephan Co, Ltd. (Thailand). Wild taro corms used in this experiment was collected from Sukhothai province, Thailand.

2.2 Preparation modified starch of wild taro corms

The wild taro corms were dried in sunlight for 1 month and crumbled using a blender then, milled and ground through a 355 µm mesh sieve. Powdered of wild taro corm was dispersed in alkaline aqueous methanol 80 %v/v (100ml). Then, monochloroacetic acid (MCA) was added in solid form to above solution and mixture for 10 min. The temperature adjusts raised to 70 ˚C for a further 60 min. The mixture paste was cooled in room temperature and filtered in suck funnel, following to resolve in water. 50% HCl was added drop by drop until neutral. The reaction product was precipitated and washed with ethanol to remove ionic salts. The carboxymethylated wild taro corm or modified starch of wild taro was removed by filtration and washing three times with methanol. The washed product was dried at 40 ˚C for 4 h. The milling was size reduced to 355 sieve size. The powder was stored in desiccator.

2.3 Preparation of printing paste

It was prepared by mixing concentrations of indigo paste were varied from 50-90 g, 5 g of modified starch of wild taro, 6 g of thiourea dioxides and 1 g of sodium hydroxide in 38 ml of water was added and continued stirring to produce a homogenous paste.

2.4 Printing process

The printing process consist of forcing a various print paste through the open areas of the screen with a flexible, synthetic rubber, squeegee. The rubber blade, which is contained in a wooden support, is drawn steadily across the screen at a constant angle and pressure. The pressures exerted must be as similar as possible [4]. The fixation was done by hot air at 60°C for 10 min. Following these steps, the fabric was then immersed with 5 g/L of H_2O_2 and finally the samples were then washed in 1 g/L of a soaping agent at 90 °C for 15 min, then air-dried at room temperature.

2.5 Evaluation of colour value, colour strength and fastness properties.

The colour value and colour strength (K/S) of the printed samples were recorded and evaluated using a spectrophotometer (Hunter Lab Color Quest XE, USA). The colour fastness of the printed samples was determined according to ISO standard.

3 RESULTS AND DISCUSSION

3.1 Effect of dye concentration on colour value

Silk fabric samples printed with natural indigo at different dye concentrations is shown in Table 1. The colour value and colour strength results obtained are presented in Table 1. The silk printed with natural indigo paste showed a blue shade. It can be observed that the colour strength increased with an increase of dye concentration.

Table 1 Colour values at varying dye concentrations (50, 60, 70, 80 and 90 g)

dye conc. (g)	colour value and colour strength					Colour obtained
	L*	a*	b*	K/S	White ness	
50	44.65	-3.78	-16.07	5.29	148.88	
60	44.52	-3.74	-17.55	5.93	148.76	
70	41.65	-2.27	-21.70	8.10	161.53	
80	41.81	3.80-	16.97	8.45	157.09	
90	40.12	3.66-	-16.12	8.94	140.15	

3.2 Effect of dyeing techniques on fastness properties

The fastness properties of silk fabric printed with natural indigo dye concentration of 50 g are presented in Table 2. Table 2 indicates that the washing fastness rating of silk fabrics printed with the natural indigo were good to very good (4 to 4-5). However, light fastness was fair (5). Colour fastness to perspiration and water of all printed silk fabrics showed good to very good (4 to 4-5).

Table 2 Colour fastness to washing, water, perspiration and light

Colour fastness to	Colour change	Colour stining					
		acetate	Cotton	Nylon	polyester	acrylic	Wool
washing	4	4-5	4-5	4-5	4-5	4-5	4-5
water	4-5	4-5	4-5	4-5	4-5	4-5	4-5
perspiration (acid)	4	4-5	4-5	4-5	4-5	4-5	4-5
perspiration (alkaline)	4	4-5	4-5	4-5	4-5	4-5	4-5
light	5	-	-	-	-	-	-

4 CONCLUSION

It is evident from the results that silk fabric can be successfully screen printed with natural indigo using modified starch of wild taro corms. The investigation shows that the recipe is suitable for printing. The modified starch of wild taro corms could be used as a thickening agents for natural indigo printing on silk fabric. Printed silk fabric exhibited good to very good color fastness.

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MICROWAVE ASSISTED DEPOSITION OF SILVER NANO COLORANTS ON COTTON FABRIC BY CHEMICAL REDUCTION METHOD

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Abstract: *Due to the localized surface plasmon resonance (LSPR) property of silver nanoparticles, it exhibits adaptable colors depending on the synthesizing measures. A facile approach toward microwave assisted assembly of greenly synthesized silver nanoparticles in cotton fabric as a novel colorants has been accomplished. Colloidal solutions of silver nanoparticles (Ag NPs) was synthesized by reduction of $AgNO_3$ with chitosan as both reducing and stabilizing agents by a simple, rapid, effective and green strategy. The assembly of novel colorant has been achieved by cationic treatment of cotton fabric by chitosan followed by immersed into pre-dispersed solution of silver nitrate (AgNO3) and chitosan in an ultrasonic benchtop cleaner bath. Optimum parameters of ultrasonic bath of was premeditated and maintained. The silver nanoparticle treated cotton fabric showed different colors because of LSPR property. The coloration occurs due to interaction between the silver nanoparticles and cationized cotton fabric in presence of chitosan as cross linker. Surface morphology, color extinction, color strength, reflectance spectra were characterized by scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy, ultraviolet (UV)-visible spectroscopy and CIELAB spectroscopy. The presence and morphologies of silver nanoparticles on the fabric surface after the coloration process with an even shade has been recognized. In addition, color fastness to wash, rubbing and light of cotton fabric colored with silver nanoparticles found reasonably superior, which will simplify the concrete commercial use as novel eco-friendly colorants ranging from antibacterial materials to biosensors and plasmonic devices.*

Keywords: *Ag nanoparticle; Chitosan; Cotton fabric; LSPR; Chemical reduction;*

1 INTRODUCTION

Nanoparticles have vast application in different fields includes biomedical, coloration, antibacterial, optical, drug-gene delivery, transistors, catalysis, distinct electron transistors and cosmetics application etc. [1, 2] . Ag nanoparticles has exclusive and convenient properties, including surface enhanced spectroscopy[3, 4], biosensors [5, 6], and plasmonic devices [7, 8]. Most of these applications are based on the unique localized surface plasmon resonance (LSPR) of silver nanoparticles. Localized surface plasmon resonance (LSPR) properties has strong absorption and scattering properties along with strong interaction towards light at definite wavelengths for the conductive electrons into the metal surface. The LSPR property of silver nanoparticles gives rise to captivating colors. However, Cotton as one of many other natural fibers have versatile applications as garments of different items because of its usual smoothness, high hygroscopicity and heat absorbent properties [9]. Coloration of fibers is pivotal for application of cotton in the textile industry. Light fading of dyes is a common phenomenon in textile research.[10, 11] The silver nanoparticles are different from traditional dyes, in that it is not the chromophore of traditional dyes but the shape and size of nanoparticles that determine the colors. In addition to color, the silver nanoparticles have significant antibacterial activity, which has been reported in the literature.

1.1 Materials

The cotton fabric was obtained from Guangdong Overflow Textile Co., Ltd. (China). AgNO3 (99.98%) (was used as the silver nanoparticle precursor), chitosan, ascorbic acid (99%) and sodium hydroxide (NaOH) were purchased from Sinopharm Chemical Reagent Co. Ltd. (China) with analytical grade and used as received without further purification.

1.2 Methodology

A novel green synthesis method was adopted for synthesis of Ag nanoparticle. Briefly, required amount of chitosan were suspended into 100 ml water for synthesis of silver nanoparticle. To induce blue color silver nanoparticle Ascorbic Acid ($C_6H_8O_6$) was added in the chitosan solution.

2 RESULT AND DISCUSSION

The zeta potential of cotton fabric was found -1.59 mV. The cellulosic cotton fabric bears negative surface charge due to the presence of hydroxyl group. Chitosan which is a strong cationizer carries positive charges.

2.1 UV–vis spectroscopy Analysis

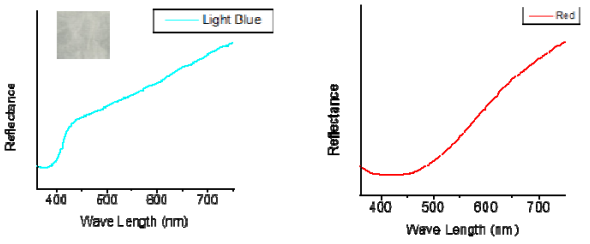

Figure 1 Reflectance spectra of Silver Nanoparticle treated Cotton fabric. Cotton fabric treated with Red, Light Blue Silver nanoparticle

2.2 Characteriazation

To observe the surface morphologies of Cotton fabric treated with silver nanoparticles SEM analysis has been carried out. Images describes, uniformly assembled of silver nanoparticles in the surface of cotton fabric to a greater extent. Fourier transform infrared radiation (FTIR) spectra were recorded using a VERTEX 70 FTIR spectrometer (Bruker Corporation, Germany) at the wavenumber range of 4000–500 cm-1 at ambient

2.3 Color fastness Analysis

The wash, light and rubbing fastness properties of the colored fabric shows a very good result displays in table 2. The higher ratings of fastness indicate the better color

2.4 Conclusion

Coloration of cotton fabric in sonochemical method by using greenly synthesized silver nanoparticle is a new approach to dye the cotton fabric in an ecofriendly way. In case of silver nanoparticle synthesized coloration it's not necessary to add soda for obtaining the alkaline condition. The measured PH of the solution is 5.5-6.5. For Blue colored solution the PH becomes 4.5-5.0 which is a great breakthrough for processing of cellulose materials. Due to no use of cationizer and fixaer during dyeing it reduce the consumption of enormous amounts of salt, soda, caustic, chemicals and dyes using in our traditional dyeing processes. The wash and light fastness properties of the colored fabric are also excellent along with brilliant color. This research will extend the way for further development of ecofriendly coloration to build and ensure the greener world to our next generation in the field of textile and silver nanoparticle.

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INVESTIGATION OF THE EFFECTS OF ENZYMATIC FINISHING PROCESSES ON THE DYEING PROPERTIES OF COTTON-POLYESTER AND POLYESTER FABRICS

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Abstract: *Pectinase and cellulase enzymes in cotton-polyester blend fabric were used to hydrophilize cotton fibers, while lipase enzyme was used to remove oils on polyester fibers in one bath, for the polyester fabric, only lipase enzyme washing was performed to eliminate the disadvantages of conventional chemical methods. Results showed that lipase, pectinase and cellulase enzymes colud be used as combination in one bath at the pre-treatment of cotton-polyester fabrics, while lipase was one of the best alternatives to soap in polyester washing at alkaline medium.*

Keywords: *sustainability, cleaner production, enzymes, combined enzymatic process, lipase, cellulase, pectinase*

1 INTRODUCTION

To develop an environmentally friendly process in textiles, one of the sectors consuming high amounts of clean water and generating wastewater to solve the world's growing population, rising energy costs, reduced water resources and rapidly growing environmental problems, cotton / polyester mixture and only polyester fabrics were subjected to enzymatic pre-treatment and then dyeing process. If the properties obtained from conventional finishing and dyeing processes can also be taken by enzymatic processes, a reduction in the number of aqueous processes in this sector consuming water in the loaded water and the elimination of the use of chemical substances in some processes will be a success for the modern textile dyeing industry.

Since the polyester fibers are fairly clean and water soluble sizing agents are used as the sizing agent, a mild washing and bleaching is sufficient before dyeing. Bleaching is also unnecessary except for dyeing in white or light colors [1]. In cotton / polyester blends cotton is generally a small component in the blend, but desizing, hydrophilization, and bleaching processes must be performed on the cotton part to obtain uniform dyeing results. Many of these fabrics are hydrophilized at 70-80°C using Na_2CO_3 and detergent in anionic form. When peroxide is preferred as a bleaching agent, the bleaching process is made in an economical, convenient and environmentally friendly way [2]. Care must be taken during coloring as the quality of the dyeing can be perceived at a high level by the human eye. Since the dyeing properties of polyester and cotton fibers are very different, there are separate steps in the dyeing process for the same coloring dyes when they are used together. The most preferred dyestuff combination for dyeing cotton / polyester blend fabrics is reactive / disperses [3]. Cotton / polyester blends are usually dyeing at high temperatures (130°C) in jet machines. The most important reason for high temperature usage is avoiding utilize of carrier. Other reasons to choose exhaustion method in jets are low solution ratios, fast dyeing cycles, energy savings and good color uniformity [4].

Today, as ecological and economic constraints are the whole industry, textiles have also sought to find alternative environmental and sustainable alternative processes and chemicals. Enzymatic processes, one of the alternative methods developed to eliminate the disadvantages of conventional chemical methods, have started to find serious use in textile finishing. Enzymes specifically catalyze reactions, are used in small quantities, do not bring in by-products, save energy, time and water, and do not harm human beings and the environment. To achieve these goals, pectinase and cellulase enzymes in cotton-polyester blend fabric are used to hydrophilize cotton fibers, while lipase enzyme is used to remove oils on polyester fibers in one bath, for the polyester fabric, only lipase enzyme washing was performed.

2 MATERIAL METHOD

The bath ratios used in the finishing process were 1:10 and the fabric weights were 5 grams. Two different fabrics were used in the study: cotton-polyester blended and 100% polyester. The blended fabrics were dyed after enzymatic (combined) and conventional pre-treatment. In the combined enzymatic pre-treatment process, desizing, hydrophilization and anti-pilling processes were carried out with the aid of amylase, pectinase, cellulase enzymes in the one bath. Both processes have been completed with bleaching and dyeing processes. The 100% polyester fabric was then dyed after being subjected to lipase, conventional and alkaline lipase enzyme washing, respectively. The results obtained from the dyeing operations after pre-treatment processes were compared with those of conventional processes.

3 RESULTS

The results of the work were determined by colorimetry with a spectrophotometer, dry and wet rubbing fastness (TS EN ISO 105-X12), washing fastness (TS EN ISO-CO6, B1M).

The explanations of the coding to be used in the tables were as follows:

PCE= Pes-cotton blended fabric enzymatic process
PCC= Pes-cotton blended fabric conventional process
C=Polyester conventional washing
E=Polyester enzymatic washing

EC= Enzymatic washing in alkaline medium

Color characteristics of different processes were as shown in Table 1.

Table 1 Comparison of color values

Colour Values					
	PCE	PCC	C	E	EC
L*	20,28	19,88	31,506	28,245	30,38
a*	8,345	7,24	5,775	7,475	5,88
b*	-29,565	-26,515	-40,68	-39,59	-40,305
K/S	27,055	25,53	17,742	20,85	19,54
%R	1,785	1,88	2,665	2,265	2,435
∆E	3,26		3,83		
				2,75	
			1,19		1,19

Table 2 Rubbing fastness

Rubbbing Fastness					
	Dry	**Wet**		**Dry**	**Wet**
PCE1	4	1	EC1	4-5	2
PCE2	4	2	EC2	4	2-3
PCE3	3-4	1	EC3	4-5	2-3
PCC1	4	1-2	E1	4	3-4
PCC2	4	1	E2	5	2-3
PCC3	3	1	E3	4-5	2-3
			C1	4-5	4
			C2	4	3-4
			C3	4	4-5

The color difference between the enzymatically and conventionally treated blended fabrics was 3,26. After different treatments applied to 100% polyester fabrics, the least color difference (1,19) was obtained between conventional and enzymatic washing in alkaline medium.

Dry and wet rubbing fastnesses were shown in Table 2.

Different processes applied to blended fabrics did not reveal any significant differences in dry and wet rubbing fastnesses, so they were similar. While there was no difference in the dry rubbing fastness of the polyester fabrics, the wet rubbing fastness values of the conventional process were slightly better than the others.

Washing fastness results were indicated in Table 3.

Table 3 Washing fastness

Washing Fastness						
	Acetate	**Cotton**	**Nylon**	**Polyester**	**Acrylic**	**Wool**
PCE1	2	3	1	3-4	4-5	2-3
PCE2	2-3	3	1	4	4-5	2-3
PCE3	2-3	2-3	1	3-4	4-5	2
PCC1	2	3	1	3-4	4-5	2
PCC2	2	2-3	1	3-4	4-5	2-3
PCC3	2	3	1	3-4	4-5	2
EC1	3	4-5	1-2	4-5	5	4-5
EC2	4	4-5	2	4-5	5	4-5
EC3	4	4-5	1-2	4	5	4-5
E1	4	4-5	2	4-5	5	4
E2	4	4-5	2	4-5	5	4
E3	4	4-5	1-2	4-5	5	4
C1	4-5	4-5	2	5	5	4
C2	4	4-5	2	4-5	5	4-5
C3	4	4-5	2-3	4-5	5	3-4

When the washing fastness values were examined, no significant difference was observed between the enzymatic and conventional treatments in the blended and 100% polyester fabrics.

4 CONCLUSIONS

The results showed that lipase, pectinase and cellulase enzymes could be successfully used as combination in one bath at the pre-treatment of cotton-polyester fabrics, while lipase was one of the best alternatives to soap in polyester washing at alkaline medium.

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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF CARBON MICROFIBER REINFORCED GEOPOLYMERS AT ELEVATED TEMPERATURES

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Abstract: *The present work deals with the effect of carbon microfiber addition on the development of microstructure and mechanical properties of geopolymers at elevated temperature. The carbon microfibers were prepared from recycled inexpensive carbon fibrous wastes by ball milling, and then subsequently incorporated under 5, 10 and 15 wt % loading into metakaoline based geopolymers. The addition of carbon microfibers was found to produce compact structure of geopolymers due to their pore filling characteristics and formation of additional calcium silicate or calcium alumino-silicate and sodium alumino-silicate hydrates. The geopolymer composite of 15 wt % carbon micro fiber was found to maintain the residual compressive strengths of 33.55 and 23.96 MPa at 400 ^{o}C and 800 ^{o}C, respectively and thus recording a minimum strength loss of 19 and 42 %, respectively. This behavior was attributed to decreased thermal stresses and restricted swelling of unreacted geopolymer phases after addition of carbon microfibers.*

Keywords: *Carbon microfibers; Geopolymer; Thermal stability; Mechanical strength; Microstructure analysis*

1 INTRODUCTION

In recent years, geopolymers have received considerable attention for their cost efficiency, chemical stability, corrosion resistance, rapid strength gain rate, low density, low permeability, low shrinkage and freeze-thaw resistance [1,2]. In addition, geopolymers are considered as an attractive replacement to ordinary Portland cement due to reduced energy consumption and less CO_2 emission during their manufacture [3–5]. The geopolymers are amorphous cementitious binders having cross-link chain of silica, oxygen and alumina (Si-O-Al) [6,7]. They are synthesized by reacting aluminosilicate source materials (i.e. fly ash, slag, metakaoline, etc) with highly alkaline activators. Despite many benefits, geopolymers still have certain limitations over ordinary Portland cement. Due to their cross-linked structure, geopolymers tend to be more brittle, susceptible to crack formation and undergo catastrophic failure as compared to ordinary Portland cement [8,9]. Previous studies have reported their fracture energy about 40 % of that of ordinary Portland cement [10]. Therefore, for further improvements of performance and durability, the improvement in fracture properties of geopolymers is extremely necessary. Although incorporation of different fibers (steel, polypropylene, polyvinyl chloride, and basalt fibers) have been found to be effective in controlling crack propagation and enhancing the fracture energy of geopolymers, the mechanical properties of geopolymers were found non-consistent and inadequate when exposed to elevated temperatures [11–13]. During fire accidents, many of these fibers fail in providing effective reinforcements due to lack of structural strength and durability at higher temperature[14]. Therefore, further research is required to identify alternative fibers which possess good thermal resistance and maintain higher residual mechanical properties when exposed to elevated temperature. The present work deals with the effect of carbon microfiber addition on the development of microstructure and mechanical properties of geopolymers at elevated temperature. The carbon microfibers were prepared from recycled inexpensive carbon fibrous wastes by ball milling, and then subsequently incorporated under 5, 10 and 15 wt % loading into metakaoline based geopolymers. Further, the composites were examined for change in microstructure, mechanical properties and toughening mechanisms after exposure to the elevated temperatures of 200, 400, and 800 °C. To the best of the authors' knowledge, this is the first study on elevated temperature properties of geopolymers filled with carbon microfibers obtained from carbon fibrous wastes.

2 RESULTS AND DISCUSSIONS

2.1 Microstructure analysis

The SEM micrographs of neat geopolymer and geopolymer composites at different temperature exposure are shown in Figure 1. The microstructure of dense and homogeneous matrix consisting mainly of alumino-silicate gel can be observed for all samples before exposure to the elevated temperatures. The smooth surfaces of carbon fibers in the geopolymer matrix indicated no degradation of carbon fibers under action of alkali in the activating solution. The strong adhesion between the geopolymer gel and the surface of the fiber can be confirmed based on presence of geopolymer layer on fiber ends pulled out from the matrix and more striations on fiber surfaces. When the samples exposed to elevated temperatures, the geopolymer composites showed lower micro structural deterioration than neat geopolymers due to mechanical percolation along with pore filling effects of

carbon micro fibers. The carbon microfibers did not exhibit any observable degradation after elevated temperature exposure. This indicated the thermal resistance characteristics of carbon microfibers that can continue to provide the reinforcement to geopolymers when exposed to higher temperatures and therefore less strength loss.

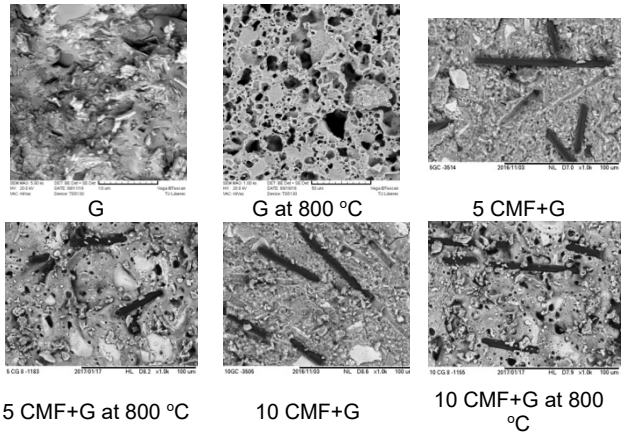

Figure 1. Microstructure of geopolymer composites

2.2 Compression strength

Table 1 shows the compression strength results of geopolymer and geopolymer composites before and after exposure to elevated temperatures. The geopolymer composites showed higher compression strength than neat geopolymers over all range of temperature exposures. From load-deformation curve, the neat geopolymer indicated a typical brittle failure mode, whereas geopolymer composites exhibited an extended period of plastic deformation (i.e. pseudoplastic behavior) unlike short drop at the point of maximum load. This non-linear behavior of geopolymer composites can be explained from the fiber-bridging and sliding after debonding and pulling-out of carbon fibers from the geopolymer matrix. This further indicated more favorable interaction between carbon micro fibers and the matrix possibly due to a combination of physical and chemical bonding. With increase in temperature till 200 ºC, all samples showed increase in compression strength. This behavior was attributed to the formation of discontinuous nano-pores and dehydration shrinkage of geopolymers due to expel of free water at 200 ºC. However, the compression strength deteriorated for all samples at 400 and 800 ºC.

Table 1. Compression strength at elevated temperature

Temperature (ºC)	G	5CMF+G	10CMF+G	15 CMF+G
30	28.43	38.97	44.22	41.33
200	36.61	44.23	48.77	45.04
400	14.85	24.21	30.08	33.55
800	11.23	19.86	21.29	23.96

This behavior can be attributed to thermal incompatibility (i.e. differential thermal expansion between geopolymer and carbon micro fibers), pore pressure effects (i.e. movement of free water and hydroxyls) and possible phase transition in geopolymers at elevated temperature. The less deterioration for geopolymer composites indicated the thermal resistance characteristics of geopolymers after the addition of carbon micro fibers, which further decreased the thermal stresses and restricted the swelling of unreacted geopolymer phases.

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IRREGULAR WINDING OF PREPREG FIBRES AIMED TO LOCAL IMPROVEMENT OF FLEXURAL PROPERTIES

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Abstract: *The undisputed benefits of using long fibre composite materials whose properties could be targeted for a particular application, consist mainly in the efficient utilization of material. By the method of the pre impregnated fibers winding, a rod with a reinforced middle part, reached by local adjustment of the winding angle in order to increase the local bending stiffness, was created. The aim of the carried work was to experimentally and subsequently by using an appropriate numerical model describe the behavior of two composite rods, one with a variable and second with a constant value of winding angle. The difference in mechanical behavior of the both structures was clearly noticeable during the experiment. At the same time, by using a suitable composite preprocessor and by choosing some multiple element sets, it is possible to accurately simulate the real behavior of such components that actually have several regions each with different mechanical parameters. Simultaneously, together with the expected different flexural strength, the classical 3-point bending test also explored the different shape of the resulting deformation in the two compared parts.*

Keywords: *composite, prepreg, winding, bending, local reinforcement.*

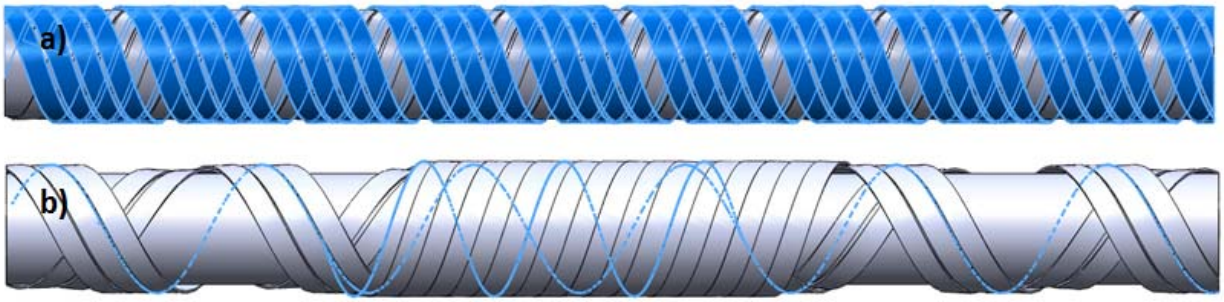

Figure 1 The CAD model of fiber layout with visible: a) Constant b) Various winding angle

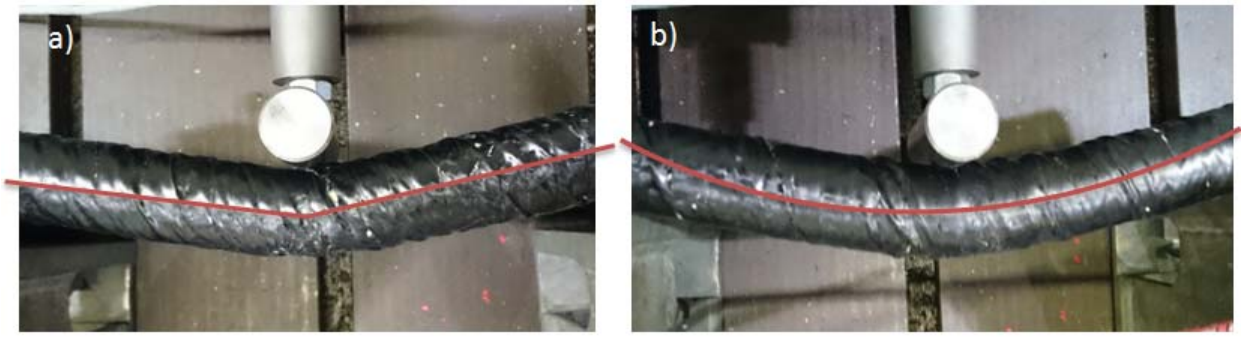

Figure 2 The shape of deformation in the bending test for: a) Homogenous b) Locally reinforced rod

1 INTRODUCTION

Constructions based on long fiber composite frames gaining significant position through all industrial sectors. Plastics materials reinforced by long fibers are widely used because of their high strength and modulus to density ratio. Whereas conventional materials show one failure mode i.e. cracking, composites can exhibit one or combination of failure modes, including fiber rupture, matrix cracking, delamination, interface debonding and void growth [1, 2]. The aim of this presented work is to study composite rods with a local reinforcement, achieved

by varying of the winding angle during their manufacturing and compare with a constant one.

2 MATERIALS AND METHODS

The used manufacturing method called winding is a simultaneous deposition of several fiber filaments. The general problem when manufacturing some rotational shapes from prepregs is that we could make only the straight shapes. This method could handle the problem and by segmentation of the main material (simultaneously wrapping of up to 20 filaments) we could create curved shapes and even parts with fluently changed cross-sections. Even though those advantages, in a real case there could be some places with an imperfect alignment of fibres and their mutually storing.
The used material was the epoxy UD carbon prepreg with thickness 0.2 mm. According to the conducted measurements is the final thickness after polymerization approximately 85 % of the original one.
The created tubes were winded from 16 thin tapes and have 4 plies with the total thickness 0.84 mm. The fibers layout in a case of the regular rod was 55/-55/55/-55, weight 158 g. In the case of the locally thickened rod, the global layout was also 55/-55/55/-55 and locally in the middle part 55/-70/70/-55, weight 165g (Fig. 1).

3 EXPERIMENT

The flexural strength of a material is the maximum stress that material subjected to bending load could resist before failure. A classical three point bending test [3] (Fig. 2) was used to compare the homogenous and locally variable tube. The applied quasi static loading had increased with step 0. 5 mm /s until caused the final displacement of used indenter 80 mm.

4 MODEL

The prediction composite behavior is very complex problem, because the process induces orientation of fibres, interface of plies etc. Finite-element method (FEM) is a powerful tool without it is today not possible to efficiently design composite parts. Numerical analysis allows us to derive the different strain energies stored in the material directions of the constituents of composite materials [4]. In our case, the models of shell composite plate of the two tubes tube have been carried out in Ansys ACP preprocessor. The model was solved as a fully contact task. For combination of solid and shell elements the pure penalty formulation with nodal-normal detection of integration points was used. The frictional support with asymmetric behavior has been set.
The simplest way of handling an initially unconstrained model was to add weak springs [5, 6]. The spring constant can be made dependent on the loading parameter, so the effect could acts only in the beginning of the simulation. The scheme of the carried model with the boundary conditions is shown in the Fig. 3.

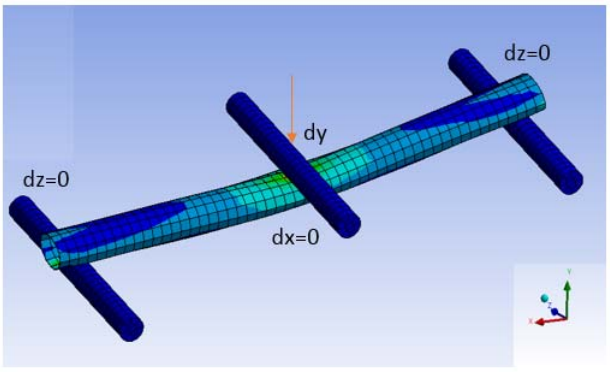

Figure 3 The layout of the solved shell / solid model

5 CONCLUSION

During the experiment we have obtained significantly different behavior for the two tested kind of rods. The experimental results were evaluated by numerical model, carried in advanced composite preprocessor. It is possible to say, that the local changes in the winding angle could not only increase (or decrease) the flexural strength, but they could also change the shape of the parts deformation and the arising material failures process as could be seen in the Fig. 2.

Acknowledgement: *The results of this project LO1201 were obtained with co-funding from the Ministry of Education, Youth and Sports as part of targeted support from the "Národní program udržitelnosti I" programme.*

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GENERALIZED MODEL AND EXPERIMENTAL VERIFICATION OF BI-AXIAL TENSILE PROPERTIES OF COMPOSITES FROM 3D ORTHOGONAL WOVEN PREFORMS

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Abstract: *This paper deals with the development of a generalized model to predict the entire load-extension behaviour of composites from 3D orthogonal woven (3DOW) preforms using finite deformation theory. The model is generalized to predict the bi-axial tensile properties (modulus, peak load and strength, strain at peak load, and toughness) of composites from 3DOW in terms of structural parameters (x-, y-, and z-fibers' tensile curves and size, matrix volume fraction, fiber volume fraction, weave structure represented by weave factor, x-, y-, z-yarn thread density, x-, y-, z-yarns packing). The model was used to generate numerical solutions for wide range of hypothetical structures. To validate the model, range of experimental load-extension curves are compared to the corresponding predicted curves. The experimental composites include preforms from 100% E-glass and hybrid structures from E-glass/Spectra, E-glass/Vectran, and E-glass/Zylon. The experimental and predicted load-elongation tensile curves are in good agreement. The model can be utilized to predict the tensile properties of composites from 3DOW and used as tool for designing structures to meet specific performance requirements without the need for the costly and length manufacturing of structures and assessment of their performance experimentally.*

Keywords: *3D composites, orthogonal woven preforms, modelling*

ACOUSTICAL PROPERTIES OF SPUNMELT MULTILAYER NONWOVENS IN RELATION TO AIR PERMEABILITY AND POROSITY

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Abstract: *In this study acoustical properties of spunmelt multilayer nonwovens in relation to air permeability and porosity have been derived. Multilayer nonwovens obtained by polyester fibers consisted of three layers. The top and bottom layers were spunbonded nonwoven and middle layer was meltblown nonwoven sandwiched between them. Each layer was produced separately to compose unbonded three-layered nonwoven structures. Spunbonded nonwoven fabrics having a basis weight of 40 gsm made from polyester trilobal cross-sectional fibers. Meltblown nonwoven fabrics having seven different basis weights ranging 50 gsm to 200 gsm made from polyester round cross-sectional fibers. And totally SMS (Spunbonded/ Meltblown/ Spunbonded) type unbonded multilayer nonwovens had basis weights ranging 130 gsm to 280 gsm. All results have been analyzed statistically. Results have shown that sound absorption, air permeability and porosity have a significant correlation for three-layered nonwoven structures. This effect becomes more significant as the basis weight increased and higher sound absorption coefficients were provided.*

Keywords: *Multilayer Nonwovens, Sound Absorption, Impedance tube, Air permeability, Porosity*

1 INTRODUCTION

Noise is undesired sound series in variable frequencies altering by the time and should be controlled for human comfort and health. One of the noise control methods is sound insulation, depends on creating a barrier to prevent the passage of sound waves and reduce sound transmission. So the major principle of sound insulation is based on sound absorption. Sound absorption means the sorption and transformation of sound energy to another type of energy, mostly heat energy. Bulky, fibrous, porous nonwovens are widely used sound absorbers for many technical applications. Because of the porosity of the structure and the fibers interlocking in nonwovens are the frictional elements that provide resistance to acoustic wave motion. When sound enters into fibrous materials, its amplitude is decreased by friction as the waves try to move through the tortuous passages. Thus the acoustic energy is converted into heat [1]. In this study sound absorption performance of SMS type multilayer nonwovens in relation to air permeability and porosity have been investigated. Lighter spunmelt nonwovens with less thickness will be a good alternative to control the sound absorption compared with commercially available bulky- heavy needle-punched sound absorbers.

2 MATERIAS AND METHODS

2.1 Materials

Spunbonded layers, flat bonded thermally, having, a basis weight of 40 gsm were produced from trilobal cross-sectional fibers in the diameter of 20-24 µm. Seven different meltblown layers had a basis weight of 50 gsm to 200 gsm with polyester (PET) round fibers at the diameter of 5-8 µm. Meltblown nonwovens were bonded thermally at same conditions to form non-stiffer middle layer of multilayer structures.SMS compositions of seven different meltblown layers with spunbonded layer, seven multilayer nonwoven structures were prepared manually. Fabric design of nonwoven samples has been illustrated in Figure 1.

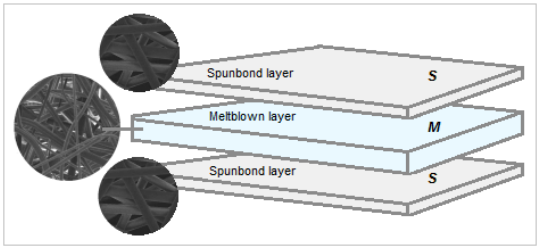

Figure 1 **Fabric design of SMS type multilayer nonwovens**

2.2 Methods

The sound absorption coefficient was measured using the impedance tube two-microphone method according to ISO 10534-2. The principle of the measurement is shown in Figure 2 schematically.

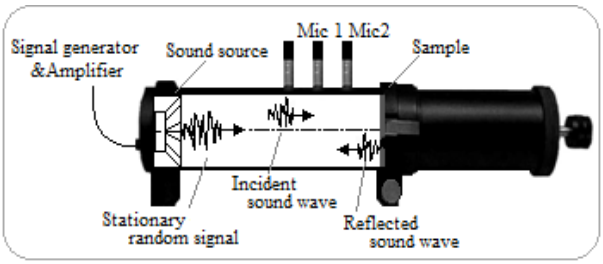

Figure 2 **Impedance tube for the two microphone transfer function method [2]**

Air permeability of multilayer nonwovens was obtained by using SDL Atlas digital air permeability tester **(**SDL-Atlas Inc., USA). The test were conducted according to NWSP 070.1.R0(15). The Capillary Flow Porometer (Porous

Materials Inc.,USA) has been successfully used to evaluate pore structures of multilayer nonwovens. The test were conducted according to the liquid extrusion method with ASTM E 1294-1389.

3 RESULTS AND DISCUSSION

The performance of sound absorbing materials is evaluated by the sound absorption coefficient (α), ranges between 0- 1, and is defined as the ratio of acoustic energy that is absorbed by the material. In Figure 3 the sound absorption coefficients of nonwoven samples can be observed for increasing fabric weights. Sample code 1 represents the lightest fabric as 130 gsm and 7 is the heaviest one as 280 gsm. As shown in Figure 3 the increase in basis weight influences the sound absorption positively. So the higher sound absorption coefficients were proved for the higher weights for the samples.

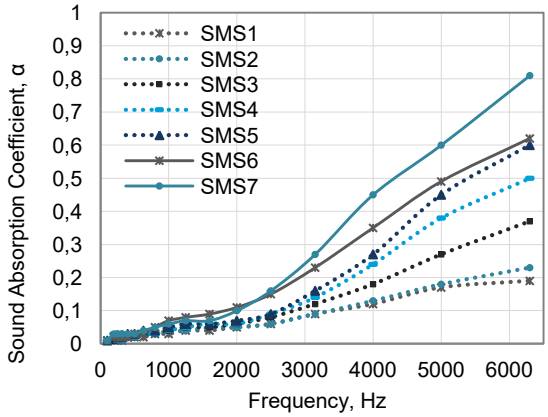

Figure 3 **Sound absorption of samples**

Air permeability of samples is seen in Figure 4 respectively, for increasing basis weights of SMS nonwovens. Air permeability becomes lower as the fabric weight increaes. At higher basis weights of the fabrics, increase in the number of fibers creates more spaces and a longer tortuous path through which the air must flow. Thus fabric structure becomes more resistant to air flow resulted with lower air permeabilities.

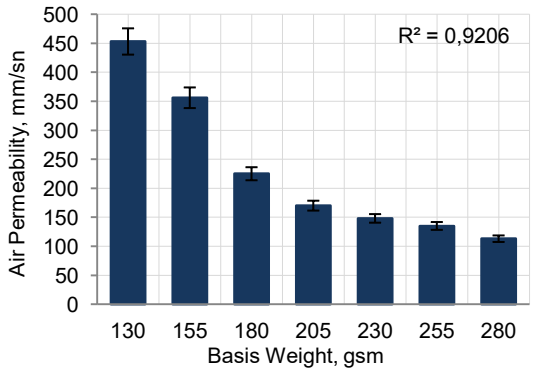

Figure 4 **Air permeability of samples**

It has determined that the basis weight is effective parameter for air permeability performance statistically. Air permeability has been effected by basis weight 92.06%. Regression equation for air permeability has been obtained from the statistical model is presented in Equation 1 where basis weight is codded A.

$$\text{Air permeability} = +179.48 - 164.89 * A + 110.46 * A^2 \quad (1)$$

Pore structure characteristics of nonwovens are important for their applications. Pore sizes of the samples shown in Table 1 are means of the measurements taken using standard ASTM procedures.

Table 1 **Porosity of samples**

Sample code	*Min. flow pore size (µm)*	*Mean flow pore size (µm)*	*Max. flow pore size (µm)*
SMS1	14,3488	22,6232	37,5659
SMS2	13,9834	22,2596	35,6322
SMS3	13,7524	20,3502	32,4952
SMS4	13,0532	20,0684	32,0458
SMS5	12,6843	19,2601	29,5589
SMS6	12,3957	18,4887	27,6804
SMS7	12,0877	16,8440	27,8747

Design Expert Analysis of Variance (ANOVA) software (Stat-Ease, Inc., USA) was used for statistical data analysis. The correlations between the independent parameter basis weight (A); on the dependent parameters; sound absorption (B), air permeability (C) and pore size (D), has been examined and the results for the data obtained in the study are shown in Table 2.

Table 2 **Correlation between variables and responses**

	A	*B*	*C*	*D*
A	1.000	0.965	-0.900	-0.938
B	0.965	1.000	-0.919	-0.976
C	-0.900	-0.919	1.000	0.913
D	-0.938	-0.976	0.913	1.000

4 CONCLUSION

The statistical results showed that air permeability and porosity were significant factors for sound absorption. Correlations between each of variables proved that sound absorption has an inverse relation with air permeability and pore sizes. Additionally all samples had low sound absorption coefficients range between 0.0–0.3 up to the frequency of 3000 Hz. The highest sound absorption coefficient 0.81 has been observed at SMS7 for the frequency of 6300 Hz at the maximum range of fabric weight of 280 gsm. At the high frequencies as the wavelenghts becomes smaller, the thinner fabrics control the sound absorption efficiently. Therefore the thinner spunmelt nonwovens compared to needle-punched ones are good sound absorbers at high frequencies.

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FILTRATION PROPERTIES OF THERMALLY TREATED NANOFIBROUS WEBS

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Abstract: *After the industrialization world is changing rapidly, especially the quality of environmental has decreased day by day, inflictive pollutants are merged with air and water. Nowadays this main environmental issues resume and recur, and menace the all humanity. In developing countries more than 2 million people die annually due to water related diseases (Dirty Water: Estimated Deaths from Water-Related Disease 2000-2020, Peter H. Gleick). Water pollution and diminishing fresh water sources are mentioned that area of urgent solution must be found. The guess is more than %50 of nations in the world will encounter that global issues at 2025 and after, by 2075 having this trouble nations number increasing about %75 of all nations. At 2020 expected filtration market value would be up to US $700b. [3,4].*

Currently many methods used for solving these concernes, seawater desalination is used by distillation, reverse osmosis(RO) or membrane distillation(MD) with progressing the new technologies[1]. Nanofiber filter media performed by electrospinning might be show potentially above mentioned properties, there are several methods for produce the nanofiber, some of them; island-in sea, gas jet techniques, drawing, template synthesis, phase separation, self-assembly, nanolithography and electrospinning. But all of these techniques have some usefullness for example; restricted material range, possible fiber assembly, cost and production rate. Electrospinning is challenging the other methods about low cost and relatively high production rate [2,3,5]. Electrospun nanofibrous membranes are promising material in the filtration industry. However, due to nature of electrospinning method, these electrospun nanofiber membranes are very thin and have poor mechanical strength thus necessitating the use of an additional support layer which can add to membrane thickness and resistance. In this study, polypropylene microfiber was used as a support layer. Polymer nanofiber mats based on polyacrylonitril (PAN), polyvinylidenefluoride (PVDF) and polyamid (PA) 6 were produced by using electrospinning method and applying thermal treatment and examined their morphology and water permeability.

All kinds of electrospun PA 6, PVDF and PAN nanofibers membranes were fabricated and tested the prepared specimen were then numerically examined and their area density values are determined. These results clarify that PAN-based specimen contains the largest amount of polymer material than PVDF and PA-6 based specimens. Regarding to this comparison; PAN-based membrane expected to have the worst water permeability without any thermal and mechanical deformation.

These results demonstrated that PAN has the coarsest fibers comparing to PA6 and PVDF, but this value also clarifies that PAN membrane owns the biggest pore sizes. On the other hand; mean fiber diameter of PVDF based membrane has the lowest value and also it has the lowest pore size compared to the others..

Keywords: *Polypropylene microfiber, polyacrylonitril (PAN), polyvinylidenefluoride (PVDF) and polyamid (PA) 6, Electrospinning.*

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DEVELOPMENT OF CASUAL GARMENTS FROM HYDROENTANGLED NONWOVEN FABRICS

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Abstract: *The cost of making apparel fabrics for garment manufacturing is very high because of their conventional manufacturing processes and new methods/processes are being constantly developed for making fabrics by unconventional methods. With the advancements in technology and the availability of the innovative fibres, durable nonwoven fabrics by using the hydroentanglement process that can compete with the woven fabrics in terms of their aesthetic and tensile properties are being developed. In the work reported here, the hydroentangled nonwoven fabrics were developed through a hybrid nonwoven manufacturing processes by using fibrillated Tencel® and bi-component (sheath/core) polyethylene/polyester (PE/PET) fibres, in which the initial nonwoven fabrics were prepared by the needle-punching method followed by hydroentanglement process carried out at optimal pressures of 50 to 250bars. The prepared fabrics were characterised according to the British Standards (BS 3356:1990, BS 9237:1995, BS 13934-1:1999) and the attained results were compared with those for a standard plain-weave cotton, polyester woven fabric and commercially available nonwoven fabric (Evolon®). The developed hydroentangled fabrics showed better drape properties owing to their flexural rigidity of 252 mg.cm in the MD, while the corresponding commercial hydroentangled fabric displayed a value of 1340 mg.cm in the MD. Tensile strength of the developed hydroentangled fabrics showed an approximately 200% increase than the commercial hydroentangled fabrics. Similarly, the developed hydroentangled fabrics showed higher properties in term of air permeability, such as the developed hydroentangled fabric exhibited 448 mm/sec and Evolon fabric exhibited 69 mm/sec at 100 Pa pressure. Thus for apparel fabrics, the work combining the existing methods of nonwoven production, provides additional benefits in terms of cost, time and also helps in reducing the carbon footprint for the apparel fabric manufacture.*

Keywords: *hydroentanglement; nonwoven apparel; durable nonwovens; Tencel®; Evolon®*

PERMEABILITY PROPERTIES AND ABRASION RESISTANCE OF COATED POLYPROPYLENE FABRICS

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Abstract: *Protective garments constitute an important class of technical textiles and they serve for various application areas such as active sports, military, medicine and fire-fighting. According to their end-uses, protective garments are expected to show one or more functional properties like chemical resistance, fire retardancy, ballistic protection and etc. One of the most shared properties of protective garments is providing a barrier against water or liquid penetration. For this purpose, fabrics are coated or laminated and their proofness properties are developed. On the other hand, nowadays, new materials are developed to be used in protective garments or known materials are adapted to this new area in order to provide novel properties or to decrease the garment cost. Polypropylene fibers, which have been produced commercially from 1960s, have not found application in protective garments except than underwear. This is due to their some technical problems such as low melting point, dyeing difficulties, etc. Despite that, the consumption of polypropylene fibers is increasing due to their low cost, lightness, wicking properties and fast drying.*

The focus of this study was coating polypropylene fabrics in order to examine their use in protective sportswear. Effects of coating polymer type and curing temperature on the specimen permeability properties and abrasion resistances were investigated in order reveal their usability in this area.

Keywords: *coating, polyurethane type, curing temperature, polypropylene fabrics, protective garments, permeability properties, abrasion resistance.*

1 INTRODUCTION

Protective garments possess various functional properties such as resistance to chemicals, fire retardancy, ballistic protection etc. according to their end-uses. In addition, most of the protective garments are expected to show waterproofness up to certain a level. For this purpose, coating or lamination is applied to protective fabrics [1, 2]. Also, some functional properties such as fire retardancy, liquid and dust impermeability and hand changes can be provided by coating.

Coated fabrics can be defined as engineered flexible composite materials that are coated with a polymer layer from one or both sides. Woven, knitted or non-woven fabrics can be used as the base fabrics for coating. Coating polymers are applied to base fabric surfaces as viscous solutions or dispersions. After the application of the polymer layers, the liquid phase is removed by heat and the polymer forms a continuous layer on the fabric surface. In addition, coating can be applied by using hot melt polymers [3, 4].

Main polymers for textile coating are natural and synthetic rubber, polyurethane (PU), polyacrylic, polyvinyl acetate and polyvinyl chloride [5]. In addition to these main types, their variants, copolymers and terpolymers are also synthesized for coating. PU is a multipurpose coating polymer, which can be used for the coating of protective garments, upholstery, artificial leather, inflatable boats and etc. PU is not a single polymer but it consists of a polymer group with similar chemical structure. The repeating unit of PU is given in Fig. 1. By changing the R, R' groups, various PU types can be obtained [5].

Polypropylene fiber consumption is increasing day by day according to its advantageous properties such as low cost, lightweight, wicking property and fast drying. However, it is not preferred for protective garments as it has some technical problems like low melting point [6].

In this study, polypropylene fabrics were coated in order to create an alternative for protective garments. This is expected to expand the usage of polypropylene fibers. Two PU coating polymer types and two curing temperatures were selected as the experimental variables.

2 MATERIALS AND METHODS

Polypropylene base fabric, aliphatic polyether (R) based PU, polyester (W) based PU, cross-linking agent and thickener were the materials of this study.

Fabrics were coated two times at the same side by using a laboratory type blade coating machine. Coated samples were cured at 120 and 140° C for two minutes as the PP has a low melting point. Waterproofness (TSE 257 EN 20811) [7], air permeability (ISO 9237) [8] and water vapor permeability (BS 3424 - Method 37) [9] of samples were determined as the permeability properties of fabrics. Fabric unit mass (TS 251) [10] and thickness (TS 7128 EN ISO 5084) [11] values were determined in order to examine the physical changes of fabrics after coating. In addition, abrasion resistance of fabrics were determined according to TS EN ISO 12947-3 [12] before and after coating.

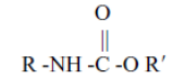

Figure 1 Urethane [5]

3 RESULTS

Sample unit masses, % add-on values and thickness values are given in Table 1. The add-on values for coated fabrics are between 21 % and 46 %. Samples that were cured at 140° C have higher add-on values. This may be due to shrinkage of base fabric at higher temperatures. Similarly, unit mass values are higher for 140° C cured samples.

Waterproofness, air permeability and water vapor permeability results of samples are given in Table 2. Air permeability of samples decreased dramatically whereas the base fabric has 205 L/m^2/s air permeability. W140 sample with the highest unit mass, did not permit the air passage. Generally, all of the coated samples were considered as windproof with less air passage than 15 L/m^2/s [5]. Water vapor permeability of fabrics also decreased after coating but the level of decrement was not as high as air permeability. Waterproofness of samples were 164 mm water coloumn (mm w.c.) maximally. Polyether type PU coated samples gave relatively higher waterproofness than polyester type PU coated samples.

Abrasion resistance results of samples are given in Fig. 2. Generally, all of the coated samples showed very good abrasion resistance and did not lose weight even after 80000 abrasion cycles.

Table 1 Sample codes, unit mass, % add-on and thickness values

Polymer	*Curing temp. (C)*	*Sample code*	*Unit mass (g/m^2)*	*% add-on*	*Thick. (mm)*
Base fabric	-	PPZ	76	0	0,223
R	120°C	R120	92	21	0,213
	140°C	R140	107	40	0,237
W	120°C	W120	99	30	0,215
	140°C	W140	111	46	0,222

Table 2 Permeability values of samples

Sample code	*Air permeability (L/m^2/s)*	*Water vapor permeability (g/m^2/24h)*	*Water proofness (mm w.c.)*
PPZ	205,7	838,3	72
R120	8,4	300,4	164
R140	7,8	445,5	151
W120	7,0	458,4	33
W140	0,0	64,7	61

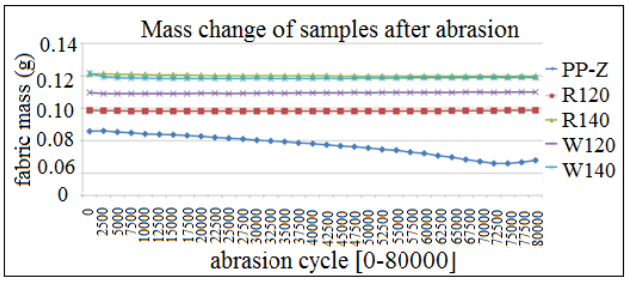

Figure 2 Abrasion resistance of samples

4 CONCLUSION

Overall, coated fabrics showed very high abrasion resistance and windproofness. Generally, results were not affected from the PU type or curing temperature, systematically. Waterproofness of coated samples were not high enough to be used in every kind of protective sportswear but samples can be preferred for windproof sportswear. Further studies are planned to enhance the waterproofness of samples by using new coating parameters.

ACKNOWLEDGEMENT: *Samples of this study were coated in Rultrans Transmisyon, Turkey. Coating polymers and auxilary materials were supplied kindly from Rudolf Duraner, Turkey and Organik Kimya,Turkey.We thank the companies for their supports.*

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NEEDLELESS ELECTROSPINNING OF PAN NANOFIBER MATS

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Abstract: *Polyacrylonitrile (PAN) belongs to the few waterproof polymers which can be spun from relatively safe solvents, allowing using PAN nanofiber mats in diverse medical and biological applications, such as tissue engineering and cell growth promotion. PAN, on the other hand, is significantly harder to use in electrospinning than poly(ethylene glycol) and other water-solvable biopolymers. This is why in a recent study we have varied spinning and material parameters for PAN dissolved in DMSO (dimethyl sulfoxide) and investigated spinnability as well as the resulting nanofiber mat morphologies.*

Keywords: *Polyacrylonitrile, electrospinning, nanospinning, nanofiber mat, spinning parameters*

1 INTRODUCTION

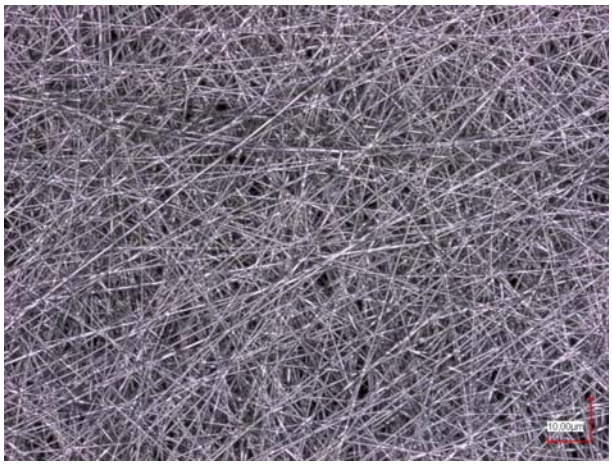
Electrospinning belongs to the primary spinning processes, resulting in fine polymer fibers with diameters in the area of some ten to some hundred nanometers. In needleless electrospinning, polymers are often spun from solutions, a process which is technically easier than melt electrospinning. Several polymers, however, cannot be solved in non-dangerous solvents. Polyacrylonitrile (PAN) belongs to the materials which can be solved in DMSO, a solvent which has to be handled with care, but does not cause problems in biological or medical applications.
While PAN is thus a typical material in electrospinning [1,2], investigations of the influence of its spinning and material parameters on the resulting nanofiber mats are scarce [3-5]. Our article give an overview of the effect of different polymer concentrations in DMSO, different base materials and a variation of the spinning parameters on the spinning process and the resulting nanofiber mats.

2 EXPERIMENTAL

PAN solutions were prepared with 5 % to 50 % PAN in DMSO by stirring for 2 hours at room temperature. Additionally, different PAN base materials were used.

Figure 1 Needleless electrospinning of a PAN solution with undesired cotton-candy-like polymer connections between high voltage electrode and substrate

Electrospinning was performed on the needleless nanospinning machine “Nanospider Lab” (Elmarco). The spinning parameters, such as high voltage, electrode-substrate distance, carriage speed, etc. were varied to find optimum conditions for the different spinning solutions.
The nanofiber mat morphologies were investigated using the confocal laser scanning microscope (CLSM) VK-9000 (Keyence) with a nominal magnification of 2000 x.



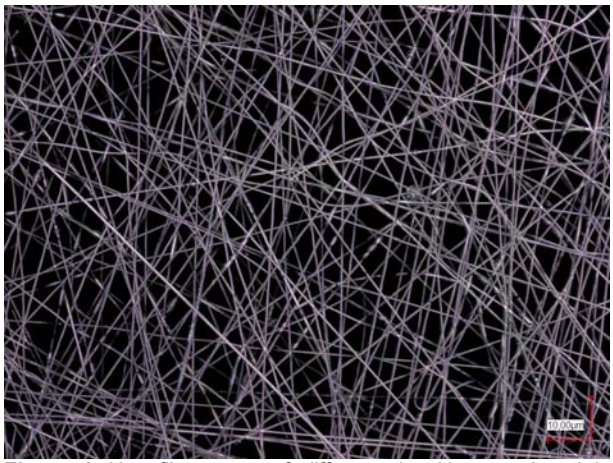


Figure 2 Nanofiber mats of different densities, produced by needleless electrospinning from PAN solved in DMSO

3 RESULTS

Depending on the solution and spinning parameters, strong deviations occur between the different spinning processes. In the worst case, directly after switching on the high voltage, cotton-candy-like polymer connections are formed between the high voltage area at the bottom of the chamber and the grounded area at the top (Fig. 1). This leads to no nanofiber mat being formed on the substrate since nearly all fibers are caught in these 3D structures. This behavior is significantly different from electrospinning typical biopolymers from aqueous solutions [6,7].
On the other hand it is possible to form even, straight nanofibers on the substrate in denser or less dense formation (Fig. 2) with ideal spinning and solution parameters. This shows the importance of carefully choosing the spinning conditions.

4 CONCLUSION

For needleless electrospinning with PAN, finding the ideal spinning and solution parameters is crucial for creation of optimum nanofiber mats. Our investigations allow for giving an overview of the influence of different parameters on the spinning process and the resulting nanofiber mats.

***ACKNOWLEDGEMENT**: The authors acknowledge gratefully the program FH Basis of the German federal country North Rhine-Westphalia for funding the "Nanospider Lab".*

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RELATIVE SURFACE AREA OF NANOMATERIALS – DREAM AND REALITY

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Abstract: *Unlike the recent overwhelming trend of nanofibers assumed to provide enormous relative surface area, the reality is quite different. The nano fibrous assemblies (membranes) are extremely thin in the order of a few microns only. They have often relatively smaller porosity compared to micro fibrous membranes. Thus by considering their porosity as well as thickness, the nano fibrous membranes do not offer so huge real surface area as is evaluated from standard approach (surface area-to-volume or surface area-to-mass ratio) because the volume or mass are for nanofibrous materials too small. Rather the micro fibrous assemblies (membranes) provide sufficient real surface area of fibrous phase for end use applications e.g. filtration or surface activation. In this contribution the basic shortcomings of standard relative surface area are shown. For estimation of relative surface area is proposed to use surface area-to-macro surface ratio which is dimensionless and dependent of porosity as well as thickness. The advantages of this definition of relative surface area are demonstrated on the example of PA 6 nano and micro membranes.*

Keywords: *relative surface area, nano membranes, micro membranes,*

1 INTRODUCTION

The fundamentals of nanotechnology lie in the fact that properties of substances dramatically changes when their size is reduced to the nanometer range. When a bulk material is divided into small size particles with one or more dimension (length, width, or thickness) in the nanometer range, the individual particles exhibit unexpected properties, different from those of the bulk material. The nanometer range is characterized by the transition of a material‘s behavior from “quantum like” behavior of atoms and molecules to the “continuum like” behavior of bulk materials. Often, nanomaterials are defined by a size range limited by at least one of the dimensions. This range should be according to EU standard 1–100 nm [1]. Especially for nano fibrous assemblies prepared by electrospinning is the mean fibrous elements thickness (diameter) is some hundreds of nanometers. But in general, all these fibers with a diameter below 1 μm (1000 nm) are often accepted as nanofibers [1].

One of the main advantages of nanomaterials is very huge relative surface area (surface area-to-volume ratio) [2]. This is in fact true for nanoparticles where are not limitations according to the macro geometry (unit volume). It is widely published that by reducing fiber diameters down to the nanoscale, an enormous increase in specific surface area to the level of 1000 m^2/g or much more is possible. By reducing the fiber diameter from 10 μm to 10 nm, a million times increase in flexibility is expected. Recognizing the potential nano effect that will be created when fibers are reduced to the nanoscale, there has been an explosive growth in research efforts around the world. Specifically, the role of fiber size has been recognized in significant increase in surface area, bio-reactivity, electronic properties and mechanical properties. The enhanced reactivity and efficiency of nano fibers is based on the claim that nanofibrous membranes provide enormous availability of surface area per unit mass [3].

Especially for nanofibrous assemblies prepared typically by electrospinning it is practically impossible to vary thickness in arbitrary range. Usually the thickness of these nano layers is up to few microns only. This is serious limitation for volume of these objects calculation because the unit of their macro surface should be multiplied by real thickness and final macro volume is then very low. It leads to low amount of nanofibers and their low total surface area per unit of macro surface. Avoiding of this limitation leads to the unbelievable huge relative surface area values which cannot be achieved in real products. The same situation appeared when the properties as sorption capacity are calculated relatively to mass.

In this contribution the basic limitation of standard relative surface area for nano fibrous assemblies are shown. For estimation of relative surface area is proposed to use surface area-to-macro surface ratio which is dimensionless and dependent of porosity as well as thickness. The advantages of this definition of relative surface area are demonstrated on the example of PA 6 nano and micro membranes.

2 RELATIVE SURFACE AREA

2.1 Surface area of fibers related to mass

The typical membrane (layer) of length L_F, width C_F, and thickness h with surface area $S_F = L_F C_F$ and volume VF=SF h is shown in fig. 1.

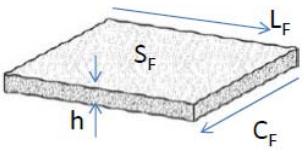

Fig. 1 Dimensions of membrane

Let this membrane is composed from N_v cylindrical fibers with length l, radius r and density ρ_F. Surface area of each fiber is $S_v = 2\ \pi\ r\ l$ and their mass is $m_v = 2\ \pi\ r^2\ l\ \rho_F$

The (*surface area-to-volume ratio*) relative surface area S_R [m^2/g] is generally defined as total surface area of *fibers* $S_V N_V$ divided by their mass

$$S_r = \frac{N_v\ S_v}{N_v\ m_v} = \frac{2}{r\ \rho_F} \qquad (2)$$

This relation is not dependent on the total fibrous assembly porosity P_o defined as

$$P_o = 1 - \frac{w_T}{h\ \rho_F} \qquad (3)$$

where w_T *i*s planar mas (usually in gsm/1000, where gsm is grams of layer per surface area in meter squared). Total mass of membrane m_T is simply

$$m_T = \rho w_T\ S_F = (1 - P_o)\ h\ \rho_F\ S_F\ . \qquad (4)$$

The total surface area of fibers S_{FT} in membrane is simply expressed as

$$S_{FT} = \frac{2(1 - P_o)\ h\ S_F}{r} \qquad (5)$$

In comparison with S_R is characteristic S_{FT} related to the thickness and overall porosity of membrane as well.

2.2 Surface area related of fibers to macro surface

Planar relative surface area (surface area-to-macro surface ratio) S_{SR} [-] is ratio of total surface area of fibers in layer S_{FT} and layer macroscopic surface area S_F

$$S_{SR} = \frac{S_{FT}}{S_F} = \frac{2\ (1 - P_o)\ h}{r} \qquad (6)$$

The S_{SR} is connected with S_R by relation

$$S_{SR} = S_R\ (1 - P_o)\ h\ \rho_F \qquad (7)$$

The dimensionless quantity planar relative surface area S_{SR} is taking in account the porosity and thickness influence on the relative surface area of fibers in membrane.

3 EXPERIMENTAL PART

PA 6 nanofibrous membrane (MN) with areal density of 1.3 g/m^2 was purchased from ELMARCO s. r. o Liberec. Spunbond PA 6 nonwoven fabrics (MM) with areal density of 100 g/m^2 was provided by Asahi KASEI Fibers Corporation.

Details about characterization and measurements of geometrical parameters of these membranes are given in [4]. SEM pictures of nano and micro membranes are shown in fig.1.

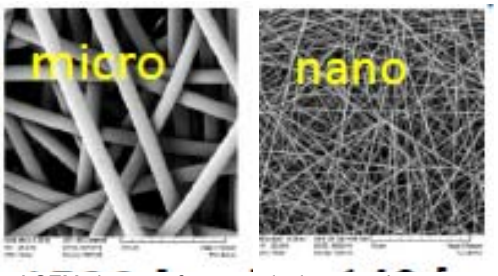

Figure. 1 SEM pictures of nano and micro membranes

4 RESULTS AND DISCUSSION

Basic characteristics of both membranes are summarized in tab. 1.

Table 1 Table type styles

Characteristic	Micro membrane	Nano membrane
r [nm]	1520	140
h [mm]	0.53	0.00185
gsm [g /m^2]	100	1.3
P_O [-]	0.83	0.36
S_R [m^2/kg]	1196.2	12987.1
S_{SR} [-]	*119.62*	16.88

The calculated relative surface area are given in tab. 1.
The ratio S_{SR} micro/ nano = 7.0850 indicates that real relative area of micro membrane is much higher in comparison with nano membrane. On the other side the ratio S_R micro/nano= 0.0921, i.e.relative area per mass is for micro membrane very low in comparison with nano membrane due to differences in thickness mainly.

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EFFECT OF ZINC OXIDE NANOPARTICLES ALONG WITH SODIUM HYDROXIDE ON SELF-CLEANING AND ANTIBACTERIAL PROPERTIES OF POLYETHYLENE TEREPHTHALATE

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Abstract: In this study, synthesis of zinc oxide nanoparticles was carried out along with the hydrolysis of polyethylene terephthalate using sodium hydroxide to increase the surface activity and enhance the nanoparticles adsorption. The polyester fabrics were treated with zinc acetate and sodium hydroxide at ultrasound bath, resulting in formation of ZnO nanospheres. The presence of zinc oxide on the surface of the polyethylene terephthalate was confirmed by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). The self-cleaning property of treated was evaluated through discoloring methylene blue stain under sunlight irradiation. The antibacterial activities of the samples against two common pathogenic bacteria including *Escherichia coli* and *Staphylococcus aureus* were also assessed. The results indicated that the photocatalytic and antibacterial activities of the ultrasound treated polyethylene terephthalate improved significantly.

Keywords: *Zinc oxide, polyethylene terephthalate, self-cleaning, antibacterial*

1 INTRODUCTION

The self-cleaning coating technology is an innovative strategy for functional finishing of textile [1-3]. Different semiconductors were used for preparation of textile with self-cleaning property. For instance, Karimi et al. produced self-cleaning cotton fabrics using nano-TiO_2 [4]. Along the same lines, Behzadnia et al. obtained photocatalytic fabrics based on zinc oxide coatings on wool fabrics [5].

Moreover, a chemical coating of cotton with zirconium dioxide nanoparticles with self-cleaning property was reported by Moazami and Montazer [6]. Also, textiles with multiple characteristics can be fabricated through applying the nano-semiconductors. Deposition of the semiconductors like TiO_2, ZnO, and ZrO_2 on textiles provides multi-functional properties such as self-cleaning, UV-protection, superhydrophilic, antibacterial, flame retardancy, etc. [7], [8]. The treated textiles with nano-semiconductors could be used in practical applications such as medical devices, healthcare, wound dressing, military, protective suits, personal care product, clothing, and others [9]. Polyester is one of the most widely used versatile polymers owing to its high strength, high modulus, abrasion resistance, heat set stability, light fastness, and chemical resistance [10].

2 METHOD

Synthesis of nano ZnO on PET through ultrasound bath: to synthesis of nano zinc oxide particles on the polyester fabric, diverse amount of zinc acetate (1, 2, 3, 4, and 5 wt.%) were used as precursor in 100 mL water in the ultrasound bath. The polyester fabrics were immersed into the solutions, and different amounts of sodium hydroxide (1, 2, 3, and 4 wt.%) were added to the bath under ultrasonic irradiation. The solution was irradiated at 65 ºC for 45 min. The treated samples were dried at 60 ºC for 30 min and then cured at 130 ºC for 4 min. At the end, the sonotreated samples were washed with distilled water and dried at 70 ºC for 24 h.

3 RESULTS AND DISCUSSION

The SEM images of raw PET Fig. 1 (A) and PET treated with zinc oxide at ultrasound bath Figs. 1 (B) and (C) are presented in Fig. 1. While the surface of the raw PET is smooth, the synthesized ZnO nanoparticles are distributed on the surface of the treated PET. spherical-shaped particles, with an average size of 52.6 nm (Fig. 1 (C)). XRD patterns were used to confirm the presence of zinc oxide on the fabric surface and to study crystalline status (Fig. 2).

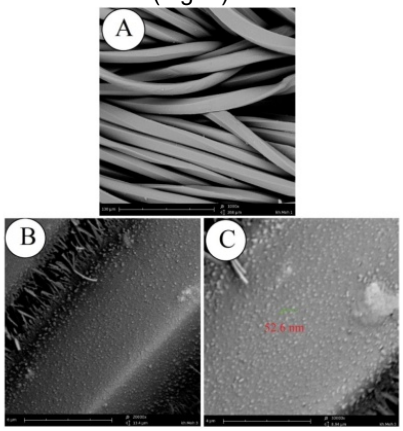

Figure 1. SEM images of various PET samples: (A) raw and (B) and (C) treated with zinc oxide at ultrasound bath

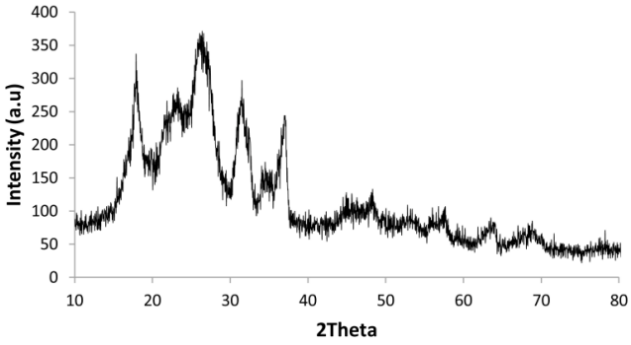

Figure 2. XRD patterns of treated polyester fabric at ultrasound baths

The FTIR spectrum of the treated sample with NaOH indicated the characteristic peaks attributed to C=O (carboxylic acid), C–O (ester acid), C–H (stretching vibration), and C–H (bending vibration) at 1715, 1000–1500, 2928, and 722 cm−1, respectively. Also, the peak at approximately 3450 cm-1 confirmed the forming of terminal groups of –OH on the surface of polyester fabric after the alkaline process, which is derived from the interaction of the hydroxide ions with the electron-deficient carbonyl groups, Fig. 3.

As seen in Fig. 4, all the zinc oxide treated samples showed higher ΔE* values arising from photocatalytic activity of ZnO nanoparticles to degrade dye stain. Results show that the amount of self-cleaning for the treated samples is higher when treated at alkaline condition.

4 CONCLUSION

As it is shown, simultaneous synthesis of zinc oxide nanoparticles and alkaline hydrolysis of PET samples surface was developed. PET samples with self-cleaning property and antibacterial efficiency were obtained by finishing process at ultrasound. Through SEM and EDS patterns, the presence of zinc oxide nanoparticles on the surface of the treated PET samples was confirmed. It was found that zinc oxide nanospheres were synthesized on the PET treated at ultrasound. Applying ultrasound irradiation in finishing process led to synthesized zinc oxide with finer size and homogenous distribution on the fiber surface.

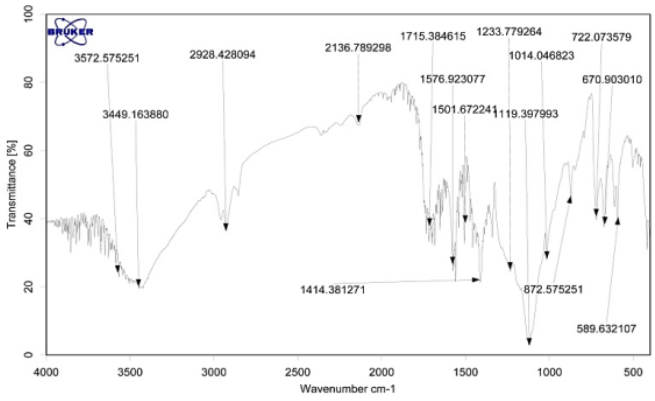

Figure. 3 FT-IR spectrum of alkaline treated polyester fabric with sodium hydroxide (4 wt.%) at ultrasound bath

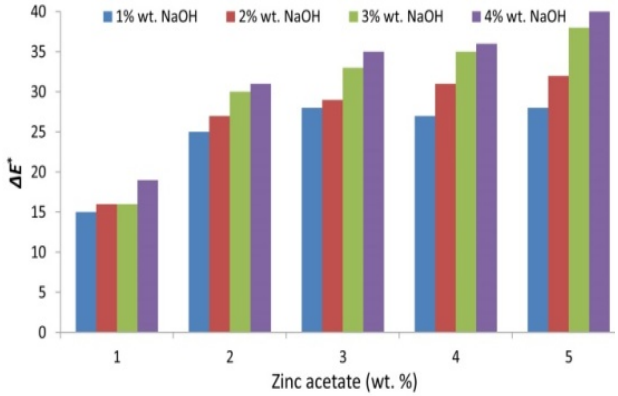

Figure 4. Comparative diagram of self-cleaning performance results of the PET samples treated at ultrasound bath

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IN SITU SYNTHESIS OF NANO PARTICLES ON TEXTILE FABRICS USING LASER ABLATION METHOD

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Abstract: *There is a growing interest in the fabrication of nanomaterials and their applications in various fields of life and technology such as electronics, health care, energy generation, and textile technology.*

In today life, cloths and garments are better to provide self cleaning properties. TiO_2 nano particles due to their noticeable and remarkable applications are widely used in the textile industry. Titanium dioxide, particularly in the anatase form, is a photocatalyst under ultraviolet (UV) light.

Photocatalytic nanocrystalline TiO_2 coatings are widely used nowadays. These particles are inexpensive, harmless, stable, and can be activated by solar energy.

In the other hands, among nanoparticles, metallic copper oxide nanoparticles are extremely regarded due to their optical, catalytic, mechanical and electrical properties, low cost preparation and many potential applications in catalysis, cooling fluid or conductive inks, heat transfer systems, antimicrobial, antifungal, antiviral agents have attracted so much attention in recent years. Also, Silver in several forms such as metallic, ionic and nanoparticle has attracted interest and are ideally suited for a vast range of applications in research and especially industrial applications. One of the interesting applications of silver nanoparticles is to enhance antibacterial properties of textiles materials.

Also individuals' interests have increased in developing nanoparticles on fabrics to their potential for use of human in various applications such as medical clothes, wound dressings, healthcare (including disposable) appliances, protective garments, veterinary and military among others.

In situ synthesis of nanoparticles in deionized water is a simple and effective route to prepare nanoparticles and absorption at the same time on textile materials. Currently, one of the most common techniques to incorporate nanoparticles onto natural textiles is by post-treatment of the fibers or the fabrics during the finishing stages of the manufacturing process. The post-treatment techniques will usually require the initial preparation of the nanoparticles and then finally attaching them to the textiles by chemical bonding. However, all these methods require multiple preparative steps to incorporate the nanoparticles onto the materials and are often time-consuming. Thus, 'one-pot' approaches for the incorporation of different chemicals onto textiles have been explored and garnered attention from researchers. There are several, chemical or physical methods to produced nanoparticles. Evidences show that the laser ablation method is superior to other methods. Indeed, laser ablation in liquids, which consists of the pulverization of a solid target in liquid ambience, gives a unique opportunity to solve the toxicity problems. In contrast to chemical nanofabrication methods, laser ablation can be performed in a clean, well-controlled environment, such as deionized water, giving rise to the production of ultrapure nanomaterials. Characteristics of nanoparticles such as their size and shape can be controlled by laser pulse parameters such as wavelength, pulse duration, laser fluency, and also the medium of ablation.

In this research, the application of laser ablation for in situ synthesis of different nano particles on textile fabrics is fully discussed. The various parameters of Laser for producing the nano particles concomitantly on textile fabrics are studied.

Keywords: *Textile, Fabric, In situ synthesis, nano particles, Laser ablation*

DEVELOPMENT OF PEO NANOFIBERS HAVING NOVEL MORPHOLOGIES VIA DISTANCE POSITIONING APPARATUS

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Abstract: *In this study, PEO nanofibers with novel architectures were developed via newly designed distance positioning apparatus in order to feed polymer solution in a different way. The surface morphology and alignment of nanofibers were observed using a scanning electron microscope (SEM). SEM micrographs revealed that different morphologies could be obtained by changing feeding position. For the first time in the nanofibers literature; nanofibers were simultaneously collected on three different positions (collector plate, X-axis, and Y-axis) and surface morphology of these nanofibers was found to be different which is promising in terms of their potential regarding utilization of same nanofibrous mat for functional applications.*

Keywords: *nanofibers, electrospinning, novel fiber architectures, new surface morphologies, functional nanofiber structures*

1 INTRODUCTION

Nanofibers are fibrous materials having enormous surface area (a football stadium wide area on a pinhead size material) and a tremendous length to diameter ratio (10^{-9} m). Nanofibers have become widespread in biomedical, health, filtration, energy, and transportation areas in recent years. Electrospinning has been widely used in the production of nanofibers [1,2]. In traditional electrospinning, nanofibers are collected in nanofibrous mat forms [3]. Those kinds of structures have quite similar morphology with the morphology of traditional nonwoven fabrics. This similarity could be attributed to basic characteristics of traditional electrospinning which are quite alike nonwoven web formation. These traditional nanofibrous mats limit the utilization of nanofibers to a few applications [4]. Therefore, in order to enhance capabilities of current electrospinning process and to alter the structure of nanofibers, new modifications were applied to the traditional electrospinning. Subsequently, needleless electrospinning, melt electrospinning, and magnetic field-assisted electrospinning were developed as novel electrospinning methods [5-8].

In this study, we report the development of polyethylene oxide (PEO) nanofibers having three different alignment styles due to different collection areas by changing feeding position via distance positioning apparatus designed for this study. Self assembling ability of nanofibers collected on three different collection points were provided and discussed in figures.

2 MATERIALS AND METHODS

In order to develop PEO nanofibers at changing morphologies, PEO polymer having a molecular weight of 1000.000 (PEO 1000.000 Mw) was purchased from Sigma–Aldrich Company. PEO solution with a concentration of 3 wt% from PEO 1000.000 Mw was prepared for processing in electrospinning with and without distance positioning apparatus.

2.1 Design of Distance Positioning Apparatus

A distance positioning apparatus was designed in order to produce nanofibers in variable morphologies. A plastic ruler of 30 cm length was drilled at 2 cm intervals beginning from its 18 cm point (Figure 1).

Figure 1 Example of a figure caption

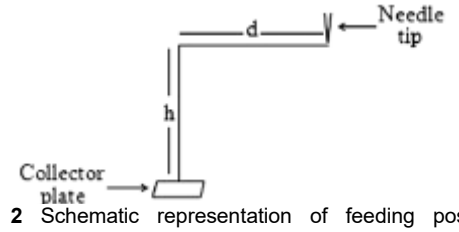

Figure 2 Schematic representation of feeding position in electrospinning via distance positioning apparatus.

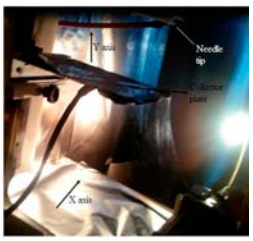

Figure 3 Photo of electrospinning setup showing collection areas of nanofibers

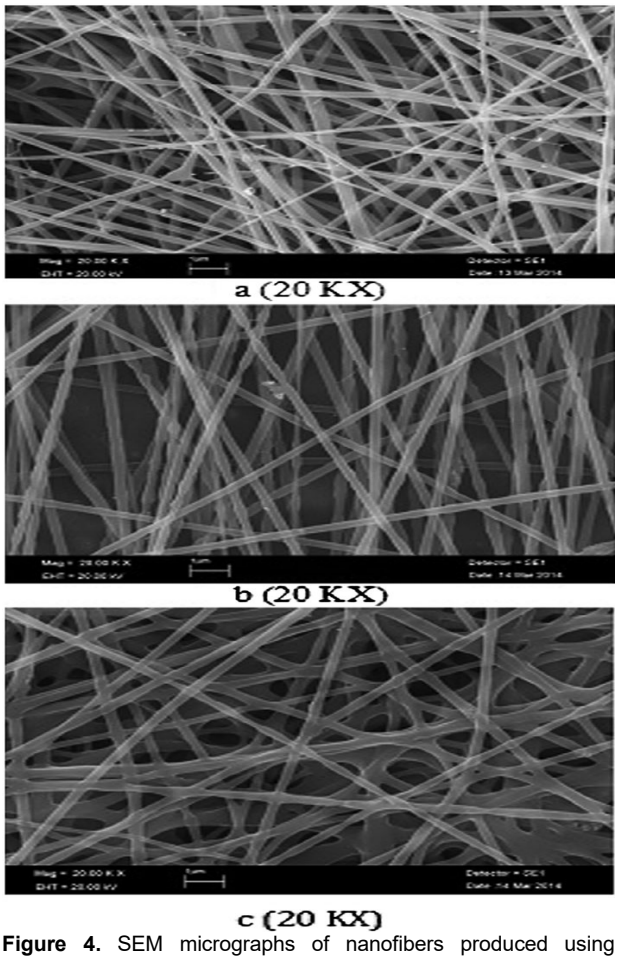

Figure 4. SEM micrographs of nanofibers produced using distance positioning apparatus (a, b and c respectively are electrospun nanofibers collected on collector plate, x axis and y axis which are shown both 20 KX and 5 KX magnifications).

2.2 Electrospinning

Electrospinning was carried out using distance positioning apparatus. A distance positioning apparatus was used to feed the polymer solution into the electrospinning area at a defined distance (d) and height (h). Thus, nanofibers were simultaneously collected at three different areas such as X-axis direction, Y-axis direction, and collector plate. The distance between collection area and distance positioning apparatus was set as 45 cm during fiber collection in direction of X axis. The distance between collection area and distance positioning apparatus was set as 25 cm during fiber collection in direction of Y axis. The height value was set as 8 cm (between needle tip and collector plate) while distance value was set as 14 cm during electrospinning (Figure 2).

2.3 Characterization

Morphologies, alignment, and fibrous structure of nanofibers were characterized using a SEM (LEO 440, Technical Sales Solutions, Beaverton, OR, USA).

3 RESULTS AND DISCUSSION

Figure 4 provides SEM micrographs of nanofibers that were produced from PEO (1000.000 Mw) solution with a concentration of 3 wt% using distance positioning apparatus at 16.9 kV power, 10 mL/h feeding rate, h = 8 and d = 14 feeding distances and 5 h duration. In this production, nanofibers were simultaneously collected on collector plate, x axis direction and y axis direction. When micrographs were investigated carefully, it is clearly seen that collection forms of nanofibers differentiate due to their collection areas are at different positions. In this way, it has become possible to produce nanofibers having three different morphologies from one feeding source by collecting nanofibers at three different areas at once.

4 CONCLUSIONS

SEM micrographs revealed that all nanofibrous mats had different alignments from each other due to different collection areas. Of all nanofibers mats, nanofibers collected in direction of x-axis were mostly aligned parallel to each other. In the same nanofibrous mat belonging nanofibers collected in direction y-axis, the occurrence of three layers having different morphology from each other, inspired the idea and possibility of different functions can be added to different layers for the same mat. These results are unique in its literature both in terms of application of designed distance positioning apparatus and in terms of morphological diversity development of obtained nanofibers.

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EXAMINATION OF AGING PERFORMANCES OF DENIM FABRICS WITH MECHANICAL PROPERTIES DEVELOPED BY NANO COATING METHOD

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Abstract: *This work compares the different washing processes (pumice, enzyme, domestic and pumice + enzyme washing process) effects on the nanofilm coated denim fabrics tensile strength properties. TiO_2 nanoparticles were used for fabrication of multilayer film deposition on denim fabrics by continuous layer-by-layer deposition process. Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy, X-ray Photoelectron Spectroscopy and Scanning Electron Microscopy were used to verify the presence of deposit nanolayers. CIELab analysis was performed on the fabrics before and after the treatment with nanoparticles by the layer-by-layer (LbL) deposition method. After aging processes, the effect of LbL deposition method on the tensile strength and colour fastness properties of denim fabrics was also investigated.*

Keywords: *denim, nano coating, aging, titaniumdioxide nanoparticle, layer-by-layer (keywords)*

1 INTRODUCTION

In recent years, a range on denim fabric treatment methods is used, such as diverse types of washing, dyeing, functional finishing and bleaching, in order to get the desired effects (Kan, 2011). But, especially, the washing and the special treatments (enzyme and/or pumice washing for aged look) on denim garments are the important parameters influencing cloth shade and the fabric mechanical properties (Khedher, 2009 and Tarhan, 2009).

2 MATERIAL AND METHOD

Indigo dyed denim fabrics were purchased from GAP Textile and used for obtaining nanofilm coated denim fabrics. Anatase titanium oxide nanoparticles (particle size <25 nm, specific surface area 200-220 m^2/g) was purchased from Aldrich and 5 g/l nanoparticle suspensions were prepared at 40 W for 1 h by Sonics Vibra-Cell Ultrasonic Homogenizer. In the deposition process, denim fabrics were deposited with 10 multilayer nanoparticle films by using a modified open-width washing machine for continuous process.

Attenuated total reflectance Fourier transform infrared spectroscopy (FTIR–ATR), Scanning electron microscopy (SEM-EDX) and X-ray photoelectron spectroscopy (XPS) measurements were used to verify the presence of the deposited nanolayers. Air permeability, color difference values, washing fastness and tensile strength analyses were performed to examine the LbL process effect on the cotton textile fabric properties. The LbL deposited nanolayers properties were analyzed after different washing process: pumice, enzyme, domestic and pumice + enzyme washing process.

3 RESULTS AND DISCUSSION

The results of the XPS analysis were used to examine the nanofilm deposition process and durability after different washing process on the denim fabrics are shown in Fig. 1. For the survey scan XPS spectrum of nanoparticle multilayer deposited denim fabrics, the distinctive peaks at 283.95, 530.11 and 460.13 eV indicate the presence of carbon, oxygen and titanium elements, respectively. After the different washing processes, the titanium peaks shows decreases especially with the enzyme-pumice process.

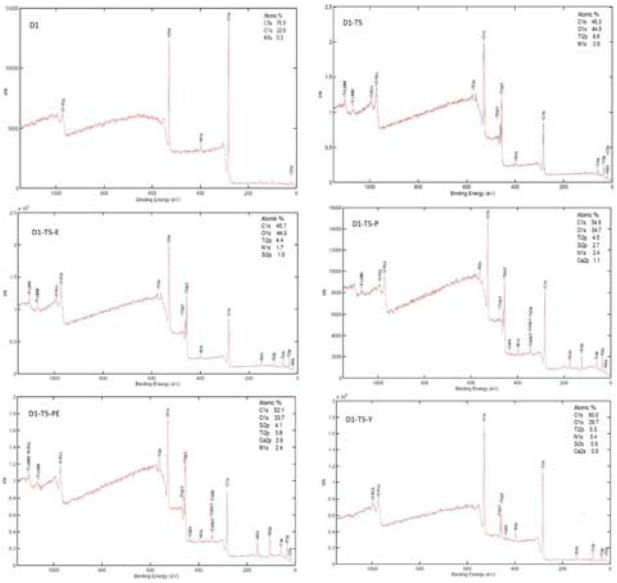


Figure 1 XPS test results

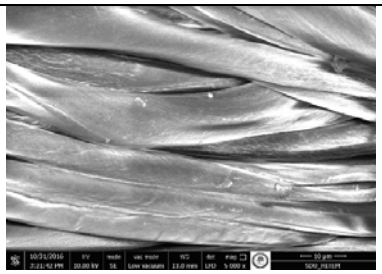
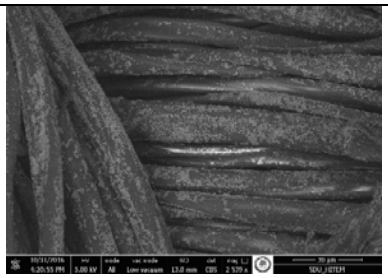
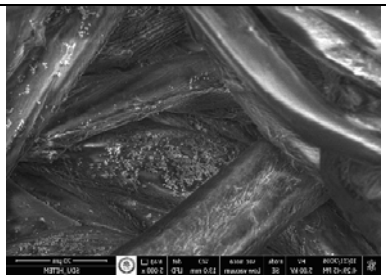
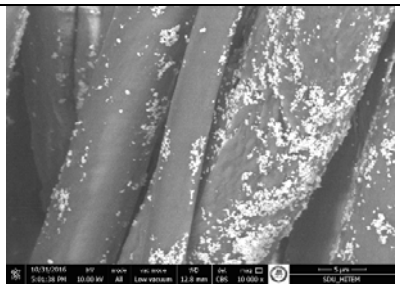
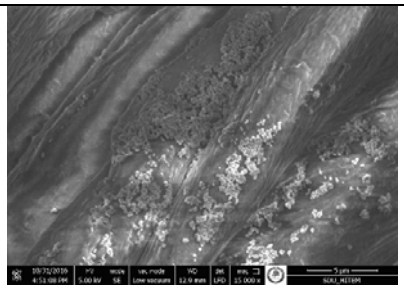
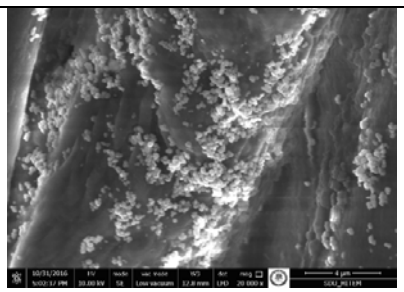
Denim	SEM
D1	
D1-T5	
D1-T5-E	
D1-T5-P	
D1-T5-EP	
D1-T5-Y	

Figure 2 SEM test results

Scanning electron microscopy was used to verify the presence of the deposited nanolayers on multilayer nanoparticle deposited denim fabrics. TiO_2 nanoparticles can be clearly seen on the fiber surfaces in the Figure 2 as D1-T5. The crystalline phase of anatase TiO_2 remained unchanged in the resultant TiO_2 film coated cotton fibers. With different washing processes Titanium element content decreases.

4 CONCLUSSION

This study shows that continuous nanofilm deposition process can be used for denim fabrics surface coatings. Different washing processes effects on the nanofilms and denim fabrics tensile strength properties evaluated. There are substantial differences on the mechanical properties of nanofilm coated denim fabrics after different washing process.

***ACKNOWLEDGEMENT**: The authors gratefully acknowledge the funding by Ministry of Science, Industry and Technology (Republic of TURKEY) project number 0645.STZ.2014. Project partner firms is GAP Textile, Calık Denim Group.*

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DEVELOPMENT OF A NOVEL DELIVERY SYSTEM USING GRAPHENE SUPPORTED NANOFIBERS FOR CONTROLLED TRANSDERMAL RELEASE OF TESTOSTERONE

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Abstract: Testosterone is a hormone which is responsible for many of the physical characteristics specific to adult males. It plays a key role in reproduction and the maintenance of bone and muscle strength. There are many studies regarding controlled release of testosterone alike agents have been issued upto now, but none of them defined a thorough method and product*. In this study, we propose a novel method and product- a composite patch- combining electrospun nanofibers, graphene and transdermal release for controlled testosterone release not only for adult people but also young people who needs this medication.*

Keywords: *testosterone, controlled drug delivery, transdermal release, graphene, nanofibers*

1 INTRODUCTION

Testosterone is a hormone which is responsible for many of the physical characteristics specific to adult males. It plays a key role in reproduction and the maintenance of bone and muscle strength. Recently, its controlled release and administration have become an area of interest [1,2]. In last decade, drug delivery has become an area of interest due to negative effect of traditional medication techniques which may result in numerous side effects on human health stem from uncontrolled dose administration. Drug administration easing controlled delivery systems such as transdermal release enable reaching treatment goals by increasing compatibility of the patient to the medication. From oral controlled drug delivery to oral controlled drug delivery and nano-pharmaceuticals, more than 15 types of drug delivery systems have been issued up to now [3]. Of all methods that have been issued, the methods combining nanotechnology-in our case nanofibers- and transdermal release are of interest and most commonly preferred method for controlled drug delivery [4]. Nanofibers are fibrous materials having enormous surface area (a football stadium wide area on a pinhead size material) and a tremendous length to diameter ratio (10^{-9} m). Electrospinning has been widely used in the production of nanofibers [5]. Graphene is a highly technological and functional materials having high Young's modulus, high fracture strength excellent thermal and electrical conductivity fast mobility of charge carriers large surface area biocompatibility. These ultra properties boost the sustainability and efficiency of the drug delivery and makes graphene an ideal candidate for transdermal testosterone release [6].
In this study, we propose a novel method and product- a composite patch- combining electrospun nanofibers, graphene and transdermal release for controlled testosterone release not only for adult people but also young people who needs this medication.

2 MATERIALS AND METHODS

In order to develop testosterone loaded graphene/PEO composite nanofibers, PEO polymer having a molecular weight of 1000.000 (PEO 1000.000 Mw) was purchased from Sigma–Aldrich Company. Grpahene was synthesized using CVD and Hummers method in our own laboratory. PEO solution with a concentration of 3 wt% from PEO 1000.000 Mw was prepared for processing in electrospinning for mixing with different ingredients within experimental process further.

2.1 Electrospinning

Electrospinning was carried out using distance positioning apparatus. The distance between collector plate and needle tip was set as 12 cm. Electrospinning was carried out using basic electrospinning apparatus (Figure 1) at 18 kV power, 11 mL/h feeding rate 6 h duration.

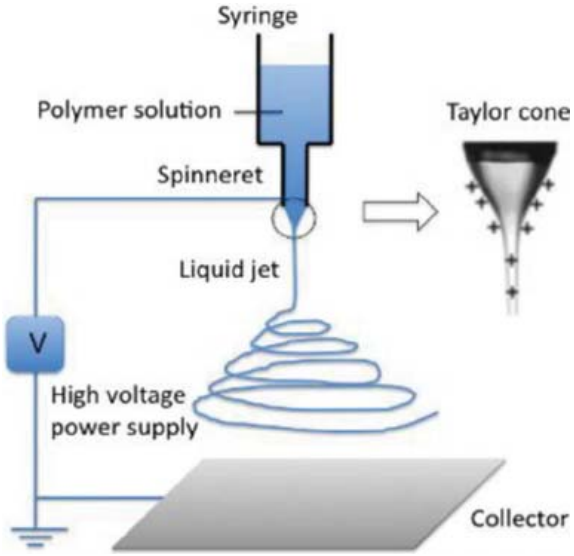

Figure 1. Electrospinning setup

2.2. Characterization

Morphologies, alignment, and fibrous structure of nanofibers will be characterized using a SEM (LEO 440, Technical Sales Solutions, Beaverton, OR, USA). In vitro and in vivo biodistribution study using experimental animals will be carried out for transdermal release characterization.

3 RESULTS AND DISCUSSION

In the first step of production, composite nanofibers containing graphene doped PEO polymer were simultaneously collected on collector plate. The morphology of the obtained nanofibers observed as a regular nanofibrous structure. 5 replications to production were applied and we have obtained the same results.

4 CONCLUSION

Nanofibers obtained within this study have been found to have a regular morphology which is promising for transdermal release applications of testosterone for adult and young people.

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POSTERS

KNIT FABRIC MERCERIZATION BY USING HIGH CONCENTRATION NAOH IN SCOURING AND BLEACHING BATH IN EXHAUSTION METHOD

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Abstract: *Single jersey cotton knitted fabrics are scoured and bleached using high concentration NaOH in order to attaining the effects of mercerization in a solitary process which can be referred to as combined scouring, bleaching and mercerizing process. The aforementioned combined processed fabric's surface morphology, fine structure, barium activity number, bursting strength, K/S value of dyed fabric were scrutinized. These properties are compared with the properties of a regular scoured and bleached fabric and a separately bleached fabric to manifest the potency of the process. Fabric treated with new combined process can be characterized by smoother, lustrous surface than the typical scoured and bleached fabric and almost same as separately mercerized fabric. It exhibits decrease in crystallinity and conversion of crystalline phase from cellulose I to cellulose II in similar manner to the separately mercerized fabric. Barium activity number, bursting strength and improvement of K/S value are also in line with the separately mercerized fabric. Above mentioned properties of combined scoured, bleached and mercerized fabric well evident the effectiveness of the process.*

Keywords: *Mercerization, surface morphology, XRD, barium activity number, crystallinity, bursting strength.*

1 INTRODUCTION

Mercerization is the most well-known method to enhance physical and dyeing properties of cotton fiber. It changes the surface morphology, fine structure i.e. crystallinity, crystallite size etc. of cotton fiber [1, 2]. It converts the cellulose chain from cellulose I to cellulose II [3, 4]. A significant improvement in dye affinity, color strength, luster, tensile strength, smoothness of cotton fabric also occurred due to mercerization [1, 5]. Knit fabric mercerization was considered to impracticable because of the stretching during mercerizing . Development of slack mercerization solves many problems of knit fabric mercerization. Now high temperature mercerization is well established [6]. In exhaustion method of fabric dyeing, the fabric is prepared by combined scouring and bleaching using NaOH, H_2O_2 and auxiliaries. From the compatibility chart of dyes and chemicals, it has been found that NaOH is very much compatible with H_2O_2. This work is the combination of slack mercerization, high temperature mercerization.

2 METHODOLOGY

Three single jersey knit fabrics of same construction are prepared. The first one is prepared by only scouring and bleaching in a sample winch machine (Dilmenler, HTHP, Turkiye) by using 0.6 g/l detergent, 0.5 g/l sequestering agent, 0.5 g/l anti-creasing agent, 2 g/l NaOH, 3 g/l H_2O_2 and 0.4 g/l stabilizer. Preparation of second samples same as the first one followed by mercerization at room temperature using 20% NaOH. The final one is also prepared in the same machine by keeping all the processing parameter same as previous except the concentration of NaOH. To bring out the effect of mercerization 16g/l NaOH was used during scouring and bleaching which is referred to as combined scouring, bleaching and mercerizing in this work. SEM, XRD, barium activity number, bursting strength of all samples are tested. All three fabrics were connected together and dyed with vinylsulfone reactive dye in exhaustion method in the same bath. For achieving precision in result, dyeing was done with three shade percentage i.e., 1%, 3% and 5% and then K/S value was measured.

3 RESULT AND DISCUSSION

3.1 Change in surface morphology

Figure 1, **Figure *2*** and **Figure *3*** clearly represent that fiber become round like structure, smoother and the natural deep wrinkles from the surface removed significantly for the separately mercerized fabric and the newly processed fabric as compared to the only scoured and bleached fabric.

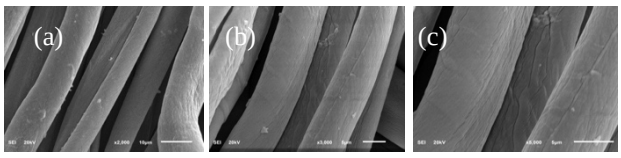

Figure 1 SEM image of conventional scoured and bleached fabric (a) 2000X (b) 3000X (c) 5000X

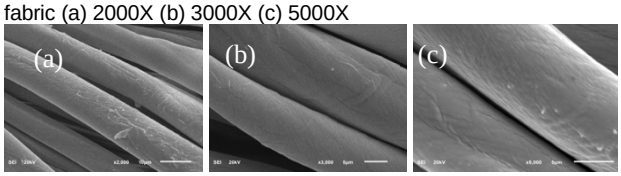

Figure 2 SEM image of conventional scoured and bleached and separately mercerized fabric (a) 2000X (b) 3000X (c) 5000X

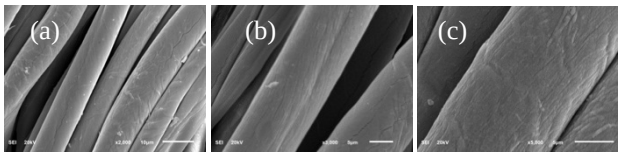

Figure 3 SEM image of combined scoured, bleached and mercerized fabric (a) 2000X (b) 3000X (c) 5000X

3.2 Changes in fine structure

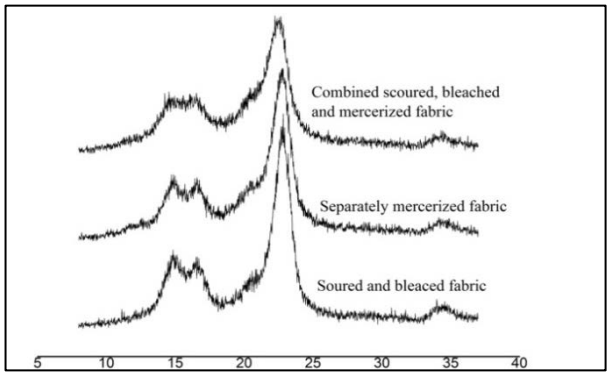

Figure 4 XRD diagrams of three different fabrics

Figure 4 represents that in comparison among three samples crystallinity of two mercerized fabrics decrease significantly. Newly processed fabric shows higher decrease in crystallinity than the separately mercerized fabric. Both two mercerized fabrics exhibit crystalline phase of cellulose II. The extent of decrease in crystallinity, conversion of cellulose I to cellulose II strongly evident that the effectiveness of combined scouring, bleaching and mercerizing.

3.3 Barium activity number

The most widely used method to determine the extent of mercerization is the barium activity number. **Table 1** shows the barium activity number of both two mercerized fabrics. In comparison between two mercerized fabrics combined scouring, bleaching and mercerizing gives lower value of barium activity number.

Table 1 Barium activity number of two mercerized fabrics

Fabric type	Barium activity number
Scoured and bleached and separately mercerized	155
Combined scoured, bleached and mercerized	141.5

3.4 Bursting strength

Table 2 displays the bursting strength of differently treated fabric. The bursting strength of both two mercerized fabrics is higher than the conventional scoured and bleached fabric. The increase in strength can be described by the alleviation of internal stresses and de-twisting of normal ribbon like structure of fiber due to the swelling process.

Table 2 Bursting strength of different fabrics

Fabric type	Bursting strength kg/cm2
Scoured and bleached	10.33
Scoured and bleached and separately mercerized	11.98
Combined scoured, bleached and mercerized	10.68

3.5 Change in color strength

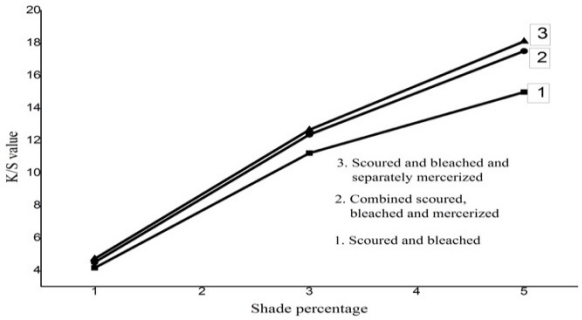

Figure 5 K-S value of different fabrics

Figure 5 shows for all shade percentages, both mercerized fabrics show higher K/S value than the un-mercerized fabric. This is due to the crystallinity. As the crystallinity of both mercerized fabrics decreased, dyes molecule can easily penetrate into the fiber.

4 CONCLUSION

Cotton single jersey knit fabric was mercerized in a new process called combined scouring, bleaching and mercerizing. Surface morphology, fine structure, barium activity number of both two mercerized fabrics, bursting strength of all three fabrics are investigated. The K/S value of all three fabrics dyed with vinylsulfone reactive dyes in different concentration is also measured. Outcomes scrutinized the effectiveness of the process.

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SPINNING OF PINEAPPLE LEAF FIBRE THROUGH COTTON SPINNING SYSTEM BY SOLO AND BINARY BLENDING AND COMPARISON OF YARN PROPERTIES

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Abstract: *Pineapple leaf fiber (PALF) is a white, smooth and lustrous natural cellulosic fiber extracted from pineapple leaves. Solo and blended spinning of pineapple leaf fiber by cotton spinning technique and comparison of the properties of produced yarn have been reported in this study. As a part of study the fibers were cut into short staple length and different properties of fibers are scrutinized. Outcomes proved that the fibers have excellent spin ability. Two separate approaches have been taken into consideration to produce resultant yarn through spinning of pineapple leaf fiber (PALF). Yarn from solo spinning with 100% PALF and blending of PALF with cotton fiber and polyester fiber through binary blending system in equal proportion has been spun. Yarn count, tensile properties, yarn evenness, hairiness have been investigated and analyzed. The results from numerical simulations analysis indicates that, yarn obtained from the Pineapple leaf fiber (PALF) has great potentiality to be used in clothing.*

Keywords: *Cellulosic fiber, cotton spinning system, spin ability, tensile strength, evenness, hairiness.*

1 INTRODUCTION

Cellulose fiber has become a trend in the development of textile. Pineapple leaf fiber (PALF) is a natural cellulosic fiber collected from pineapple leaves. Every year tones of PALF are being produced but very small portions are being used[1]. Pineapple leaf fiber are collected from the pineapple leaves either by scrapping, retting, or decortications and used for significant purposes without any additional input cost[2]. PALF is white, creamy and lustrous fiber. Various investigations show that pineapple leaf fiber is mainly composed of cellulose, hemicellulose, lignin, wax, pectin, inorganic and so on, the cellulose content of 56% - 82%. PALF contributed with excellent mechanical properties compared to other natural fibers. It has high specific strength and stiffness and it is hydrophilic in nature due to high cellulose content. In addition, these fibers can easily retain dyes. The crystallinity and preferred orientation of crystallites in pineapple fibers are high and the average fracture strength of the pineapple leaf fiber is high and the linear density is low, so there is a high fiber spin ability and yarn quality. Until now, there is no special spinning system have been designated for PALF spinning system[3]. Nowadays PALF are spun into yarns using existing fibers spinning system including jute spinning system, semi-worsted and flax system by binary or multi blending[3]. However, the PALF yarns produced still coarse and still not in line with cotton yarns properties[3]. In this work the fiber was prepared to spin into cotton spinning system by cutting extracted and pretreated fiber according to its effective length and then yarn is made from the fiber, although the various table text styles are provided.

2 MATERIALS AND METHODS

Extracted and pretreated PALF fibers were cut into staple length and different properties of fiber i.e. fiber length, fiber morphology, tensile properties are examined. Then fibers were blended with cotton in equal proportion (50% PALF+50% cotton) followed by blended with polyester in equal proportion (50% PALF+50% polyester). Then yarns were produced from both aforementioned blended fibers. Another yarn also produced from 100% PALF fiber. Laboratory scale opening, carding, drawing, simplex and ringframe were used to manufacture all the yarns. The characteristics of all the yarns i.e. yarn count, evenness, hairiness were studied by using testing equipment in Wuhan Textile University and a comparison among them are made.

3 RESULT AND DISCUSSION

3.1 Morphological structures of fiber

SEM image of the surface of PALF fiber depicted at Figure 1, shows that it exhibits polygonal cross section, has no skin structure and very irregular in shape. The longitudinal view of surface represents that fibers are possessed with many obvious grooves. Consequently, PALF shows excellent cohesion in yarn.

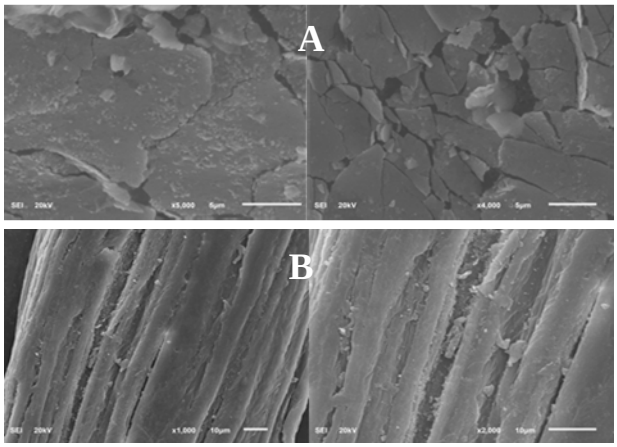

Figure 1 Cross sectional (A) and longitudinal (B) view of PALF

Table 1 Tensile properties of pine apple leaf fiber

	Breaking strength cN	Breaking strength | cN /dTex	Elongation at break mm	Elongation at break |%	Breaking work | cN * mm	Breaking time | s	Yield strength | cN	Yield elongation | mm	Initial modulus | cN / dTex
Average value	44.01	4.40	0.77	3.85	15.774	2.31	10.813	0.264	76.714
Maximum value	114.79	11.48	1.36	6.81	60.95	4.08	51.31	0.81	179.8
Minimum value	11.42	1.14	0.38	1.88	2.33	1.13	1.12	0.01	17.32
CV%	47.37	47.37	30.67	30.67	70.93	30.64	100.805	69.68	51.54

3.2 Tensile properties of fiber

Tensile properties of PALF is summarized in the Table 1 exerts that PALF has excellent tensile properties compared to most of the natural fibers. All these properties strongly evidence the spin ability of PALF to manufacture yarn.

3.3 Tensile properties of yarn

Table 2 illustrates that among the three yarns, PALF-Polyester blended yarn (50% PALF+50% Polyester) shows higher tensile properties than the others. This can be explained by the higher strength of polyester. Though PALF possessed excellent tensile properties, the yarn produced from the 100% PALF shows lower mechanical properties compared two other two yarns. This is due to the less number of fibers, more specifically less surface area in the cross section of the yarn.

Table 2 Tensile properties of all types of yarn

Yarn type	Yarn count (Ne)	Average breaking force (cN)	Average elongation %	Average breaking time (s)	Average tenacity (cN/tex)
100 % PALF	10	479	5.78	4.23	9.39
50%PALF +50% Cotton	10	587	6.1	4.68	10.13
50% PALF +50% Polyester	10	798	11.28	6.83	13.85

3.4 Yarn evenness

Table 3 Evenness of different types of yarn

	100% PALF	50% PALF+50% cotton	50% PALF+50% polyester
Uniformity U %	27.9	29.18	28.598
CVm %	33.78	38.449	39.343
Thin place -30%	10890	15255.9	12698.3
Thin place -50%	4126	5701.9	4502.8
Thick place +35%	5998	6842.4	6312.3
Thick place +50%	3453	5195.4	3952.9
Neps +200%	5121	5758	5236.6

Table 3 represents that in comparison to all three types of yarn, yarn produced from 100% PALF shows higher evenness. This can be explained by fiber fineness. The diameter of the PALF is higher than the cotton and polyester. Moreover, the fiber was processed with laboratory scale machinery and precision in mixing was not in expected level. Furthermore, PALF fibers were possessed near about same characteristics thus produced more uniform yarn than the blended yarn.

3.5 Yarn Hairiness

Figure 2 shows that100% PALF contained yarn shows excellent properties in terms of hairiness. This is due to the presence of less amount of short fiber.

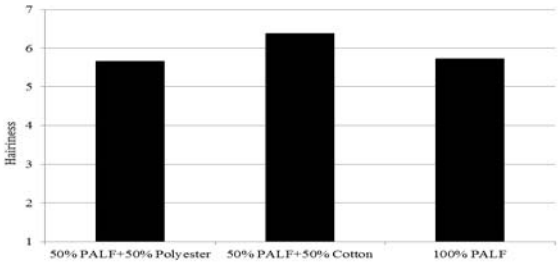

Figure 2 Hairiness of different yarns

4 CONCLUSION

All the yarns show excellent tensile properties but yarn evenness is poor compared to other solo staple fibers yarn of same count. But precision in evenness can be achieved by effective pretreatment and by slight modification of spinning technology. By effective modification, PALF can be used as a source of clothing.

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ELECTRONIC TEXTILE FOR MOTORCYCLIST CLOTHING

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Abstract: *In recent years, motorcycling is become more and more popular. It is known that even in relatively warm weather, moving air is cooler and constant exposure to wind when riding may cause a chilling effect that leads to hypothermia. Hypothermia is a subnormal body temperature that can cause loss of concentration, slowed reactions, loss of smooth and precise muscle movement. Motorcyclist may lose ability to concentrate and react to changing traffic conditions. We propose the using of electric heating elements in the suit for increasing comfort for motorcyclist. The results of this investigation confirmed the effectiveness of electric heating element in motorcyclist suits.*

Keywords: *hypothermia, motorcyclist clothing, e-textile, thermal properties.*

1 INTRODUCTION

Today there is known a wide variety of clothing design for motorcyclists, which depends on the type and style of motorcycle (for a certain kind of sports or used in everyday life). Clothing for motorcyclists is classified into 3 groups:

1. Non protective (clothing that creates a barrier to weather conditions: wind, rain, snow, etc.);
2. Non protective but clothing are equipped with protectors marked CE on shoulder, knee, back or cubits;
3. Protective (clothing with increased protection by the use of plastic protectors, connected to each other).

There are some basic requirements put forward to the clothing of motorcyclists. First of all clothing should be reliable, due to the increase of human traumatism during competitions, accidents and falls. At present, the requirements of reliability provided by the protective inserts and technological elements of clothing (silhouette, shape, cut) [1, 2]. Satisfaction aesthetic and ergonomic requirements are also important. Improving the aesthetic requirements to clothing may be provided by the use of reflective materials and elements, which are also informed of the motorcyclist's presence on the road in the dark. Improving the ergonomic requirements, especially in cold weather, should be directed to the exclusion of hypothermia motorcyclists. Thus, an increase thermal property of the clothing for motorcyclists by the use of various materials, including e-textile is important. We propose alternative methods of increasing the thermal properties of motorcyclists clothing – the use of electric heated elements in the suit. It is so-called e-textiles – is the integrating electronics into textiles.

2 EXPERIMENTAL PART

The paper deals with clothing for motorcyclists of first group – "non protective". It was selected the textiles which are used for clothing in this group. Characteristics of textiles are shown in Table 1.

In Ukraine assortment of jackets for motorcyclists with a warming lining does not allow provide comfortable conditions that satisfy ergonomic requirements. We propose to use a heating element. The heating is carried out by connecting this element to the power supply system of the motorcycle. This element is located inside the lining fabric and made of nichrome wire. Scheme and connection of the heating element to the motorcycle are shown in Fig. 1 and Fig. 2.

Table 1 Structural performance of textiles

Article number	Raw composition, %	Surface density, g/m2
Top fabric		
45103	PES – 100	130
100596	PES – 100	215
Lining fabric		
32115	PES – 100	92

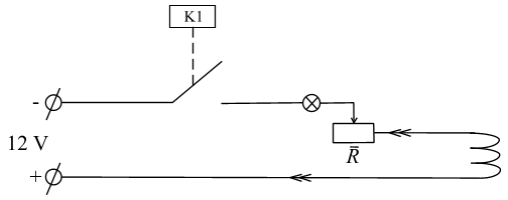

Figure 1 Connective scheme of the heating element to the motorcycle

Figure 2 Connection of the heating element to the motorcycle

Two types of packages that differ of top fabrics were investigated:

- package №1 – 45103 + 32115 + heating element + 32115;
- package №2 – 100596 + 32115 + heating element + 32115.

It was investigated the temperature in the space under clothing. Study was carried out under real conditions: at night, on a motorcycle Yamaha YZF-R6 on the road with asphalt covering. Driving speed was varied from 10 to 60

km/h (range - 10 km/h). Air temperature ranged from 10 to 20 ± 2°C with an interval of 5°C, wind speed ranged from 0 to 4 m/s. The temperature was measured by a digital thermometer WSD-10.

3 RESULTS AND DISCUSSION

It was selected for studies the input data: air temperature (T_{air}, ^{0}C), the wind speed (v_{wind}, m/s), the air humidity (W,%). The studies were carried out in three variants by different climatic conditions (Table 2).

Table 2 Dynamic of temperature changing in the space under the clothes (package №2)

Variant of investigation	Characteristic of environmental conditions	Driving speed, km/h	Temperature in the space under the clothes, T_{sp}, ^{0}C	
			Heating element "off"	***Heating element "in"***
1	T_{air} = 10±2^{0}C; v_{wind} = 4 м/s; W =94%	0	27,4	48,2
		10	26,3	46,2
		20	25,8	43,8
		30	24,6	42,0
		40	24,0	41,6
		50	23,6	40,2
		60*	24,1	41,9
2	T_{air} = 15±2^{0}C; v_{wind} = 2 м/s; W =80-88%	0	28,8	48,7
		10	27,1	47,8
		20	26,1	44,6
		30	25,6	42,8
		40	25,2	42,2
		50	24,8	40,9
		60*	25,2	42,0
3	T_{air} = 20±2^{0}C; v_{wind} = 3 м/s; W = 53%	0	30,6	49,0
		10	29,0	47,9
		20	28,2	46,6
		30	27,6	44,8
		40	26,5	44,1
		50	26,0	43,2
		60*	26,3	44,8

* 60 km/h – is the speed maximum for moving in Ukraine through cities and villages

Analysis of the results showed that the temperature changing in the space under the clothing is the similar for all variants. With speed increasing to 60 km/h temperature in the space under the clothes is reduced about 3,5 – 5,0 ^{0}C. However, the using of the heating element allows to maintain the temperature under the clothing in the range 41 – 45 ^{0}C, thus excluding hypothermia. The temperature in the space under the clothing where heating element is switch off is about 20 ^{0}C – it is not comfortable conditions.

The disadvantages of these studies are in the complexity of the temperature determining by movement at speeds above 60 km/h, and the absence of control system of the heating element. This system has to control more accurately and regulate temperature in the space under the clothing.

4 CONCLUSION

Our results indicate on effectiveness of using electric heating element for increasing the thermal insulation properties of motorcyclist clothing. The heating system has to include the control system for control the temperature in the space under the clothing.

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LIQUID MOISTURE TRANSPORT PERFORMANCE OF TEXTILES

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Abstract: *The main purpose of this study was the selection of the textiles for using as layers in multilayer textile composite with predicted liquid moisture transport properties. In this paper are the results of studies the influence of fabrics structure and its raw composition on the liquid moisture transport performance of textiles. Moisture management property of the textiles was examined using MMT instrument.*

Keywords: *textiles, multilayer textiles, liquid moisture transfer.*

1 INTRODUCTION

The multilayer textile composites can be obtained by bonding the individual textiles in one multilayer structure. Such composites consist of textiles with various functional properties of different structure and different fibrous composition.

The aim of our work is to design of multilayer textile composites with predicted liquid moisture transport properties: quick absorbing of moisture, its quick transport, distribution and reliable accumulating in textile composite volume. At the same time these liquids does not have to penetrate in external environment. Some test methods are known to measure liquid water absorbency and water vapor transport in textiles. These methods are characterized different aspects of moisture management characteristics, namely, diffusion ability, wicking, water vapor permeability, drying time etc. However, the other methods are unable to measure the behavior of dynamic liquid transfer in to textiles.

In this work the liquid moisture transport properties were characterized by using the Moisture Management Tester (MMT). The method can be used to measure quantitatively liquid moisture transfer in one step in a fabric in multidirections, where liquid moisture spreads on both surfaces of the fabric and transfers from one surface to the opposite [1].

2 EXPERIMENTAL PART

It was investigated 6 types of textiles which differ by structures, compositions and physical properties (Table 1).

Table 1 Structural performance of textiles

Property	Sample code					
	S	***Pq***	***E***	***A***	***L***	***BA***
Type of textile	knitted fabric				woven fabric	
Fiber type, %	PP-100	Cotton-100	Viscose-100	PP-40 Cotton-60	PES-100	PES-100
Surface density, g/m^2	95	207	330	183	160	180
Thickness, mm	0,7	0,8	0,8	1,6	0,3	0,3

Moisture Management Tester (MMT) (SDL Atlas), was chosen as testing equipment for its dynamic wicking process visualizations. Ten moisture management indexes can be used to characterize the moisture management properties of textile (Table 2).

Table 2 Liquid moisture transport performance of textiles

Properties		Fabrics sample code					
		S	***Pq***	***E***	***A***	***L***	***BA***
Wetting Time, sec	T*	5,2	22,7	9,1	3,4	6,6	-
	B*	5,2	11,6	9,3	119,9	6,8	-
Absorption Rate, %/sec	T*	59,7	26,3	57,6	43,9	60,2	-
	B*	64,8	44,6	64,7	0,0	72,9	-
Max Wetted Radius, mm	T*	21,7	13,3	13,3	25, 0	25,0	-
	B*	21,7	15,0	13,3	0,0	28,3	-
Spreading Speed, mm/sec	T*	3,2	0,6	1,3	4,2	4,3	-
	B*	3,3	0,8	1,3	0,0	4,4	-
One-Way Transport Capability, %		55	257	78	-649	108	-
Overall Moisture Management Capability		0,46	0,44	0,32	0,00	0,56	-

* T- top; B - Bottom

3 CONCLUSION

Based on values of these indexes, the textiles are classified into categories:

- water proof fabric – “BA”;
- slow absorbing and slow drying fabric – “A”;
- fast absorbing and slow drying fabric – “E”, “”;
- fast absorbing and quick drying fabric – “S”, “Pq”, “L”.

Presented above classification is given the opportunity to design multilayer textile composites with predicted liquid moisture transport properties. The requirements to textile composite dictate the order of initial textiles arrangement in multilayer structure: the first layer have to provide quick absorption and quick transport of water; the next layers must have good liquid distribution ability on layer surface and liquid accumulation and the last one have to serve as good barrier against liquid penetration. According these data for future investigation were designed two types of textile composites: (S+A+E+L+BA) and (S+ L+A+E+ BA).

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THE USE OF 3D GEOMETRIC MODELS IN SPECIAL PURPOSE KNITWEAR DESIGN AND PREDICTING OF ITS PROPERTIES

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Abstract: *The article deals with the issues of predicting special purpose knitted fabrics properties. We suggest solving this problem by designing a 3D geometric model of a knitwear structure. The proposed technique has been used to design a 3D model of a double-layered knitwear structure, which is used for ballistic protective clothing manufacturing*

Keywords: *3D modeling, weft-knitting, loop length, B-spline, knitted structure, yarn central line geometry, special purpose knitted fabrics, personal protective equipment, armor protection.*

INTRODUCTION

The special purpose knitted fabrics for personal protective equipment have to meet a number of requirements for physical, mechanical, hygienic and other properties, as they are subjected to various types of force application during wear. They are made of high tenacity threads and are used to protect users against the following risks: effects of small arms projectiles; effects of shrapnel from explosives; effects of stabbing and cutting weapons. Clarifying the relationship between threads characteristics and their configurations in an interlooping structure on the one hand and protective properties of fabrics on the other hand is a difficult task which demands a special approach and accuracy [1, 2].

Designing of a special purpose knitted fabrics is concerned with choosing the optimal physical-mechanical and geometric characteristics. In this project we have discovered the ways to solve the problem of properties optimization of personal protective equipment based on the analysis of the characteristics of the input materials by using universal computer simulation systems. Such systems perform the analysis of physic-mechanical objects under investigation on the basis of their 3D geometric models. Therefore, one of the crucial points for an imitation research of the reliability of individual armor protection products that are made of high tensile strength knitwear is the adequacy of the mathematical description of its structure. It is known that BFS depth deformation of knitted fabrics is connected to the redistribution of the yarn in the knitwear structure. Thus, the model, which is used to assess the reliability of armor protection has to coincide with the shape and the loop length of the real prototype.

RESULTS AND DISCUSSION

The task of predicting of the special purposes knitted fabrics properties is proposed to be solved by constructing a 3D geometric model of the knitwear structure. 3D geometric modeling of the knitted fabrics structure requires an exact display of the configuration of the axial line of the yarn in its structural elements [3,4]. To describe the configuration of the yarn central line in the loop of the plain-knitted structure the authors have used the mathematic theory of B-spline construction. In the model, the length of the spatial curve varies with the change of the inclination angle of the tangent at the interlacing point as an independent variable. This makes the model flexible and feasible for use in 3D modeling systems where the loop length of the virtual knit pattern must coincide with the loop length of the real prototype. The suggested technique is realized at constructing of a 3D model of the structure of double-layer knitwear made of high tenacity polyester yarn. We have generated the models of the knitted fabrics structures by using software which was developed by us [5].

On fig. 1 and fig. 2 image of a virtual sample of a plain-knitted structure fragment and a 3D structure of a double-layer knit with tuck connection of layers built by the means of this program is shown [5].

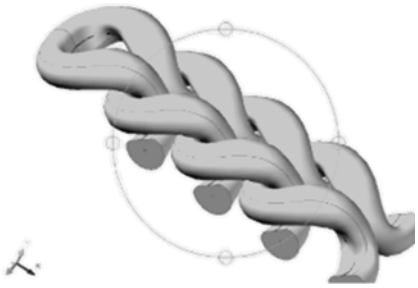

Figure 1 3D geometric model of a plain-knitted structure

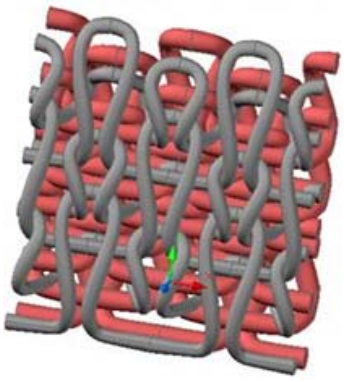

Figure 2 3D geometric model of a weft double-layer knit with tuck connection flayers

When designing special purpose knitwear for fencing clothing manufacturing, virtual models allow us to predict its pressure bearing capacity against multiple impact points caused by a tip of a fencing weapon; to visualize the hits of the blade tip on the stitches and predict their deformation; to design an optimal knitwear structure with the specified physic-mechanical properties [6].
During experimental research we produced the weft knit structure samples made of different raw materials and studied their structure parameters. For each sample we designed a 3D model with geometric parameters that coincide with the real prototype parameters. We defined the angle values at tangent point of a fabric for each sample. Value of an independent angular parameter used as an independent variable γ, changing of it allows getting a spatial curve of a necessary length.

CONCLUSIONS

The results of the conducted researches testify to the high level of conformity of the 3D model, namely, by the parameters of the loop length, course spacing and wale spacing the real parameters of its structure.
Further researches will focus on defining the relation between the independent variable γ and yarn physic-mechanical properties which will allow using the developed technique for predicting the stability of knitwear to various dynamic loads without making a sample on knitting equipment.

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THERMOPHYSIOLOGICAL PROPERTIES OF DRY AND WET FUNCTIONAL SPORTSWEAR MADE OF SYNTHETIC FIBRES

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Abstract: *In recent time knitted fabrics are being increasingly used for sportswear. This type of clothing should insure the thermal comfort regardless of the activity of wearer and in all weather conditions. Among the thermal properties the most important are thermal conductivity and resistance as well as water vapour permeability. Sportswear often is getting wet (sweat, humid environment) which can significantly affect the thermal properties, while most of the testing methods performs measurements only in the dry state. Therefore, in the paper were presented the investigation of thermal properties in dry and wet state of the different kinds of knitted fabrics. The presented researches proved that wet knitwear significant loses thermal comfort. This phenomenon is exacerbated with increasing moisture content of material and depends on the structure and the filling of test materials.*

Keywords: *thermal comfort, knitted sportswear, Alambeta, Permetest, RWVP*

1 INTRODUCTION

Thermal and water vapour resistance as well as thermal contact feeling of common sportswear do not exhibit big differences when measured in dry state. The advantages of functional sportswear appear when it is used under real wearing conditions involving the presence of sweat. Then the parameters of good comfort near the skin can be unbalanced and the well-being of the wearer may be lost. Comfort is defined as “the absence of displeasure or discomfort” or “a neutral state compared to the more active state of pleasure” [1]. There is general agreement that the transfer of heat, moisture and air through the fabric are the major factors of thermal comfort. Many authors have pointed out that the major factors influencing heat transfer through a fabric are the thickness and enclosed air [2-3]. Contrary to a commonly accepted theories garments, due to sweat sorption or because of humid, rainy climate are often used in wet state, which has influence on their comfort properties [4-6]. In the case of sportswear, this is a very important issue, as it not only results in getting worse sports results but also can cause health problems and in extreme situations even the sportsman’s life

2 EXPERIMENTAL MATERIALS, METHODOLOGY AND DEVICES

The tested samples were special knitted underwear for various sports and consisted of the polyester, polyamide and polyurethane fibres. Their characteristics were given in Table 1. They were measured in a laboratory with the temperature of 21-23ºC and 50-55% relative humidity.
As a measuring device to determine thermal properties Alambeta apparatus has been used while to determine water vapour permeability Permetest device has been used. The measurements took only a few minutes, which ensured reliable results for the wet fabric, as the sample's moisture during the measurement remains almost constant level.

Table 1 Table type styles

No	Raw material	Struc.	Weight, g/m^2	Thick., mm	Application
1	87%PES/ 13%PU	Plain	335	1,09	underwear insulation layer
2	90%PES/ 10%PU	Plain	205	0,81	underwear insulation layer
3	81%PES/ 19%PU	Plain	155	0,59	underwear
4	75%PES/ 25%PU	Plain	140	0,67	underwear
5	42%PA/ 42%PES/ 16%PU	Plain	115	0,35	underwear

The simplified mathematical model for thermal conductivity (λ) includes just conductivity of fabric and water. In this model, the space filled by air will be replaced by water. Total thermal resistance is of single layer wet fabrics is believed to be a parallel link of thermal resistance of textile (R_T) and thermal resistance of water (R_w), due to presence of continuing water-filled channels between the fabric surfaces. Considering the dry fabric mass (and surface) as 1 (100%) and the moisture content U lower than 1 (<100%), simplest thermal model could be following:

$$\lambda_{RES} = (\lambda_d + U\lambda_W)/(1+U) \quad (1)$$

Thermal resistance (R) depends on fabric thickness (h) and thermal conductivity (λ):

$$R = \frac{h}{\lambda} \quad (2)$$

3 EXPERIMENTAL RESULTS

The examples of research results are displayed on Fig.1 to 4. From the graphs follows, that in the dry state the knitted sportswear characterised different value of

thermal resistance (r, Km^2W^{-1}) depending on weigh. This tendency decreases as the weight and thickness of tested samples decrease. Based on results in wet state can be concluded that together with increasing of moisture percentage in the fabric the thermal resistance (r) significantly decreased. Regards as the water vapour permeability all knitwear tested in dry state characterised good level of relative water vapour permeability (RWVP, %) and proper absolute water vapour permeability (AWVP, $Pa*m^2W^{-1}$). The ability to water vapour permeability is resulted of the composition, structure and weigh of tested samples.

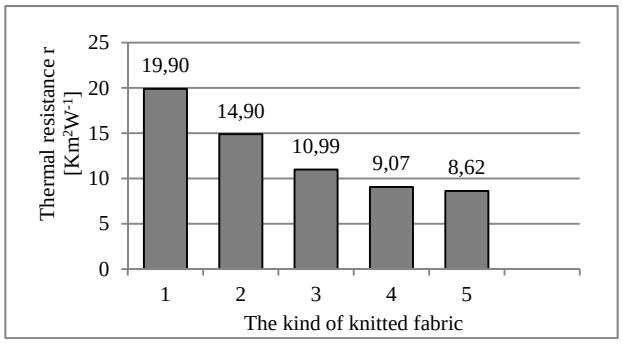

Figure 1 Thermal resistance of knitted sportswear in dry state

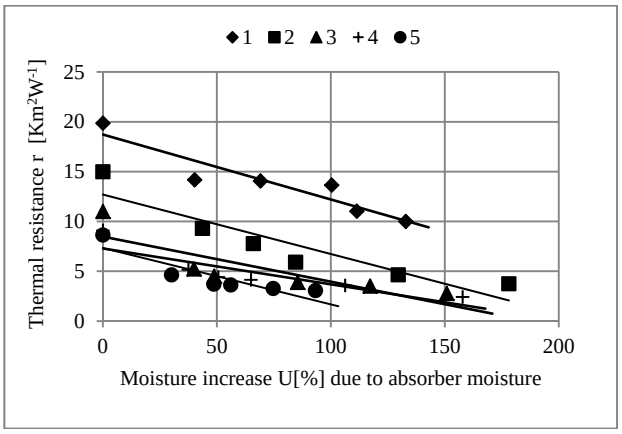

Figure 2 Effect of fabric moisture content on thermal conductivity of knitted sportswear

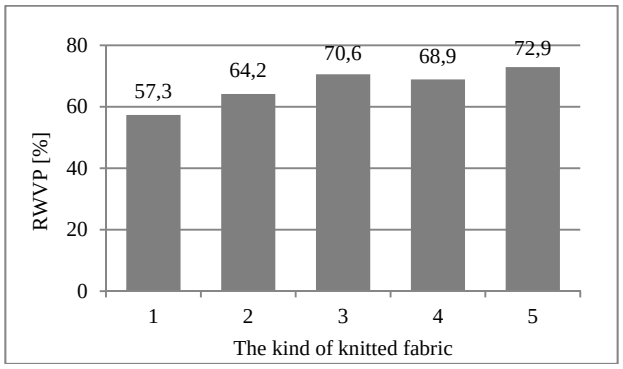

Figure 3 Relative water vapour permeability [%] of the knitted sportswear

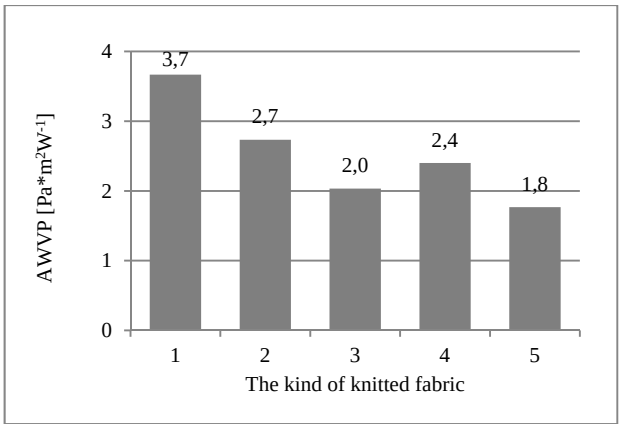

Figure 4 Absolute water vapour permeability [%] of the knitted sportswear

4 CONCLUSION

From the presented research follows, that with increasing moisture content in knitted sportswear significantly worsen their thermal properties and the ability to heat transport. This is caused by substituting of the air in pores by water with higher thermal conductivity. Therefore, the physiological properties of fabrics, which are becoming increasingly wet as a result of use, are subjected to sudden changes, which adversely affects the quality of wearing apparel. Knowledge of these phenomena is very important in aspects of clothing design and technology, especially in case of sportswear protection garment, which are often used in extreme weather conditions with high humidity. The deterioration of thermal properties in this case can highly reduce the performance of athletes, as well as adversely affect their health.

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THE BIO-SCOURING OF COTTON KNITTED FABRIC IN DEPENDANCE OF ENZYME CONCENTRATION

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Abstract: *The enzymatic pre-treatments of cellulose fabrics possesses environmental benefits in comparison with the conventional agents. This paper deals with the bio-scouring of knitted cotton fabric with neutral pectinases varied in concentration in comparison with sodium hydroxide. The influence of enzyme concentration was evaluated through the properties of knitted fabric: degree of polymerization, ash content, hydrophilicity, water retention value and whiteness.*

Keywords: *cotton, knitted fabric, pectinase, degree of polymerization*

1 INTRODUCTION

Raw cotton fibres contain around 95 % of pure cellulose balanced by the non-cellulosic impurities of proteins, oils, waxes, pectins, carbohydrates and inorganic materials that should be removed in pretreatment processes, e.g. desizing, scouring, and bleaching. The enzymatic pre-treatments of cellulose fabrics due to its environmental benefits and special performance became dominant in comparison with the conventional processing of textiles. The use of protease, lipase, pectinase, cutinase and cellulase, individually or in a mixture can replace alkali scouring. Amylase, glucose oxidase and peroxidase enzymes can be used for desizing and bleaching of cotton-like fabrics [1-6]. It was proved that the effects of bioscouring with neutral pectinases proved to be much better than alkali scouring. From the ecological point of view the use of neutral pectinase was of benefit as there was no need for neutralisation of the wastewaters [5].
The paper deals with bio-scouring of cotton knitted fabrics with two concentrations of pectinases due to optimization of process parameters.

2 MATERIAL AND METHODS

2.1 Material

The raw interlock knitted fabric of 100 % cotton, 190 g/m^2, having 26 wales/cm and 28 courses/cm was used.

2.2 Procedures

Prior to scouring, cotton knitted fabric was thoroughly washed in Ahiba Turbomat (Datacolor) with 1 g/l non-ionic surfactant, modified fatty alcohol ethoxylate, Felosan FOX (CHT-Bezema), BR 1:20, at 90 °C through 30 min.
Raw cotton knitted fabric was alkali scoured for 2 h at 98 °C in autoclave (Scholl) by pad roll using 3 % NaOH and 2 g/l of non-ionic surfactant, modified fatty alcohol ethoxylate Felosan NFG (CHT-Bezema), wet pick up 100 %. Afterwards, it was rinsed and neutralised until pH 7 was reached.
Two concentrations of Beisol PRO (CHT-Bezema), commercial enzyme mixture based on pectate lyase, 2 and 4 % (owf), were applied for bio-scouring by exhaustion procedure. The fabric was treated in a bath containing 1 g/l Felosan FOX, at pH 8, BR 1:10 at 55 °C for 20 min. It was rinsed until pH 7 was achieved.
Bleaching with hydrogen peroxide (HP) was performed by exhaustion procedure in Mathis Turbomat (Datacolor) with bath containing: 5 ml/l H_2O_2 (35%), 1 g/l NaOH, 1 g/l of stabilizer, organic chelate forming compounds based on hydroxycarboxylic acids, Contavan GAL (CHT-Bezema), 1 g/l Felosan FOX, 3 ml/l mixture Na_2SiO_3, $Na_2Si_2O_5$; BR 1:20, at 90 °C, 40 min. Labels and treatments are given in Table 1.

Table 1 Labels and treatments

Label	Sample	Treatment
R	Raw	-
A	Alkali scoured	NaOH
E 2	Enzymatic - 2 % owf Beisol PRO	Bio-scouring
E 4	Enzymatic - 4 % owf Beisol PRO	
S	Scoured	Scouring
B	Bleached	HP bleaching

2.3 Methods

Degree of polymerization (DP) was determined according to DIN 54270-2 (1977-08). The ash content (A) was determined according to ASTM D1102 - 84(2013). Degree of whiteness (W_{CIE}) acc. to DIN 6167:1980-1 was calculated from spectral characteristics measured on remission spectrophotometer SF 600 PLUS CT (DataColor). Hydrophilicity was determined according to drop test (AATCC 79-2010) and vertical wicking test (DIN 53924:1997-03). In the vertical wicking test the time allowed for the water front to move 10 cm was measured. Water Retention Value (WRV) was determined according to DIN 53814:1974.

3 RESULTS AND DISCUSSION

The pectin on cellulose fibres is a complex mix of different substances out of pectin, cellulose, protein etc. including Ca, Mg and Fe which forms an interlaced net structure heavy solved in water. It is important to degrade the pectin net structure in order to obtain bio-scoured cotton with a

good hydrophilic effect. A complete degradation is unnecessary because the fragments can be washed out and fats and waxes can be emulsified by non-ionic surfactant. Furthermore, the pectinase has to be inert in the presence of sequestering agents so that they complex the metal ions during the enzymatic degradation out of the pectin structure.

Table 2 Degree of polymerization (DP) and ash content (A [%])

	DP		A [%]	
	S	***B***	***S***	***B***
R	3041.0	-	1.29	-
A	2138.6	1982.4	0.23	0.15
E 2	2911.0	2845.2	0.32	0.31
E 4	2898.1	2847.6	0.31	0.31

From the results shown in tab.2 can be seen that alkali scouring led to damage the cotton cellulose. The level of depolymerisation indicates presence of oxycellulose, what is enhanced in HP bleaching. For the bio-scoured fabrics no significant difference regarding enzyme concentration was noticed. As calcium and magnesium ions are directly connected to the polygalacturonic polymers, the ash either consists of deposits of mineral salts as such, or mineral salts that have undergone certain chemical modifications as a result of calcination. The amount of mineral ash (tab.2) is accurate index of the presence of mineral deposits and can be an indirect measurement of scouring efficiency. In this case it can be seen that alkali scouring again leads to higher efficiency, but the fiber damage should be taken in consideration.
The aim of scouring and bleaching is to achieve hydrophilic and minimal damage cotton fabric of satisfactory whiteness (tab.3-4).

Table 3 Hydrophilicity according to drop and vertical wicking test

	Drop test [s]		Vertical test [s]	
	S	***B***	***S***	***B***
R	-	-	-	-
A	< 1	< 1	209.79	173.48
E 2	< 1	< 1	232.42	176.00
E 4	< 1	< 1	228.72	178.99

Table 4 Water retention value (WRV [%]) and degree of whiteness according CIE (W_{CIE})

	WRV [%]		W_{CIE}	
	S	***B***	***S***	***B***
R	31.7	-	16.2	-
A	28.9	29.3	34.5	64.0
E 2	28.5	29.0	23.3	62.2
E 4	29.6	30.1	23.8	62.1

The impurities elimination was analyzed by hydrophilic behavior of cotton knitted fabrics. It is evident from the results for whiteness (W_{CIE}) that the removal of genetic and added impurities during alkali scouring led to enhanced whiteness. Bio-scouring degraded only the pectine, therefore the whiteness of the bio-scoured cotton is lower. However, the bleaching with HP removed pigments resulting in enhanced whiteness.

The results of the drop test confirmed the hydrophobic nature of raw cotton fabric and the expected better hydrophilicity of the scoured cotton fabrics. There is no difference between alkali and bio-scoured cotton. The results of vertical wicking test, indicate that the bio-scoured cotton fabric has improved hydrophilicity, but still lower than the alkali scoured fabrics. In this case, such high absorbency can be attributed to the fiber damage as well as scouring process, considering the degree of polymerization (DP). Bio-scoured cotton fabric regardless of concentration applied showed excellent hydrophilicity as well. It is less then alkali scoured, but after HP bleaching similar results were achieved. It is to point out that water retention values confirmed better water absorption of bio-scoured samples than alkali one.

4 CONCLUSION

Bio-scouring of cotton fabrics with two concentrations of neutral pectinases, 2 and 4 % owf, were performed and compared to alkali scouring. The chemical damage, ash content, whiteness and hydrophilicity were determined after scouring and bleaching processes.
When considering the chemical damage of the fabrics, the best results were achieved by bio-scouring. When considering the hydrophilicity and whiteness, better effects are achieved by alkali scouring, but it possible that it can be attributed to fiber damage as well. However, after the HP bleaching, obtained results are similar. Considering ecological impact, bioscouring with neutral pectinase proved to be much better than alkali scouring.
Higher applied concentration of enzyme showed slightly better hydrophilicity. Considering optimization of enzymatic process and achieved effects the lower one of 2 % owf is sufficient enough.

Acknowledgement: *The work has been supported by Croatian Science Foundation under the project 9967 Advanced textile materials by targeted surface modification.*

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THE MOLECULAR MASS EFFECT ON MECHANICAL PROPERTIES OF CHITOSAN FIBERS

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Abstract: *Chitosan fibers have been prepared from an acetic-acid solution (2%) by a coagulation method. It was established that optimal concentration of chitosan solution depends on its molecular mass for fibers fabrication. The influence of molecular mass value on mechanical properties of chitosan fibers has been studied. Fibers of the best mechanical properties have been obtained with 210 kDa chitosan sample, whose fibers have a strength 188 MPa and Young modulus 11,5 GPa.*

Keywords: *chitosan, fibers, wet spinning, mechanical properties*

1 INTRODUCTION

Chitosan, a derivative of the natural polysaccharide chitin, has a biocompatibility, biodegradability, bactericidal activity, and high sorption characteristics. Due to such properties chitosan based materials find a lot of applications in pharmacology and medicine. Recently, fibers, films and porous block materials have been applied as matrices for cellular technologies, tissue engineering and transplantology [1-4].

1.1 AIM OF THE WORK

The works [5, 6] describe the methods for obtaining fibers from chitosan, as well as the results of studying the structure and mechanical properties. Studies of the resorption of chitosan fibers in vivo are presented in the work [7]. At the same time, there is practically no information on the effect of the characteristics of chitosan macromolecules, primarily molecular weight, on the process of spinning fibers and their properties. Therefore, the aim of the work was to study the influence of the molecular weight of chitosan on the features of the spinning process and strength and elastic characteristics of fibers.

1.2 MATERIALS AND METHODS

Chitosan samples of similar deacetylation degree were used for processing the fibers. The characteristics of polymers are given in Table 1.
Molecular mass M_{SD} of chitosan samples were determined by an absolute method based on sedimentation and diffusion analysis in their dilute solutions in 0.33 M CH_3COOH+0.2M CH_3COONa. Velocity sedimentation was investigated using Beckman XLI analytical ultracentrifuge. Translation diffusion coefficients of chitosan molecules were received by means of the isothermal diffusion study in Tsvetkov diffusometer.

Table 1 Molecular characteristics of chitosan

№	The characteristics of chitosan polymers		
	Raw materials	***Deacetylation degree, DD, %***	***M_{SD}, kDa***
1	crab	96	65
2	crab	94	150
3	shrimp	91,5	210

Rheological measurements of polymer solutions were conducted on the rheometer Physica MCR 301 (Anton Paar) at 20°C according to the method of “cylinder in the cylinder” in the regime of shear flow with the shear rates 10^{-4}- 100 sec^{-1}. 5 ml of solution was placed into the rheological cuvette and the dependence of viscosity (η) on the shear rate ($\dot{\gamma}$) was obtained.

The fibers were processed by coagulation method [5,6,8], on the laboratory equipment developed at the Institute of Macromolecular Compounds RAS. Precipitator was the mixture 10% solution of NaOH and C_2H_5OH in the proportion 1:1. Monofilament processing was flowed through the die hole with the diameter of 0.6 mm, the feed rate of the solution through the die hole was 5.5 mm/sec; the time of precipitation was 150 sec. The factor of orientation drawing (λ) of the monofilament in the coagulation bath was varied from – 20% (shrinkage) up to +100%. The fibers were washed in the distilled water and then dried at a temperature of 50°C during 10 min.
The study of the structure were conducted on the microscope Supra-55 VP (Carl Zeiss). The measurements of the mechanical properties of the processed fibers were carried out on the testing machine Instron 5943 at RT and the load speed of 10 mm/min; basis length of the fibers was 100 mm. The cross section (S in m^2) of the monofilaments was estimated by the formula S = tex/ρ, where tex is the mass of 1 m of monofilament (mg) and specific gravity (ρ) of CS is equal 1400 kg/m^3. Prior to the mechanical testing the fibers were placed in special box with relative humidity 66% for 24 hours.

2 RESULTS AND DISCUSSION

The rheological properties of 2% acetic-acid solution of chitosan are given in Fig. 1.

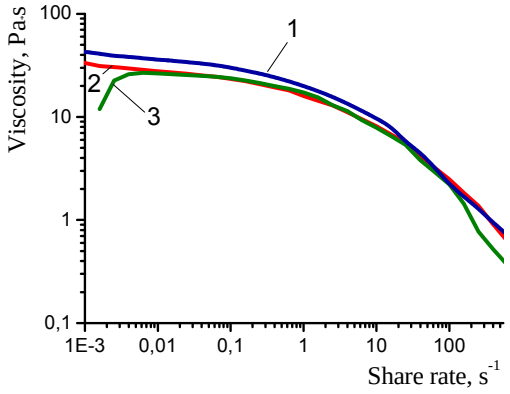

Figure 1 Dependences of viscosity on shear rate for chitosan solution with different molecular weight

As seen in Fig. 1 the dependencies of the viscosity (η) on the shear rate ($\dot{\gamma}$) for all investigated solutions are similar and have a nonlinear behavior.
The increasing of chitosan molecular mass leads to increasing of solution viscosity and decreasing of the optimal concentration of chitosan in solution. The optimal concentrations of chitosan for processing were determined (Table 2).
The obtained results allowed developing of optimal processing conditions. It was shown that the decreasing in the molecular mass of chitosan to 65 KDa as well as the its increasing to 400 kDa hider the factor of orientation drawing (λ). In this case, the factor of orientation drawing was 20%.
The optimum molecular mass was 210 kDa that made possible to draw the fibers up to 100%. These fibers have highest mechanical properties: strength is 188 MPa, Young modulus is 11,5 GPa, elongation to break is 4,8 %.

Table 2 Properties of chitosan fibers

№	*Optimal concentration of chitosan in solution, %*	*Maximum orientation drawing, %*	*Mechanical properties*		
			Strength, MPa	*Young modulus, GPa*	*Elongation to break, %*
1	6,3	40	110	7,7	3,9
2	5,0	100	169	11,5	3,3
3	4,0	100	188	11,5	4,8

The molecular mass of chitosan doesn't effect on appearance of the fiber. All obtained fibers have a smooth surface and homogeneous structure (Fig 2).

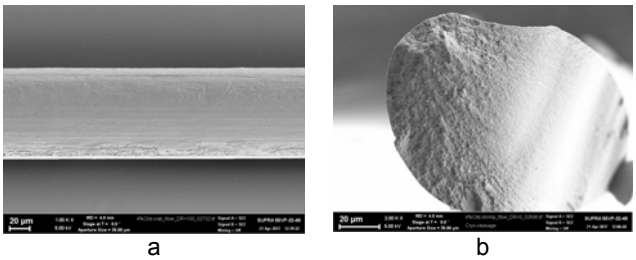

Figure 2 SEM micrographs of chitosan fibers: longitudinal view (a) and cross-section (b)

The obtained fibres may be used
– as the matrices for cell replacement technologies and tissue engineering as well as for the creation of muscle, cartilage tissue and serve as the basis for blood vessels and nerves;
– to produce new biodegradable surgical suture materials;
– to receive hemostatic material.

Acknowledgement**: The authors are grateful to the Russian Science Foundation Grant # 14-33-00003 for financial support.**

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NEEDLELESS ELECTROSPINNING OF PAN NANOFIBER MATS

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Abstract: *Polyacrylonitrile (PAN) belongs to the few waterproof polymers which can be spun from relatively safe solvents, allowing using PAN nanofiber mats in diverse medical and biological applications, such as tissue engineering and cell growth promotion. PAN, on the other hand, is significantly harder to use in electrospinning than poly(ethylene glycol) and other water-solvable biopolymers. This is why in a recent study we have varied spinning and material parameters for PAN dissolved in DMSO (dimethyl sulfoxide) and investigated spinnability as well as the resulting nanofiber mat morphologies.*

Keywords: *Polyacrylonitrile, electrospinning, nanospinning, nanofiber mat, spinning parameters*

1 INTRODUCTION

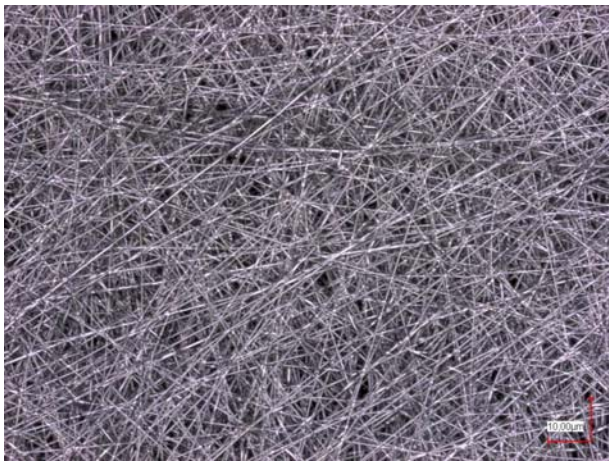
Electrospinning belongs to the primary spinning processes, resulting in fine polymer fibers with diameters in the area of some ten to some hundred nanometers. In needleless electrospinning, polymers are often spun from solutions, a process which is technically easier than melt electrospinning. Several polymers, however, cannot be solved in non-dangerous solvents. Polyacrylonitrile (PAN) belongs to the materials which can be solved in DMSO, a solvent which has to be handled with care, but does not cause problems in biological or medical applications.
While PAN is thus a typical material in electrospinning [1,2], investigations of the influence of its spinning and material parameters on the resulting nanofiber mats are scarce [3-5]. Our article give an overview of the effect of different polymer concentrations in DMSO, different base materials and a variation of the spinning parameters on the spinning process and the resulting nanofiber mats.

2 EXPERIMENTAL

PAN solutions were prepared with 5 % to 50 % PAN in DMSO by stirring for 2 hours at room temperature. Additionally, different PAN base materials were used.

Figure 1 Needleless electrospinning of a PAN solution with undesired cotton-candy-like polymer connections between high voltage electrode and substrate

Electrospinning was performed on the needleless nanospinning machine “Nanospider Lab” (Elmarco). The spinning parameters, such as high voltage, electrode-substrate distance, carriage speed, etc. were varied to find optimum conditions for the different spinning solutions.
The nanofiber mat morphologies were investigated using the confocal laser scanning microscope (CLSM) VK-9000 (Keyence) with a nominal magnification of 2000 x.



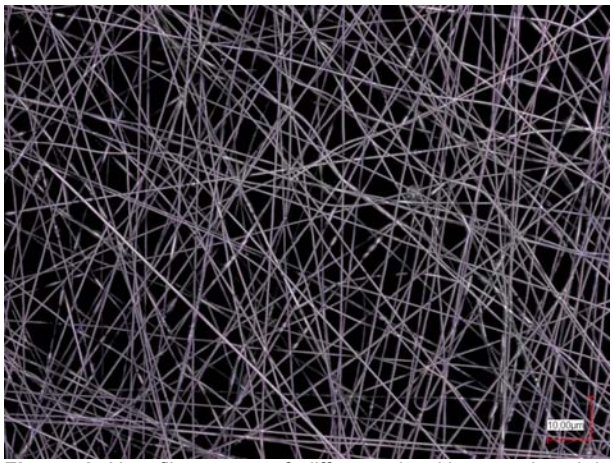


Figure 2 Nanofiber mats of different densities, produced by needleless electrospinning from PAN solved in DMSO

3 RESULTS

Depending on the solution and spinning parameters, strong deviations occur between the different spinning processes. In the worst case, directly after switching on the high voltage, cotton-candy-like polymer connections are formed between the high voltage area at the bottom of the chamber and the grounded area at the top (Fig. 1). This leads to no nanofiber mat being formed on the substrate since nearly all fibers are caught in these 3D structures. This behavior is significantly different from electrospinning typical biopolymers from aqueous solutions [6,7].
On the other hand it is possible to form even, straight nanofibers on the substrate in denser or less dense formation (Fig. 2) with ideal spinning and solution parameters. This shows the importance of carefully choosing the spinning conditions.

4 CONCLUSION

For needleless electrospinning with PAN, finding the ideal spinning and solution parameters is crucial for creation of optimum nanofiber mats. Our investigations allow for giving an overview of the influence of different parameters on the spinning process and the resulting nanofiber mats.

***ACKNOWLEDGEMENT**: The authors acknowledge gratefully the program FH Basis of the German federal country North Rhine-Westphalia for funding the "Nanospider Lab".*

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THE INFLUENCE OF PRETREATMENT AND VARIOUS *CROSS-LINKING AGENTS* ON BINDING OF β -CYCLODEXTRIN AND COTTON

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Abstract: *β-Cyclodextrin (β-CD) is a cyclic glucose polymer that can include other molecules within a structural cavity to form a microcapsule with many products based on organic and inorganic compounds. The purpose of this research was to establish an optimal method of bonding β-cyclodextrin onto cotton, using citric (CA) and maleic acid (MA) as non-aggressive cross-linking agents.* The grafted amount was determined by gravimetric method and the treated fabrics were analyzed by Fourier transform infrared spectroscopy (FTIR). *Scanning electron microscopy (SEM) was employed to study the morphology and structure of cellulose materials treated with β-cyclodextrin. The results indicated that probably a more stable bonding between cellulose and β-cyclodextrine was achieved in the sample, which was pre-treated in alkaline bath and treated with β-CD and MA as cross-linking agents.*

Keywords: *Cotton, NaOH pre-treatment, β-Cyclodextrin , citric acid, maleic acid*

1 INTRODUCTION

Cyclodextrins (CDs) are cyclic, water-soluble, non-reducing, macrocycle carbohydrate polymers. Pure CDs were prepared by Freudenberg and co-workers, who reported that CDs were onstructed from α-(1-4)-linked D-glucopyranose units, in a ring formation. The most common of these naturally occurring, ring-shaped molecules are the α- (alpha), β- (beta) and γ- (gamma) CDs formed by six, seven and eight glucose units and which enclose cavities of approximately 0.6, 0.8 and 1.0 nm in diameter.[1] In the textile area, cyclodextrins have been used for imparting properties such as: UV protection, slow release of fragrances, insecticide delivery and antibacterial properties.[2] *The problem that occurs when using β-cyclodextrin on a textile material is its durability on washing.* The purpose of this research was to establish an optimal method of bonding β-cyclodextrine onto cotton, using pretreatment in alkaline bath and then treatment in bath with citric (CA) and maleic acid (MA) as non-aggressive cross-linking agents.

2 EXPERIMENTAL

2.1 Materials

The fabric was 100% cotton desized, scoured, chemically and optically bleached, with the surface mass of 177 g/m². Modifications to achieve target properties were performed using β-cyclodextrin produced by CycloLab R&D Ltd.

2.2 Fabric Treatment

All samples were pretreated for 60 seconds in 14% sodium hydroxide. Bath formulations are shown in Table 1.

Impregnation was performed at laboratory padder Benz (Zurich, Switzerland) with wet pick-up of approximately 100%. Laundering was performed with Polycolor, Mathis apparatus according to EN ISO 6330:2000 [3] with standard detergent.

Table 1 Treatment conditions

Bath	β-CD [%]	Binder [g/l]	Catalyst [g/l]	Curing time [s]	Curing T [°C]
1	25	CA 70	SHP* 65	120	175
2	25	MA 70	SHP* 65	120	175

*SHP - Sodium Hypophosphite Monohydrate

2.1 Scanning electron microscopy (SEM) study

Prior to Scanning electron microscopy **(**SEM) study, the samples were coated with gold in a sputter coater. The specimens were observed with Mira, Tescan, field emission scanning electron microscope.

2.2 FTIR measurements

The treated samples were analyzed by ATR-IR spectroscopy using a Fourier transformation of infrared spectrometer (FTIR) (PerkinElmer, software Spectrum 100). 4 scans at a resolution of 4 cm^{-1} were recorded for each sample between 4000 cm^{-1} and 380 cm^{-1}. To measure the intensity of the ester carbonyl band samples were treated with a 0.1M NaOH solution at room temperature for 2 min to convert the free carboxylic acid on the fabric to a carboxylate anion so that the ester carbonyl band could be separated from that of the overlapping carboxylic acid carbonyl. The ester carbonyl band intensity in the IR spectra of the treated cotton fabric was normalized against the 1314 cm^{-1} band associated with the COH bending mode of cellulose.

2.3 Weight Measurements

The amount of β-CD grafted to the fabric was determined by ISO 3801:1977.

3 RESULTS AND DISCUSSION

The results of SEM characterisation of both treated samples confirmed the presence of β-CD on cotton surface before and after Home Laundering (HLWD) cycle (Fig. 1 and 2).

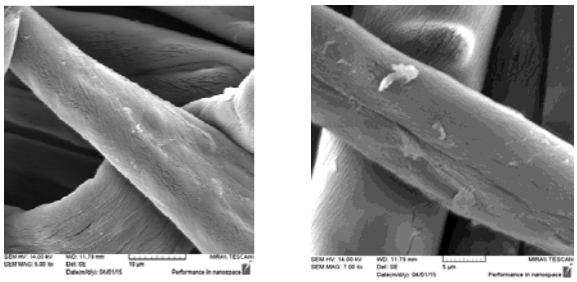

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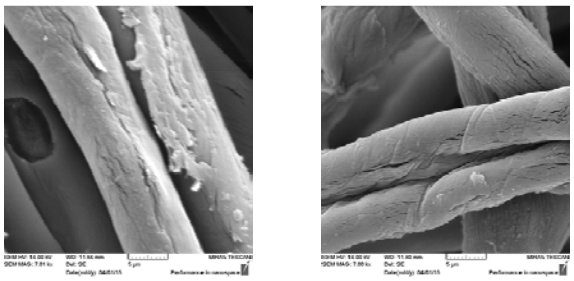
Figure 1 SEM images of treated sample in bath 1 before (a) and after (b) HLWD cycle



a b

Figure 2 SEM images of treated sample in bath 2 before (a) and after (b) HLWD cycle

Figure 3 and 4 show representative FTIR spectra of untreated cotton fabric and cotton fabric treated in bath 1 and 2 before and after HLWD cycle.
On the spectral curves recorded on a FTIR-ATR spectrometer, higher physico-chemical changes on the sample treated in bath 2 are visible (Fig.4) which suggests the presence of β-CD in the structure of a cotton material. On the sample treated in bath 1 (Fig. 3) by this method none significant changes are detected in the physicochemical properties of the cellulosic material.

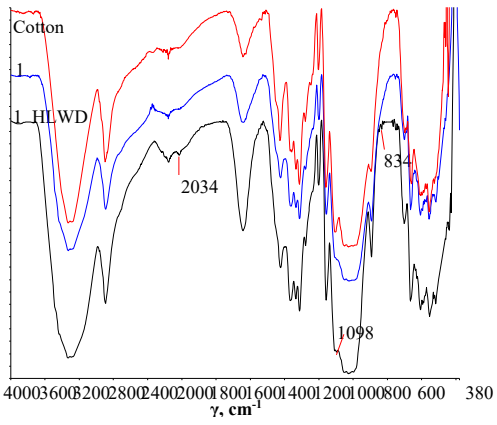


Figure 3 Fourier transform infrared spectra of untreated cotton and treated cotton in bath 1 and after one cycle of wash (CA3_HLWD)

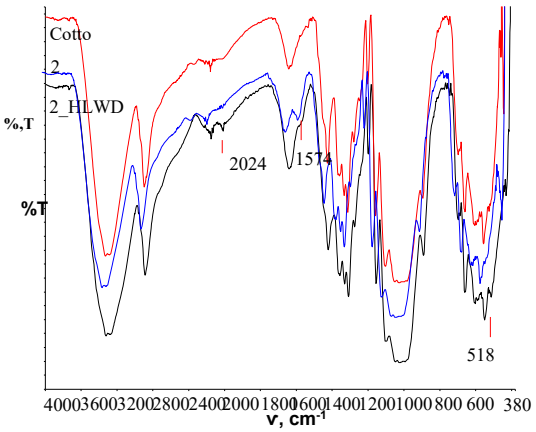


Figure 3 Fourier transform infrared spectra of untreated cotton and treated cotton in bath 2 (MA3) and after one cycle of wash (MA3_HLWD)

The sample treated with citric acid gained more mass CA (21,5%) than the sample treated with maleic acid (17,8%), which would suggest that sample treated with citric acid retained more β-CD. After one HLWD cycle both samples retained majority of mass gain which indicates proper bonding of cellulose and β-CD.

4 CONCLUSIONS

Alkaline pretreatment had an influence on the binding of β-cyclodextrin to cotton fabric through citric and maleic acid as a crosslinking agent and a sodium hypophosphite catalyst. SEM images and FTIR characterization confirmed presence of β-cyclodextrine on the cotton structure in both treated samples. The sample treated with citric acid gained more mass than the sample treated with maleic acid and after HLWD cycle both samples retained majority of mass gain which indicates proper bonding of cellulose and β-CD.

***Acknowledgement**: This research was performed within the framework support for research: Functionalisation and caracterisation of textile materials for achieving protective properties (TP3-16), financed by the University of Zagreb and Croatian Science Foundation under the project 9967Advanced textile materials by surface modification.*

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THE ROLE OF FABRIC COMPOSITION, NUTRIENTS, TEMPERATURE AND HUMIDITY IN THE SURVIVAL CAPABILITY OF MULTIDRUG-RESISTANT BACTERIAL PATHOGENS

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Abstract: *We investigated the role of environmental conditions (presence of nutrients, three kinds of textile and two types of modelled environment) in the survival capability of four multidrug-resistant bacterial species. We found that multidrug-resistant Staphylococcus aureus and Klebsiella pneumoniae strains were significantly more viable in the presence nutrients. All species showed the highest viability on towel, and at general temperature (T=25°C) and relative humidity (Rh=52%) of a hospital environment.*

Keywords: *survival capability, healtcare-associated bacteria, nutrients, textiles, humidity, temperature*

INTRODUCTION

Bacterial strains are able to keep their survival capability and virulence on inanimate surfaces, which can become sources of healthcare-associated infections [1, 2]. The duration of survival varies largely within one species from a few hours even to several years [2-4]. In a previous study we quantitatively examined the survival capability of 60 healthcare-associated, multidrug-resistant bacterial strains (MDRB) on cotton textile in conditions similar to a hospital environment (without additional nutrients, at 25°C and 52% relative humidity) [5]. We determined that all of the investigated bacteria were able to survive in an extent to pose health risk in the hospitals, but the role of environmental conditions in the survival of bacteria is still controversial [3].
In this study we investigated whether the presence of nutrients, the chemical composition or the weaves of the textiles, the temperature and the relative humidity are able to influence the survival capability of MDRB.

1 MATERIALS AND METHODS

We examined four multidrug-resistant bacterial species: vancomycin-resistant *Enterococcus faecium* (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), multidrug-resistant *Acinetobacter baumannii* (MACI), and multidrug-resistant *Klebsiella pneumoniae* (MRKP). We compared the survival capability of 15 strains of each species on plain weaved, 100% cotton sheet (areal density: 104 g/m^2) inoculated using either 0.9 w/w% physiological saline solution or Nutrient Broth (manufactured in the National Public Health Institute, Hungary).
Based on the results we selected three bacterial strains from each species, the ones with the highest, the median and the lowest survival capability for the additional experiments. We examined their survival capability on two other types of textiles (plain weaved, 80-20% cotton-polyester sheet and 100% cotton terrycloth towel) and compared the data to the results obtained with the plain weaved 100% cotton sheet.
We modelled two environmental conditions, one as a general environment in a hospital ward (T=25 °C, Rh=52%, maintained using saturated $Mg(NO_3)_2$ solution), and the other as close contact with the patient's body (T=35°C; Rh=83%, maintained using saturated KCl solution). We investigated the survival capability of the selected twelve strains at these circumstances, inoculated the bacteria in 0.9 w/w% saline solution onto the plain waved 100% cotton sheet. In all survival experiments 10^5-10^6 Colony Forming Units (CFUs) were inoculated onto the square shaped textile swatches, with a side length of 2.5 cm and 1 cm in case of the sheets and the towel, respectively. The number of viable CFUs was determined using spread-plate method immediately after inoculation as well as after three and seven days. We selected the most appropriate incubation periods to show the results. Each strain was tested twice, the results were averaged. The survival capability of a bacterial strain was determined as the average viable CFU on a swatch. We used IBM SPSS Statistics Data Editor and dependent t-test to perform the statistical tests, $P \leq 0.01$ was considered to be statistically significant.

2 RESULTS AND DISCUSSION

In the literature longer duration of bacterial viability was described in the presence of organic contaminants (protein, serum) [3, 6]. Table 1 shows our results.

Table 1. The effect of nutrients in the survival capability of 15 strains of each species. Data show the mean (M) and the standard deviation (SD) of survival capability after 3 days (MRKP, MRSA) or 7 days (MACI, VRE).

CFU/ swatch	saline		nutrient broth	
	M	SD	M	SD
MRKP	4,8E+0	1,2E+1	1,4E+2	1,8E+2
MACI	1,6E+3	2,1E+3	1,2E+3	1,0E+3
MRSA	8,7E+1	1,0E+2	2,2E+2	1,5E+2
VRE	1,9E+2	9,6E+1	1,7E+2	1,5E+2

Based on our data MRKP and MRSA strains showed significantly ($p<0.01$, 3 day) higher survival capability when inoculated in Nutrient Broth compared to saline solution. Nevertheless, there was no significant

difference in the survival capability of MACI and VRE isolates concerning the presence of nutrients.
The effect of the surface-type to the survival of the bacteria is a controversial topic [3, 7, 8]. We investigated the survival capability on three types of textiles. We did not find any significant differences in the survival of bacteria. The reason could be the small number of examined strains. However, all four species showed the highest viable CFU on towel (Table 2).

Table 2. The effect of textile types. Data show the mean (M) and the standard deviation (SD) of survival capability of 3 strains per species, after 3 days of incubation.

CFU/ swatch	cotton sheet		cotton-polyester sheet		cotton towel	
	M	SD	M	SD	M	SD
MRKP	1,8E+1	2,1E+1	0,0E+0	0,0E+0	4,7E+1	8,1E+1
MACI	2,8E+3	1,8E+3	1,3E+2	2,1E+2	3,4E+3	5,6E+3
MRSA	2,1E+2	1,4E+2	4,7E+2	4,4E+2	2,7E+3	2,5E+3
VRE	3,6E+2	2,5E+2	1,5E+3	2,6E+2	3,2E+3	3,0E+3

The Gram-negative species proved to be the less viable on the cotton-polyester sheet. On the other hand, the Gram-positive bacteria showed lower survival on cotton than on cotton-polyester textile, which is consistent with the findings of Neely and Maley [9].
We investigated the survival capability of the selected twelve strains in two modelled environments. Significant differences were not found, however all isolates showed less viability at higher temperature and higher humidity (Table 3). Some other investigations confirm this trend [3, 8], others show contrary opinions [6, 10].

Table 3. The effect of environmental conditions. Data show the mean (M) and the standard deviation (SD) of survival capability of 3 strains per species, after 3 days of incubation.

CFU/ swatch	T=25°C, Rh=52%		T=35°C, Rh=83%	
	M	SD	M	SD
MRKP	6,0E+1	5,4E+1	0,0E+0	0,0E+0
MACI	5,0E+3	4,0E+3	1,3E+1	1,2E+1
MRSA	1,4E+2	8,9E+1	0,0E+0	0,0E+0
VRE	4,5E+2	3,6E+2	1,4E+2	9,7E+1

3 CONCLUSIONS

Our aim was to investigate the role of environmental conditions to the survival capability of healthcare-associated pathogens. We found that the presence of nutrients can increase the survival capability of the examined multidrug-resistant bacteria. All species showed the highest viability on cotton towel, and at 25°C with 52% relative humidity. The fabric composition affect the survival capability of the Gram-positive and Gram-negative bacteria differently. The examination of more isolates is needed to support our initial findings.

***ACKNOWLEDGEMENT**: The authors wish to express their sincere thanks to Judit Borsa and Hosam E.A.F. Bayoumi Hamuda (Óbuda University, Hungary) for their permanent support and advices. The authors are grateful to Gyula Vörös for his assistance in the statistical evaluation.*

***FUNDING:** This work was supported through the New National Excellence Program [code number: ÚNKP-16-3/IV.] of the Ministry of Human Capacities.*

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MEDICAL TEXTILE EQUIPMENTS FOR CLASS ONE WITH A NON-INVASIVE CHARACTER

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Abstract: *The research work is focused on the medical textiles like clothes, linen, towel and other medical items for professionals and patients. These medical items are defined by the relevant technical standards and EU requirements. The requirements for the textile fabrics in the healthcare sector are determined in terms of the end use according to its purpose and usage. Basic requirements for medical items are specified in Government Regulation of the Czech Republic no. 336/2004 Coll., which determines technical requirements for medical items in accordance with European Directive 93/42 / EEC. This directive specifies the basic parameters of these products from the point of view of their safety and lays down classification of medical devices into classes' I-III according to the risk of use. The theme of project no. FV 10098 MEDITEX is medical textiles products showing characteristics for Class I. This presents a low risk of use from the point of view of the user's health. These are mostly non-sterile, non-invasive products that are not subject to the pre-market approval process.*

On the basis of a survey of the Czech market, these products are used as textile products in healthcare, rehabilitation, spa and after-care and long-term care facilities. Based on the findings and information, it is apparent from the point of view of the material composition what kind of the fabrics is commonly used in these facilities. The material composition of 36.9% of the total products consumed consist of 100% Cotton in mercerized treatment, 24.1% of the material was made of 100%PES, material composition 65PL/35CO is represented by 20.2% of products, material composition 50PES/50CO is represented by 16.7% of products from offered assortment, other types of material composition and use of special fibers is represented in the assortment of medical products of Czech suppliers only Marginal 2.1% of products. It is clear that there is a need for research and development of new types of textiles in mixtures with new, functional fibers in order to achieve the special utility properties of the products.

One of the key objectives was to find a suitable solution for achieving the special utility properties of the fabrics for the manufacture of medical items according to their purpose and usage. The utility value of these items are then defined in terms of the useful properties like vapor resistance, antibacterial treatment, active protection of the health of workers in the environment affected by infectious and toxic influences, better user comfort of employees and clients in terms of improvement of personal feelings and work performance, and economic product relations and easy maintenance of products with respect to environmental protection.

In the field of health care, the thermo-physiological properties of clothing and the characteristics of air transport, water vapor and moisture are an essential component of comfort. Secondly, the feeling of comfort is influenced by a good make of clothing, a practical and aesthetic design. Requirements for properties are governed by ČSN P ENV 14 237 "Textiles in Health Care". This standard defines the basic properties and methods of textile testing for health care to ensure the suitability of the product for the intended use. It sets minimum requirements to meet acceptable usability.

To ensure better properties of medical devices and to achieve antibacterial, anti-inflammatory, thermoregulatory and other active functions, new fibers have been identified. These new fibers and yarns made are the main bearers of the desired functions in designing fabrics with a prognosis of expected utility properties. The resulting mixed functional yarns are thus output from the first phase of the fiber processing into the sheet. Depending on the type of yarn used and the yarn construction, special functional properties of the sheet can be achieved, which are then evaluated according to various (selected) methods for assessing the physiological comfort during their use, especially the most important utility properties - the evaporation resistance Ret. The required bedding properties are defined by ČSN P ENV 14 237 "Textiles in Health Care", where the resistance value for water vapor Ret ≤ 6 [Pa.m^2.W^{-1}] is also recommended. Therefore, the result of the evaluation of the vapor resistance were carried out by various methods and shows the utility properties of medical clothing.

Keywords: *medical textiles, utility properties, comfort, vapor resistance*

EVALUATION OF THERMAL PROPERTIES UNDER CONDITIONS OF FAST FLOWING AIR

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Abstract: *The subject of this article is the evaluation of thermophysiological comfort of clothing under condition of flowing air. For this purpose, a special device has been created, which is capable of generating an air flow of variable velocities. Under these conditions the values characterizing thermal insulating properties of the textile material sample are recorded on a human arm model, which is placed in the wind tunnel.*

Keywords: *thermophysiological comfort, thermal insulation, aerodynamic tunnel, fast flowing air*

1 INTRODUCTION

Nowadays, consumers evaluate not only the visual aspect of clothing, but also their functional properties. As the protection against cold is inherently essential among the basic functional properties, their thermal insulation capability is one of the most important qualities. Therefore, these properties are repeatedly investigated and requested. Thermal comfort is often defined as that condition of mind which expresses satisfaction with the thermal environment. It depends on the heat transfer between the body and the environment. It is also related to the thermal resistance and water vapour permeability of the garments [1,2,6].
Thermal insulating properties of fabrics can be evaluated by several methods and devices. The individual methods differ from another in terms of measurement, measured values, sample size, and for example ambient climatic conditions. However, the standards used do not include a device that evaluates the thermal insulation properties under real conditions - with the use of flowing air at different flow rates. Recent research has been carried out mostly using different models of body parts and also methods using air flow [3,4,5].

2 MEASURING DEVICE

2.1 Description of the measuring device

As can be seen in Figure 1, the measuring system consists of two basic components, the aerodynamic tunnel and the human arm model.

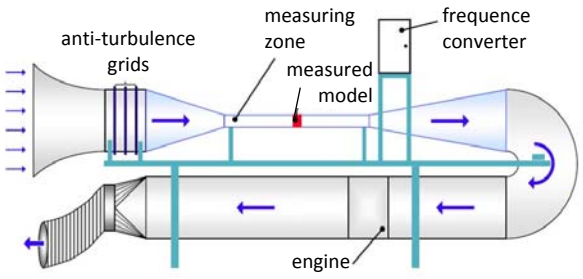

Figure 1 Diagram of the measuring device

The wind tunnel is five meters long. The measurement is carried out in the upper section of the tunnel, which is one meter long. In the middle of the measuring zone a cylindrical measuring module, representing the human arm, is placed. The model is composed of a heated cylinder, surface of which simulates the surface temperature of the human arm. Around the measured model sensors are placed at regular intervals to detect the thermal resistance of the fabric.

2.2 Adjusting measurement conditions

The device is controlled by a program built in the LabVIEW programming environment. Thanks to flexibility of the program we can set several important parameters of the air flow specification in the wind tunnel even in course of measurement, which is unique for our model. We control the air flow velocity and adjust it continuously to maintain the desired value thus obtaining more accurate data.

2.3 Model of human arm

The human arm model has a form of a cylinder. In its core is a heater that heats the surface to the temperature of the human body skin. This temperature is around 32°C. Around the cylinder are eight uniformly distributed alphameters (A0-A7). The alphameter A0 is located directly against the air flow (on the windward side of the measured model), alphameter A4 is located on the other side of the cylinder (on the leeward side of the model). The other sensors are distributed at angles of 45 degrees. See figure 2.

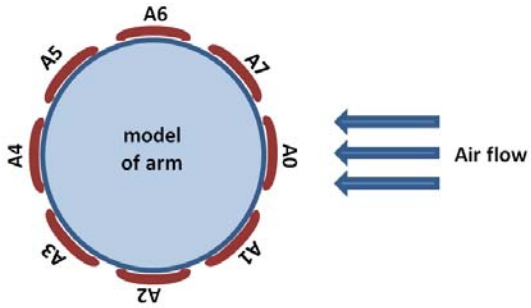

Figure 2 Human arm model with alphameters A0-A7

3 MATERIALS

Four different types of fabrics were used in experiment. The first one is cotton woven fabric, designed as the first layer of clothing. The material is highly breathable. The second fabric is fleece knit fabric as a second layer of clothing. Breathability of this fabric is also high. Third and fourth fabrics are used as upper layers of garments. Their breathability is insignificant. Table 1 presents the specification of used fabrics.

Table 1 Specification of used fabrics

Sample	*Fabric structure*	*Raw material*	*Weight [g/m^2]*
M1	Woven fabric	100% CO	240
M2	Fleece fabric	100% PES	300
M3	Neoshell barrier fabric	100% PAD; 100% PES	129
M4	Softshell Power Shield barrier fabric	50%PES, 38% PAD, 2% Spandex; 100% PES	292

4 METHODS

The thermal insulation properties of group of textile fabrics were measured by human arm model in wind tunnel. The airflow intensity in wind tunnel was changed during measurement. It was possible to discern differences in heat loss depending on the angle position in the air flow.

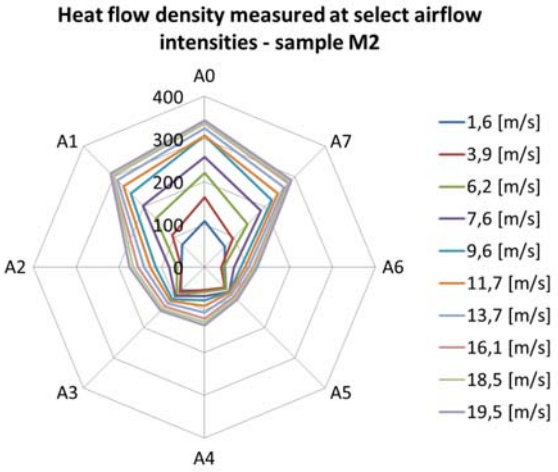

Figure 3 Measuring the variation of the heat flow on the sample M2 at different velocities of the flowing air

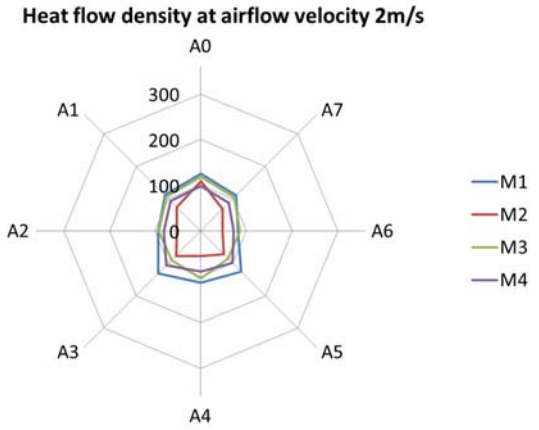

Figure 4 Heat flow density at airflow velocity 2 m/s

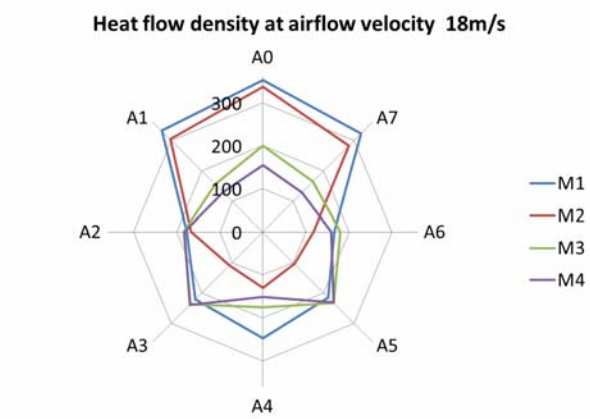

Figure 5 Heat flow density at airflow velocity 18 m/s

5 CONCLUSION

Standard methods for measurement of thermal insulation properties can only simulate the perpendicular direction of airflow to the fabric and only one concrete speed of airflow. Our wind tunnel with the human arm model allows an airflow direction which simulates real conditions when wearing clothes. This device also allows to monitor heat loss changes depending on varying airflow speed and depending on the angle of airflow to the fabric.

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THERMO-MECHANICAL PROPERTIES OF PLA FIBRES

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Abstract: *Nowadays is the use of synthetic polymer materials a daily matter. There is still increasing amount of polymer waste. The inability to decompose this waste results in landfill and environmental damage. Biodegradable polymers represent a new chapter in the development of polymeric materials and have a wide range of uses. PLA fibers containing the fluorescent pigment can be used as a new material with multifunctional properties from biodegradable and renewable sources.*

Keywords: *poly(lactic) acid, biodegradable fibres, thermo-mechanical properties, fluorescent pigment.*

1 INTRODUCTION

Biodegradable polymers can be defined as polymers that decompose into low-molecular products by the action of micro-organisms and their enzymes. By combining the production of polymers from renewable sources and biodegradability, the possibility of extending the lifecycle of plastic products has emerged. Their resistance to physical or mechanical influence is lower compared to synthetic polymers, but can be improved by the addition of suitable additives or creating blends with other biodegradable polymers [1].

The most used biodegradable polymer is poly(lactic acid) (PLA) [2]. PLA is made from lactic acid. Monomer - lactic acid can be produced by fermentation or chemical synthesis from carbohydrates. Fermentation of carbohydrates from agricultural crops such as sugar cane, potato and corn is more preferred [3, 4].

By combining the production of polymers from renewable sources and biodegradability, the possibility of extending the lifecycle of plastic products has emerged [5]. The addition of plasticizers to the mixture increases plasticity and resistance to external effects. There is the requirement that they must be stable, non-volatile and well mixable with the polymer. For a research materials made of PLA have a huge potential bioplasticizers based on citric acid like acetyltributylcitrate (ATBC) [6].

Practical applications of fluorescent pigments have many positive properties of results in a wide range. The PLA fibers containing such pigments can be used as a new material with multifunctional properties produce from renewable and biodegradable materials.

2 EXPERIMENTAL PART

2.1 Materials used

- Poly(lactic acid) **6201D PLA** (Ingeo™ biopolymer) (produced by Nature Works LLC)
- Poly(lactic acid) **6202D PLA** (Ingeo™ biopolymer) (produced by Nature Works LLC)
- plasticizer Acetyltributylcitrate – **ATBC** (citrofol B II) (produced by Junbunzlauer Ladenburg GmtH, Germany)
- fluorescent pigment EA-15 (**pig.**) (produced by RADGLO® EA).

2.2 Fibre preparation

Before the spinning, PLA granulates and PLA granulates with plasticizer were dried in a laboratory oven for 3 hours at temperature 80°C and then they were mechanical mixed with fluorescent pigment. PLA fibres and modified PLA fibres with plasticizer and fluorescent pigment were prepared using the pilot continual line by the spinning at the temperature 190°C with the take-up speed 150 $m.min^{-1}$. The concentration of plasticizer was 7.5 wt.% for fibres from PLA 6201 and 5 wt.% for fibres from PLA 6202. The concentrations of fluorescent pigment in fibres were 0.1; 0.3; 0.5 and 0.8 wt.%. The undrawn fibres were drawn at the maximum drawn ratio λ_{max}.

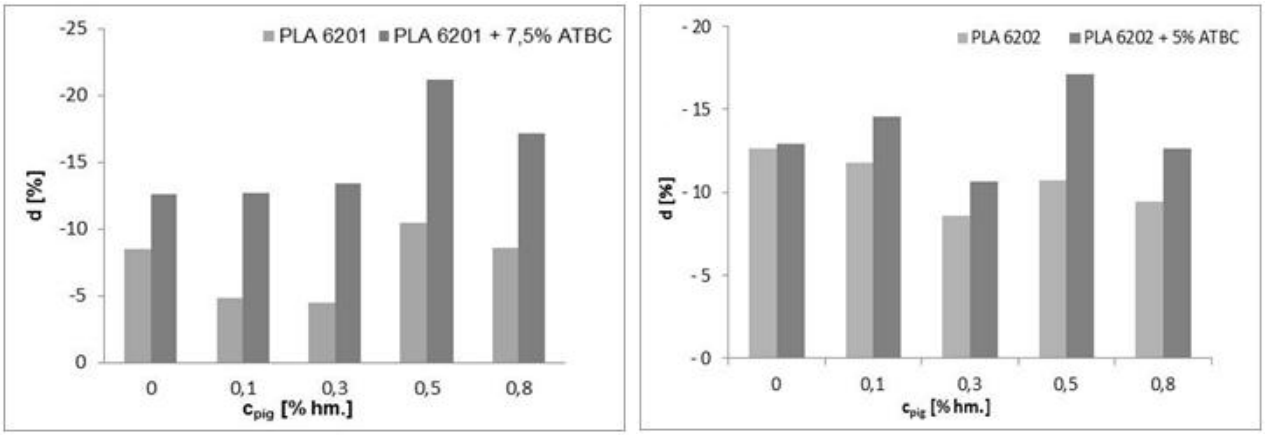
2.3 Methods used

Thermo-mechanical characteristics of PLA and modified PLA fibres were measured by equipment Schimadzu TMA-50. There were measured the deformation (extension or shrinkage) of fibres at constant load in the temperature range 30-100°C (heating speed 5°C/min). The length of fibre's sample was 9.8 mm.

3 RESULTS AND DISSCUSION

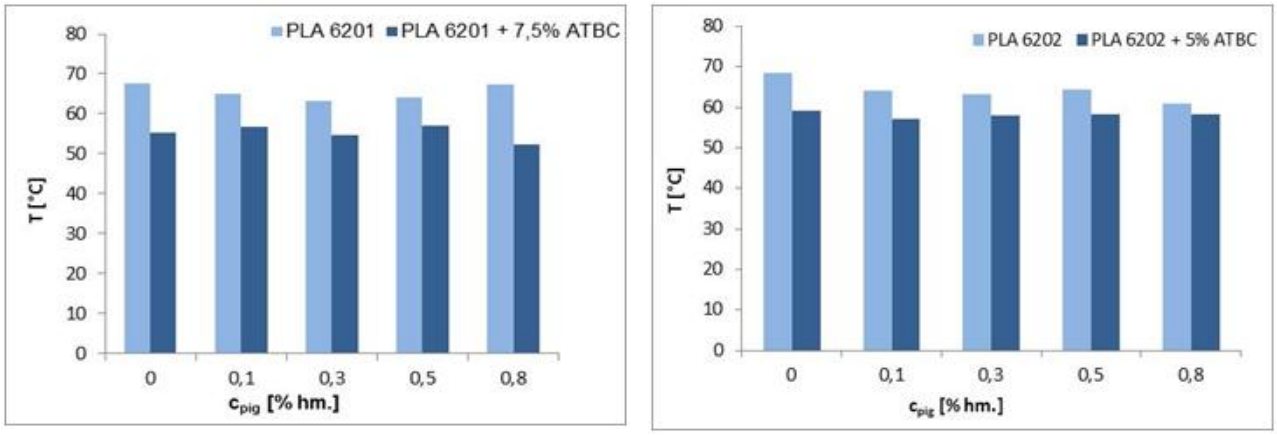
The dimensional stability of all the fibers in both series was manifested by their shrinkage (Figure 1a, 1b). The PLA/P fibers deform less by the applied force so they have better dimensional stability than the PLA/ATBC/P fibers. The deformation (shrinkage) of PLA 6202/P fibers is the same as for PLA 6201/P fibers but deformations are higher. The effect of plasticizer on the deformation of PLA 6202/ATBC/P fibers is also the same as for PLA 6201/ATBC/P fibers, i.e. Increases fiber deformation.

The concentration of the fluorescent pigment does not have significantly effect on the temperature of deformation of fibers prepared from PLA 6201 and the PLA 6202 drawing on the maximum drawn ratio λ_{max}. Pigmented fibers of both types of PLA have higher temperatures of deformation than fibers containing plasticizer (Figures 2a, 2b).



a. b.

Figure 1 Dependence of deformation (shrinkage) on concentration of fluorescent pigment for PLA/P and PLA/ATBC/P fibres: a) PLA 6201, b) PLA 6202



a. b.

Figure 2 Dependence of temperature of deformation on concentration of fluorescent pigment for PLA/P and PLA/ATBC/P fibres: a) PLA 6201, b) PLA 6202

4 CONCLUSION

The work was aimed at the preparation of PLA fibres with contain of plasticizer and compare two types of PLA for produce new modified fibres for application as safety materials from biodegradable a renewable materials. The results obtained by experimental work have confirmed that it is possible to prepare the PLA fibres and modified PLA fibres with plasticizer and fluorescent pigment.

ACKNOWLEDGEMENT: This work was supported by the Slovak Research and Development Agency under the contract No: APVV-14-0175.

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EFFECT OF THE NANOPARTICLE'S SHAPE ON PROPERTIES OF POLYPROPYLENE FIBRES

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Abstract: *Polypropylene (PP) fibres are used as reinforcement in concretes. Increased adhesion of PP fibres to matrix could be achieved by physical modification of PP fibres with inorganic additives. The aim of our paper is the presentation the effect of particle's shape on mechanical properties of modified PP fibres.*

Keywords: *polypropylene, modification, nanoadditive of silica fume, silicate composite*

1 INTRODUCTION

Polypropylene (PP) fibres are wide used material, mainly for their good physical-mechanical properties, low density and low price. One of the most significant technical applications of polypropylene fibres is the building sector. The using of fibres in concretes, respective in other silicate composites, improves their specific properties, for example PP fibres can increase toughness of concrete, improve abrasive resistance, chemical resistance and prevent the rupture spread.

The handicap of polypropylene fibres is their low affinity to silicate matrix, what worsens the processing and useful properties of materials. The negative character of PP fibres in composites can be eliminated by addition of various substances like fillers, solid particles, additives, nanoadditives and others.

The organic and inorganic particles (silica fume, halloysite, TiO_2,…) are used as nanoadditives in polymeric materials. The modification of PP by these particles can improves the adhesion to silicate matrix of composite, roughening otherwise smoot surface of PP fibres, fixation of particles and changes the structure of PP fibres [1, 2, 3].

Halloysite (HNT) is a type of natural occurring clay minerals with nanotubular structure. Due to the variety of crystallization conditions and geological occurrence, HNT adopt different morphologies such as tubular, spheroidal and plate-like particles, of which the tubular structure is the most common and valuable. The inner diameter is 1-30 nm, outer diameter is 30-50 nm and length of HNT is 100-2000 nm.

Silica fume is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm.

In this work the halloysite and silica fume were used for modification of PP fibres. Mechanical properties were evaluated for considering the effect of shape of inorganic particles on modification of PP fibres.

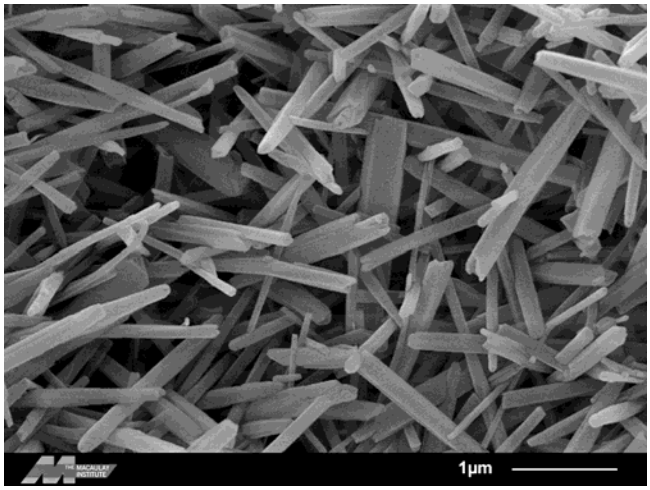

Figure 1 SEM picture of halloysite [4]

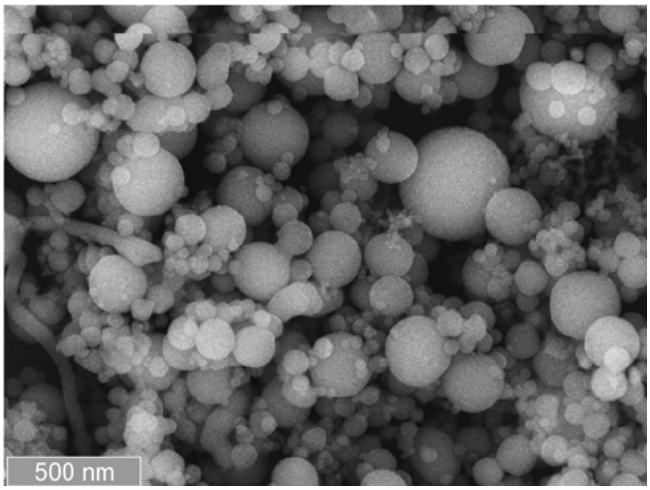

Figure 2 SEM picture of a silica fume [5]

2 EXPERIMENTAL PART

2.1 Materials used

- Polypropylene PP TATREN HT2511 (**PP2511**) with MFR = 25 g/10 min and polypropylene PP TATREN HT1810 (**PP1810**) with MFR = 20.6 g/10 min (both produced by Slovnaft Company, Slovakia),
- Halloysite (**HNT**) (Aldrich Chemistry, product of USA) and silica fume (**SF**) as nanoadditives,
- Tegopren 6875 (**TEG**) organomodified siloxane, (produced by Evonik Industies) as dispersant.

2.2 Fibre preparation

At the first the pure PP, inorganic nanoadditives (5% wt.) and dispersant were mixed and subsequently they were melting using the twin screw extruder. These PP concentrates were used for preparing of modified PP fibres with the 1, 3 and 5% of nanoadditives and 3% of dispersant TEG. PP fibres and modified PP fibres with nanoadditives were spinning using the pilot continual line at the temperature 240°C with the take-up speed 150 $m.min^{-1}$. The undrawn fibres were drawn at the maximum drawn ratio λ_{max}.

2.3 Methods used

Mechanical properties of PP and modified PP fibres were evaluated by the Instron 3343 equipment. The mechanical characteristics of the PP and modified PP fibres were determined in accordance with STN EN ISO 2062.

3 RESULTS AND DISSCUSION

The fibers with 1 and 3 wt.% content of inorganic nanoparticles and dispersant TEG achieve significantly better tenacity in comparison with pure PP fibers (Tables 1 and 2). Modified PP fibres with 5 wt.% of nanoparticles have lower drawn ratio and tenacity of these fibres decreases. Similar dependencies show the values of Young's modulus of modified PP fibres. Elongation at break of modified fibres decreases with content of nanoparticles (up to 3 wt.%) compared to PP fibres.

Table 1 Fineness (T), tenacity (σ), elongation at break (ε) and Young's modulus (E) of PP 2511 modified fibres

fibre	λ_{max}	T [tex]	σ [cN/tex]	ε [%]	E [N/tex]
PP 2511	4.5	17.8	30.4	28.7	3.16
PP+1% HNT+TEG	5.7	14.8	34.4	22.5	3.66
PP+3% HNT+TEG	5.5	15.0	32.8	22.5	3.29
PP+5% HNT+TEG	3.0	22.6	7.9	72.1	0.91

Table 2 Fineness (T), tenacity (σ), elongation at break (ε) and Young's modulus (E) of PP 1810 modified fibres

fibre	λ_{max}	T [tex]	σ [cN/tex]	ε [%]	E [N/tex]
PP 1810	3.7	17.1	30.1	67.6	3.28
PP+1% SF+TEG	5.0	14.1	47.0	22.5	4.86
PP+3% SF+TEG	4.7	15.7	42.1	20.8	4.13
PP+5% SF+TEG	3.0	12.5	18.7	36.3	2.28

At concentration of nanoparticles 5 wt.%, there is a change, and elongation at break increases. In this case, the agglomerates or aggregates can be created because the content of nanoparticles in polymer matrix is too high. Higher content of nanoparticles effects negative the processing and drawing of modified PP fibres, what causes the worsening of mechanical properties of fibres. PP fibres modified by silica fume achieve higher values of maximum drawn ratio, tenacity and Young's modulus as PP fibres modified by halloysite.

4 CONCLUSION

The results show that the modified PP fibres with content of nanoadditive silica fume have better mechanical properties as PP fibres modified by nanoadditives halloysite. It can be caused by spherical shape of silica fume particles and their better distribution in polymer matrix. The change of macro-morphological structure, due to surface roughness of modified fibres, can improve their adhesion to the concrete matrix.

ACKNOWLEDGEMENT: *This work was supported by the Slovak Research and Development Agency under the contract No: APVV-14-0175.*

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ALTERNATIVE METHOD FOR EXHAUSTED DYE BATH RECYCLING BASED ON REMOVAL OF RESIDUAL DISSOLVED ACID DYES

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Abstract: *This work presents the results of dissolved acid dyes precipitation and removal by action of liquid ion exchangers in co-action of inorganic flocculants. After addition of cationic surfactant and at aqueous iron or aluminium sulfate the precipitation occurs and practically decolorized aqueous phase is obtained. The treated water was completely decolorized by addition of powdered charcoal and subsequently reused in dyeing process.*

Keywords: *reactive dye, ion exchange, ionic liquid, flocculant*

1 INTRODUCTION

In batch dyeing a certain amount of textile material is loaded into a dyeing machine and brought to equilibrium with a solution containing the dye and the auxiliaries over a period of minutes to hours. In batch dyeing, dye, alkali (sodium hydroxide or sodium carbonate or bicarbonate) and salt are added to the dye bath in one step, at the start of the process, or stepwise. Its amount is determined by the reactivity of the system and the desired depth of shade (cold dyers are applied at lower pH compared to warm and hot dyers). Salt is added to improve bath exhaustion: the concentration employed depends on the substantivity of the dye and on the intensity of the shade. After dyeing, the liquor is drained off and the material is rinsed and then washed off with the addition of auxiliaries.

Concentrated waste water streams (spent liquors) containing hardly- or non-biodegradable substances (chlorinated dyes, etc.) compounds should be treated at source. For the textile finishing industry, advanced oxidation with a Fenton-like reaction is proposed as a viable pretreatment technique. However, application of strong oxidants sometimes causes production of adsorbable organic halogens (AOX) by reaction of NaCl with dissolved organic compounds and it is not able to remove of dissolved inorganic salts.

Mentioned problems could be solved by efficient removal of dissolved dyes from spent dyeing liquors with subsequent re-use of colorless aqueous NaCl solution for next dyeing step. Usually membrane techniques are applied in various ways for the treatment of segregated streams to allow water reclamation and re-use closely integrated with the process. However, membrane separation is very expensive technique. By our opinion, the cost-effective removal of dissolved dyes tested in this work is based on ion-exchange accompanied by separation of dissolved dyes by flocculation and subsequent action of low quantities of common adsorbent (active carbon).

Effective removal of acid dyes from spent dyeing liquor is based on ion exchange reaction caused by addition of hydrophobic quarternary ammonium halides (R_4NX [1]) into the spent liquor. R_4NX serve as a liquid anion exchanger. We observed that the replacement of halide anions of R_4NX by larger anions (anions of the acid dyes) proceeds smoothly even at room temperature [2,3]:

$$R_4N^+X^- + \text{dye-}SO_3^-Na^+ \rightarrow \text{dye-}SO_3^-R_4N^+ + Na^+ + X^-$$

The interaction of these dyes with R_4NX salts gives slightly soluble ionic salts which can settle after a long contact time or can be removed more efficiently by the action of common inorganic flocculants aluminum or ferric chloride.

2 MATERIALS AND METHODS

2.1 Dyes and reagents

The tested dyes (Tab. 1) and quarternary ammonium salts R_4NX (cetyltrimethylammonium bromide, cetylpyridinium chloride, benzyldimethylstearylammonium chloride, didecyldimethylammonium chloride) were supplied by Sigma-Aldrich Co. Aqueous 1×10^{-2} M R_4NX and 1×10^{-1} M of $AlCl_3$ or $FeCl_3$ stock solutions were used in this study.

2.2 Instruments

A UV-visible spectrophotometer Libra S22 (Biochrom, Great Britain) was used to measure the absorbance values of the dyes to establish their λ_{max} and concentrations. A magnetic stirrer HeiTEC (Heidolph Instruments GmbH&Co.) was used for stirring of (model) spent dyeing baths.

2.3 Precipitation of dyes

Aqueous R4NX solution was added dropwise to 100 mL of (model) spent dyeing bath in molar ratio R_4NX : dye-SO_3^- = 1 : 1 or until precipitation occurs and subsequently 0.1M aq. $AlCl_3$ or $FeCl_3$ was added drop wise until pH value reached pH~6. The volume of solution was replenished up to 200 mL. After 15 minutes of stirring at the speed of 400 rpm and the temperature of 23±2°C, filtration by suction and measuring dye

concentration in filtrates, The maximum decolorization efficiency (*DE %*) of dyes was determined from absorbance measurements, according to the concentration-absorbance standard curves at the respective maximum adsorption wavelength of the individual dye solutions. Afterwards, *DE %* was calculated from (1):

$$DE\ (\%) = [1 - (A/A_0) \times 100] \quad (1)$$

where A and A_0 denote the absorbance in the solution after and before precipitation, respectively.

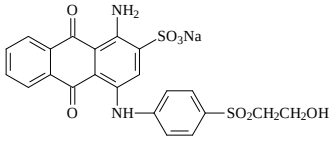
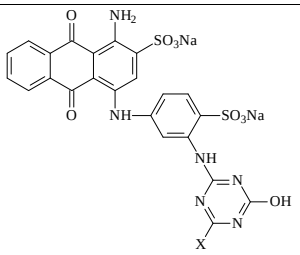
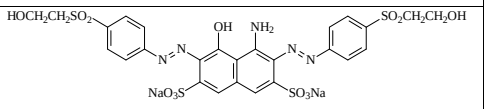
3 RESULTS AND DISCUSSION

In the preliminary experiments, it was found that used ammonium-based ionic liquids have the desired ability to precipitate the hydrolyzed reactive dyes from the model spent dyeing baths.

We described earlier that the optimal quantity of sulphonate groups bound in dye structure (number of dye–SO_3Na, n dye-SO_3Na) plays a crucial role in calculation of optimal dose of salts containing large organic cation (for example ionic liquids) [4-6].

However, the produced dye-SO_3NR_4 ion pairs are often dispersed in treated aqueous solution. Hence simple removal of dye-SO_3NR_4 form the treated aqueous solutions is a problem which was solved by simple coagulation and flocculation using cheap aluminum or iron salts as inorganic flocculants.

Table 1 Description of used dyes

Tested reactive dye	Chemical structure
Hydrolyzed Remazol Brilliant Blue R	
Hydrolyzed Procion Blue MX-R **(X = Cl or OH)**	
Hydrolyzed Reactive Black 5	

Complete decolorization of treated aqueous phase (more than 90 % of dye was removed) was accomplished by sorption on powdered charcoal (1-5 g/L). Differences between coloration of spent dyeing bath and treated one is documented in Fig. 1.

Using addition of cheap and simply available quarternary ammonium salts and co-action of coagulants, both model and real spent dyeing baths were decolorized.

Figure 1 Picture of spent black dyeing bath and the same bath treated by precipitation and subsequent adsorption .

***ACKNOWLEDGEMENT**: This work was supported by TECHNOLOGY AGENCY OF THE CZECH REPUBLIC, PROJECT NO. TG02010058-GAMA01/007.*

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CHARACTERISATION OF ELECTROSPUN FIBERS MADE OF PVA OR PVAc AND COLLAGEN DERIVATIVE

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Abstract: *One of the greatest potential in electrospun fiber is the area of bioengineering. For many biomedical applications, the materials used have to be biocompatible, thus natural polymers have a distinct advantage over synthetic materials. In this study, electrospinning of collagen derivative (CD) of porcine skin with polyvinyl alcohol (PVA) and polyvinyl acetate (PVAc) were carried out. We investigated morphology, rheology of the prepared fibers. CD incorporation in above-mentioned compositions, allows expanding applications of final nonwoven polymer materials.*

Keywords: *collagen, PVA, PVAc, electrospinning.*

1 INTRODUCTION

Leading global trend in the fibers production technology is to reduce the diameter of threads filament to micro- and nanoscale size. Nanofibers became an important group of one-dimensional nanostructures because of their unique properties such as high surface area, high porosity, and their high safety in comparison with other nanomaterials [1,2]. These abilities improve the quality of products and allows creation of innovative materials. Today there are many methods of ultrafine fibers forming: melt-spinning, aerodynamic spraying molten fibers in the form of a jet of compressed air (melt-blowing), forming a molten mixture of polymers and nanofibers by electrospinning.

Electrospinning has several advantages over other production methods such as the relative ease of use and being cost-effective, production of fibers in a diameter range of lower than 100 nm, easy incorporation of active materials such as drugs, vitamins, antioxidants, metallic nanoparticles, etc. Moreover, organic and inorganic materials, which are temperature sensitive, are resistant to electrospinning process due to the absence of heat [1].

Gelatin is widely employed in food industries, cosmetics, pharmaceutical and medical applications due to its biodegradability and natural abundance. Also, gelatin has shown a great interest in fiber formation via electrospinning technology according to its unique chemo-physical properties such as surface tension along with its viscosity and conductivity [3].

2 MATERIALS AND METHODS

In the present work, we investigated the possibility of increasing the collagen derivative (CD) concentration of electrospinnable solutions by using the mixture of CD with polyvinyl alcohol (PVA) and polyvinyl acetate (PVAc) in suitable ratios. A collagen derivative solution was prepared from skins of young pigs by acetic acid hydrolysis. PVA and PVAc (10 % solution) was prepared by stirring for 40 minutes on a water bath. Afterwards, PVA or PVAc was incorporated into the CD solution, the dispersion was maintained at 25-30 ^{o}C for 30 min under stirring until complete dissolution. We prepared following ratios 9:1, 8:2, 7:3, 6:4 and 5:5 of each of the compositions - PVA/CD; PVAc/CD.

The electrospinning set-up consisted of a 10 ml syringe with stainless steel blunt needle (0.5 mm inner diameter), a home-made syringe pump, and stainless steel plate as fiber collector, power supply 30 kV. The syringe needle was the anode, and the stainless steel plate was the cathode. The spinning geometry was horizontal.

3 RESULTS AND DISCUSSION

Optimum ratios for both PVA and PVAc composition are 9:1, 8:2 and 7:3. The optimal distance between syringe needle and collector was 16 cm. While increasing the CD content takes place drop formation, which leads to impossible electrospinning formation. This requires further studies of rheology characteristics of compositions, the inner diameter of needle and distance between syringe needle and collector. Described the features of the structure (diameter – up to 1 mkm) and properties of nonwoven polymeric materials obtained by electrospinning method.

4 CONCLUSION

Application of collagen derivative allows expanding the applications of final nonwoven polymer materials due to the wide range of reactive groups of collagen and their incorporation with other modifiers such as drugs, vitamins, antioxidants etc.

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RHEOLOGICAL, COLORISTIC AND PROCESSING BEHAVIOUR OF POLYPROPYLENE MASTERBATCHES FOR NANOCOMPOSITE FIBRE PREPARATION

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Abstract: *The current Asian dominance in the world production of standard types of chemical fibres results in the necessity to sophisticate European fibre and textile products. Modification of the mass or surface of materials by nanotechnologies is one of the most prospective ways how to ensure special mono- and multi-functionally modified fibre properties of clothing and technical textiles. Permanent antimicrobial (AMB) treatment of the fibre mass belongs to the most desired functional modifications of chemical fibres. It involves the use of AMB additive masterbatch with appropriate rheological, coloristic and processing properties necessary for the preparation process of AMB modified fibres. This article presents the results of the study of the influence of two types of nanoadditive, as potential carriers of AMB active ingredient, and various dispersing systems on rheological, coloristic and processing properties of polypropylene (PP) nanoadditive masterbatches. The achieved experimental results are evaluated according to suitability of the properties of prepared nanoadditive masterbatches for the process of nanocomposite PP fibres preparation.*

Keywords: *nanoadditive, dispersant, PP masterbatch, rheology, coloristic and processing properties*

1 INTRODUCTION

In textile industry, functional modifications of chemical fibres that provide protective, hygienic and comfort properties of textiles are the most desired. This group mainly includes permanent antimicrobial (AMB) modification of the fibre mass [1-3]. Current market offers AMB additives with the average particle size in micro regions (d_{50} = 2-4 μm). Using nanoadditive as a carrier of AMB active ingredient with much higher specific surface more even spread of AMB active ingredient on the surface of carrier will be achieved. At the same time, AMB efficacy will be achieved at even proportionally lower contents in comparison with current microadditives.

2 EXPERIMENTAL AND METHODS

2.1 Materials

Isotactic powdered polypropylene (PP) with MFI = 10.2 g/10 min (LyondellBasell). Inorganic nanoadditives: A – ultrafine precipitated silica, mean particle diameter 18 nm (Degussa GmbH) and B – ultrafine precipitated calcium carbonate, mean particle diameter 45 nm (Cales de LLIERCA S.A.). Dispersant: D1– the condensation product of PA3 and stearic acid (BASF AG); D2 – condensation product of stearic acid and polyethylene glycol (Clariant Corp.) and D5 – condensation product of stearic acid and propylene oxide (Sloveca s.r.o.).

2.2 Preparation of PP masterbatches

Preparation of PP masterbatches with 10.0 wt. % nanoadditive content (Table 1) was performed on laboratory twin-screw extruder Werner-Pfleiderer with screw diameter 28 mm from PP, nanoadditives and dispersing system at constant screws rotation speed of 250 min^{-1} and constant extrusion temperature 220 °C.

Table 1 Composition of prepared PP masterbatches

Sample	PP [%]	Nanoadditive		Dispersant	
		Type	[%]	Type	[%]
PP	100.0	-	-	-	-
I	86.0	A	10.0	D1	4.0
II	86.0	A	10.0	D1+D2	2.0+2.0
III	86.0	A	10.0	D5	4.0
IV	86.0	B	10.0	D1	4.0
V	86.0	B	10.0	D1+D2	2.0+2.0
VI	86.0	B	10.0	D5	4.0

2.3 Methods used

Measurement of rheological properties of PP nanoadditive masterbatches was made by the capillary rheometer Gottfert RG20 at temperatures 230, 240 and 250 °C in the range of shear rates (D) from 180 to 4500 s^{-1}. Flow consistency index K and flow behavior index n from Ostwald de Vaele power law were evaluated. Viscosity and activation energy of flow were evaluated at shear rates: 500 s^{-1} and 1000 s^{-1}.

Measurement of coloristic properties of nonadditive and nanocomposite PP fibres with the fineness of 3.0 dtex and content of 0.1 – 0.5 wt. % of nanoadditives was performed on the device Hunterlab UltraScanXE. The following coloristic properties were evaluated: L* color gradient light to dark, a* red to green, b* yellow to blue, WICIE– whiteness index, YIE-313/10– yellowness index.

The MFI of PP masterbatches was evaluated using capillary rheo-viscometer Dynisco Kayness according to Standard STN EN ISO 1133. The filterability was evaluated using filtration single-screw extruder with screw diameter 25 mm and pore density of filtration sieve of 16000 pores per cm^2.

3 RESULTS AND DISCUSSION

Appropriate rheology of PP nanoadditive masterbatch melt is an important precondition for its application in the preparation of nanocomposite PP fibres. The results obtained through the study of the influence of the type of nanoadditive, as well as of evaluated dispersing systems (Table 1) on rheological characteristics of the melts of PP masterbatches are presented in Table 2, 3 and 5.

Table 2 Parameters K, n determined from corrected flow curves by Rabinowitsch correction of prepared PP masterbatches

Sample	230 [°C]		240 [°C]		250 [°C]	
	K	n	K	n	K	n
PP	7924	0.389	6855	0.405	5884	0.417
I	9378	0.331	7808	0.345	6144	0.357
II	7149	0.359	6430	0.360	5393	0.368
III	6613	0.360	6471	0.356	6587	0.360
IV	9695	0.324	8013	0.340	7092	0.344
V	7126	0.346	6008	0.361	5537	0.362
VI	6622	0.341	5321	0.360	4793	0.367

Table 3 Activation energies determined from corrected flow curves by Rabinowitsch correction of PP masterbatches

Sample	Activation energies [kJ.mol^{-1}]	
	D = 500 [s^{-1}]	D = 1000 [s^{-1}]
PP	13.5	11.4
I	28.1	26.1
II	24.6	23.9
III	16.1	15.2
IV	21.0	19.5
V	16.9	15.7
VI	17.7	15.8

The types of inorganic nanoadditives as well as the types of used dispersing systems influence the rheology of PP masterbatches to various extents. In terms of rheology for the process of nanocomposite PP fibre preparation the most suitable is masterbatch VI with nanoadditive B and dispersing system D5, since it has the lowest viscosity, it intensifies the non-Newtonian flow characteristics the least, it has the lowest flow consistency index K and low activation energy of the flow.

Appropriate coloristic properties of PP masterbatches are second important precondition. The results of the influence of PP masterbatches on coloristic properties of nanocomposite PP fibres are presented in Table 4.

Table 4 Coloristic properties of nonadditive PP and PP nanocomposite fibres (nanoadditive content 0.50 %, dispersant content 0.20 %)

Sample	L*	a*	b*	WICIE	YIE-313
PP	94.18	- 0.32	- 0.08	86.04	- 0.41
I	94.63	- 1.32	4.44	66.45	7.40
II	94.67	- 0.57	1.76	78.81	2.94
III	94.80	- 0.38	0.56	84.59	0.79
IV	93.87	- 0.76	3.66	68.15	6.42
V	94.29	- 2.02	5.95	58.61	9.66
VI	94.96	- 0.39	0.11	87.01	- 0.09

The types of nanoadditives as well as the types of used dispersing systems influence the coloristic properties of nanocomposite PP fibres. In terms of coloristic properties the masterbatch VI with nanoadditive B and dispersing system D5 is most suitable for the process of PP nanocomposite fibre preparation. When it is used, the coloristic properties of nanocomposite PP fibres are practically comparable to nonadditive PP fibres.

The third important precondition for the application of PP nanoadditive masterbatches is its suitable processing properties. The results of the evaluation of processing properties of prepared PP nanoadditive masterbatches are presented in Table 5.

Table 5 Melt flow indexes (MFI), viscosities (η), filterabilities (F) and variation coefficients (CV_X) of prepared PP masterbatches

Sample	MFI* [g/10min]	CV_M [%]	η* [Pas]	CV_η [%]	F [MPa/kg]
PP	10.2	2.2	797.2	2.1	-
I	9.2	4.4	905.7	4.3	559
II	11.7	3.5	709.6	3.5	723
III	9.8	1.8	836.1	1.8	1369
IV	9.2	4.3	918.1	4.3	184
V	11.4	2.4	728.5	2.3	94
VI	11.4	2.3	728.5	2.3	94

* 230 °C/2.16 kg (shear stress τ = 19500 Pa)

The results of the evaluation of processing properties show that the prepared PP masterbatches are suitable in terms of MFI and viscosity. However, in terms of the most important parameter filterability only nanoadditive B masterbatches (samples IV-VI) are suitable. Low filterability of these masterbatches shows the high degree of dispersion of nanoadditive in PP matrix.

4 CONCLUSION

The obtained results show that the types of nanoadditives as well as the types of dispersing systems influence the rheological, coloristic and processing properties of PP masterbatches to various extents. Precondition that the suitable masterbatch must have suitable rheological, coloristic and processing properties was met only by the masterbatch VI with nanoadditive B and dispersing system D5. From the rheological aspect, this masterbatch intensifies the non-Newtonian flow characteristics the least, it has the lowest flow consistency index K and low flow activation energy. At the same time, it is suitable also from the coloristic aspect, because the coloristic properties of nanocomposite PP fibres are practically comparable to nonadditive PP fibre. This masterbatch also has suitable processing properties, mainly filterability. Its low value proves a high degree of nanoadditive dispersion in PP matrix, so this masterbatch has no negative impact on stability of the preparation process of nanocomposite PP fibres. It follows from the above that nanoadditive B is a perspective potential carrier of AMB active ingredient for PP fibre systems, provided that it is additived in the mass of nanocomposite PP fibres with PP masterbatch VI.

Acknowledgement: *This work was supported by the Slovak Research and Development Agency under the contract No. APVV-15-0016.*

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BUFFERING AND ANTIBACTERIAL PROPERTIES OF COTTON CANVAS WITH DOLOMITE/ZnO-STYRENE-ACRYLIC COMPLEX COATING AND THEIR COMPARISON WITH PROPERTIES AFTER THE ACCELERATED AGING

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Abstract: *In this study, we report evaluation of buffering and self-sterilizing coating complex obtained by dolomite and zinc oxide particles incorporation into styrene–acrylic layer applied to cotton fabric. Surface properties of the coating were evaluated by SEM, EDS and 3D optical microscopy. Antimicrobial properties were determined using a mixture of G+ and G- bacteria (Escherichia coli, Staphylococcus epidermidis and Streptococcus mutans) that was in dynamic contact with canvases for 24 hours. Alkalizing - buffer capacity of the surface layer supplied to the system by dolomite was tested by the addition of acetic acid. All these properties were simultaneously tested on the same canvases that have been previously exposed to the so-called hot (105 °C) and wet aging (80 °C, 65 % RH). The aging was provided in the climatic test room for 144 hours and the properties of canvases before and after aging were compared and evaluated.*

Keywords: *dolomite, zinc oxide, acrylic coating, antibacterial, bicarbonate buffer*

1 INTRODUCTION

Composite materials based on metal (nano)particles attract significant attention due a wide range of physical–chemical properties. These materials are not simply physical mixtures. They can be defined as complex materials with organic and inorganic components intimately mixed. Modification of coating polymeric matrices leads to novel properties such as growth prevention or adhesion reduction of microorganisms. There is a significant interest in the development of antimicrobial and durable materials for application in the food industry, or biomedical devices. In some fields, such as archiving museums, librarianship, preservation or storage, the longtime of their use and aging of materials increase the demands on these properties. These materials should combine desirable attributes such as potent bactericidal and fungicidal efficiency, environmental safety, low toxicity, and easy, cost-effective fabrication.

Carbonates are salts of carbonic acid and occur in the form of minerals and rocks commonly found in nature. Especially alkaline earth metal carbonates (Ca^{2+} and Mg^{2+}) are very widely used in many productions and industrial processes, for example in the construction industry [1], food [2], metallurgy [3], for the treatment of contaminated water and soil [4] [5], and fertilizers [6]. Calcium carbonate $CaCO_3$ (limestone) occurs in many crystalline modifications (calcite, aragonite, alabaster, travertine, marble). Also, magnesium carbonate $MgCO_3$ and calcium magnesium carbonate $CaMg(CO_3)_2$ are naturally found in many modifications, varieties and with different chemical impurities (Fe, Mn, Zn, Pb and others). [7] Dolomite is a non-toxic, inexpensive, widely available double carbonate with slightly alkaline and buffering capabilities. It crystallizes in the trigonal-rhombohedral system and depending on the admixture it is white, gray or pink. Unlike bicarbonates, carbonates, except for ammonium carbonate and alkali metal carbonates, are practically insoluble in water. Carbonates are important environmental buffering agents. They are part of the carbon dioxide/bicarbonate/carbonate buffer, which, above all, serve the world's oceans to neutralize and counterbalance acidic influences in the environment. This buffering system is also key in many biological processes such as maintaining a constant blood pH [8] and internal environment within homeostasis (1).

$$CO_2 + H_2O \leftrightarrows H_2CO_3 \leftrightarrows HCO_3^- + H^+ \quad (1)$$

Zinc oxide ZnO at low concentration is non-toxic to human and displays good biocompatibility to human cells. ZnO showed a wide range of antibacterial activities of different microorganisms, including both Gram-negative and Gram-positive bacteria. [9] It was also confirmed that reinforcement of ZnO in the biocomposites introduces their antibacterial activity. [10]

2 EXPERIMENTAL PART

2.1 Preparation of samples

Cotton fabric (Royal, PK) was used for preparation of coated canvas (area weight 156 g/m^2, thickness 0.29 mm, plain weave, fineness of warp yarn 50 tex, fineness of weft yarn 40 tex, pre-dyed with the Direct Green 28 (CI No. 14155, azodye, concentration 0.5 %), coated with starch on the reverse side, width 50 cm. Acronal S 996 S (BASF SE, GE) - aqueous polymer dispersion based on ester of acrylic acid and styrene (viskosity of 2 Ns/m^2) was used as a basic coating paste. All following additives were thoroughly mixed into this basic matrix: laboratory-prepared cellulose dispersion to increase strength [11] [12], granulated natural pink dolomite (Forestina, CZ), powdered zinc oxide declared as nanoparticles (Bochemie, CZ), two benzisothiazole pigments: Aquacolors Red (temperature resistance 160 -180 °C and light fastness 5-6, pH 7.5; Sioen, BE), and Aquapaste Green 856 (temperature resistance to 200 °C and light fastness 8, pH 8; Orgapaste, FR).

Part of the canvas was subjected to the artificial accelerated aging. According to standards [13] and [14] for accelerated aging of paper and board by dry heat treatment or moist heat treatment, part of the canvas was subjected to the so-called hot aging (at 105 °C for 144 hours), another part of the canvas was subjected to the so-called wet aging (at 80 °C and 65% of relative humidity for 144 hours). The relation between accelerated and natural aging represents a serious problem. The changes monitored upon accelerated aging procedures must be correctly extrapolated to the ambient conditions. Nevertheless, in accordance with data in the literature, it is stated that three days of accelerated aging of paper and other cellulosic materials at 105 °C correspond to 25 years of natural aging. [15]

2.2 Characterization of coating surfaces

The particle size used as additives and the appearance of the coated surface were scanned by optical methods. Particle size of ZnO and dolomite was measured using the particle size analyzer and laser scattering device (HORIBA LA-920, JP). The surface and cross-section of canvas were monitored using SEM scanning electron microscope VEGA TS 5130 (TESCAN, CZ) and the 3D digital multifunction microscope HIROX RH 2000 with MXB 2500REZ lens and diffuse adapter (HIROX, JP). This optical method also characterized the canvas surface roughness Rz. In accordance with standard JIS [16], Rz is the sum of the average absolute value of then height (five highest peaks) and the average absolute value of the depth (five lowest valleys from the average line of he roughness curve) on the weft yarn, in microns. Ten-spot average roughness was chosen at zoom 500x. Energy-dispersive X-ray spectroscopy (EDS), when backscattered electrons at a sampling depth of 1-2 microns characterize the chemical composition of investigated surface, is part of SEM device. EDS was chosen as a method of chemical characterization of the coating surface and percentage quantification of the monitored metals (Zn, Ti, Ca, Mg).

2.3 Buffering test

Twenty-five cm^2 of each canvas including the reference sample (cotton fabric coated with only acrylic coating without additives) was immersed in 50 ml of purified deionized water for 2 days at 22 ± 2 °C to achieve an equilibrium of water with both CO_2 from the atmosphere and carbonate containing dolomite. After 48 hours, the pH of the water in each beaker was measured. Then 0.5 ml of 27 mM acetic acid was added to each beaker. All pH changes were continuously potentiometrically measured at various time intervals up to 24 hours after application of acetic acid using glass silver chloride reference electrode.

2.4 Microbiological test

A mixture of G+ and G- bacteria containing *E. coli, Staphylococcus epidermidis and Streptococcus mutans* was prepared using a liquid culture medium Trypto-Soya Broth (TSB) (Biovendor, CZ) at 37 °C for 24 hours. By dilution with distilled water, bacterial suspension of concentration 10^5 CFU/ml was prepared. Thirty ml of this suspension was dosed into plastic tubes, to which samples of all four cloths were added (each with an area of 32 cm^2), i.e. canvas without aging, canvas after hot aging, canvas after wet aging, and comparative sample (canvas without addition of additives). One tube with bacterial suspension was left without the addition of canvas. All samples inserted into the bacterial suspension in tubes were shaken for 4 hours on a shaker at speed of 150 rpm to achieve dynamic contact of the bacterial suspension with the canvas surface. After 1, 8 and 24 hours, 1 ml of suspension was taken from each tube, it was spotted on the surface of the agar in Petri dishes (TSA-Tryptone soya agar, Biovendor, CZ). These samples were cultivated at 37 °C for 24 hours and then bacterial colonies were counted.

***ACKNOWLEDGEMENT**: This work was supported by the project No. DF13P01OVV004 Exploration, conservation and care of modern library collections - materials and technologies provided by the Ministry of Culture within the Program of applied research and development of national and cultural identity (NAKI).*

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THE TESTS OF CYCLIC LOADING OF COMPOSITES WITH TEXTILE STRUCTURE ON TEST MACHINE WITH VIDEO-EXTENSOMETER

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Abstract: *In this contribution, the composites with textile reinforcement and rubber matrix are studied experimentally. The reinforcement is in the form of fibre and material is PA 6.6 and PES. These composite with textile structure are applied in tyres for passenger cars, conveyor belts etc. The aim of research work of authors is design of method for cycle loading tests of composites which consist of textile and steel cords together. The test machine Autograph with test mode Control of software Trapenzium X is used for tests of cyclic loading in tensile with cycle loops. The image analysis is applied for obtaining of information about geometry parameters of cords. The results of tests and geometry parameters are needed for creation of computational models of composites such as parts of tyre-casing by Finite element analysis.*

Keywords: *composite, textile fibre, PA 6.6, PES, tyre, cyclic loading, video-extensometer, cycle loop*

1 STRUCTURE OF TYRE PARTS WITH TEXTILE

The standard automobile radial tyre is typically composites with textile and steel reinforcement and rubber matrix which consists of elastomer parts and parts with textile-cords (especially PA 6.6 and PES rayon textile fibers are used) and steel-cords in tyre tread as reinforcements.
The cord structure of selected tyre-casing, which is designated as 245/40 R18 type, is represented on Fig. 1.

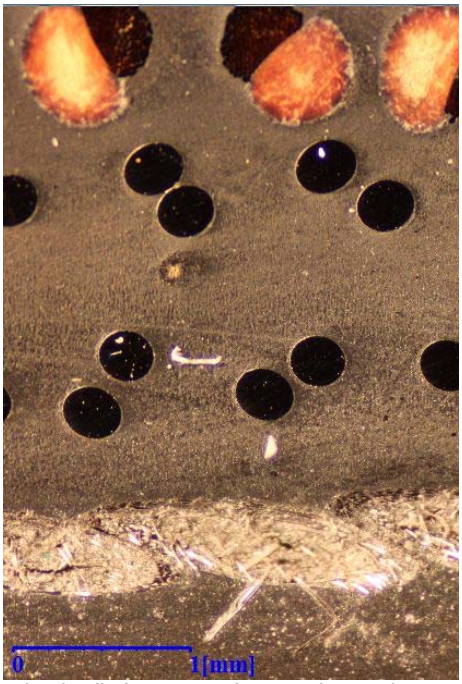

Figure 1 The detail of structure of tyre-casing 245/40 R18

The sidewall also shows the material of cords and number of plies in the sidewall and under the tread of tyre-casing.

The sidewall of tyre for passenger cars consists of one polyester ply and into tread are namely four plies: one polyester-, two steel- and one polyamide- ply. The tyre with symbol Extra load may have two polyester or two polyamide plies.
The detail of polyamide cord in tread is on the Fig. 2.

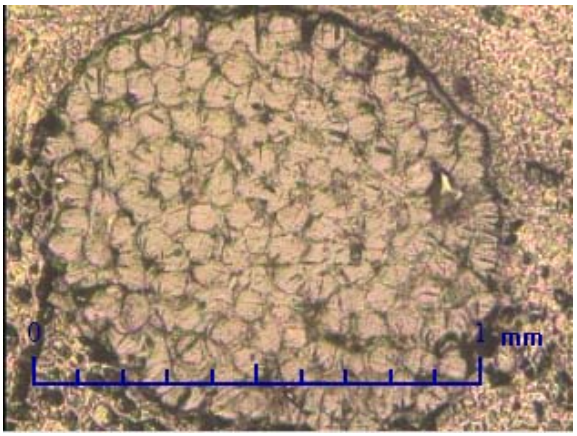

Figure 2 Polyamide cord in tread of tyre-casing 245/40 R18

2 METHOD FOR CYCLE LOADING

The tests of cyclic loading of these composites are requested for the verification analysis between experiments and computational modeling of tyres. Standards and methodology of optimal testing of composites with textile structure have not been determined yet but the determination can be based on the behaviour of elastomers under cyclic loading [1]. For textile materials, DIN 53835-13 standard is defined [2] and according to mentioned standard the conditions are takes into consideration during the first 5 cycles.
The test machine Autograph AG-X plus 5 kN – Schimadzu with video-extensometer with test mode Control of software Trapenzium X is used for tests of cyclic loading in tensile with cycle loops.

The design of method for cycle loading tests of composites with textile fibre and rubber matrix on test machine with video-extensometer is necessary. The method for different elongation with cycle loops is designed.

3 IMAGE ANALYSIS OF COMPOSITES

The geometric configuration of the reinforcements is the main factor for the specification of the materials parameters, which would be used for description of the whole area of casing under the tread.
The image analysis is applied for obtaining of information about geometry parameters of cords such as distances between cords, ply thickness and cord diameters etc.
The geometric parameters of the reinforcements of tyre-casing 245/40 R18 are showed on the Fig. 3.

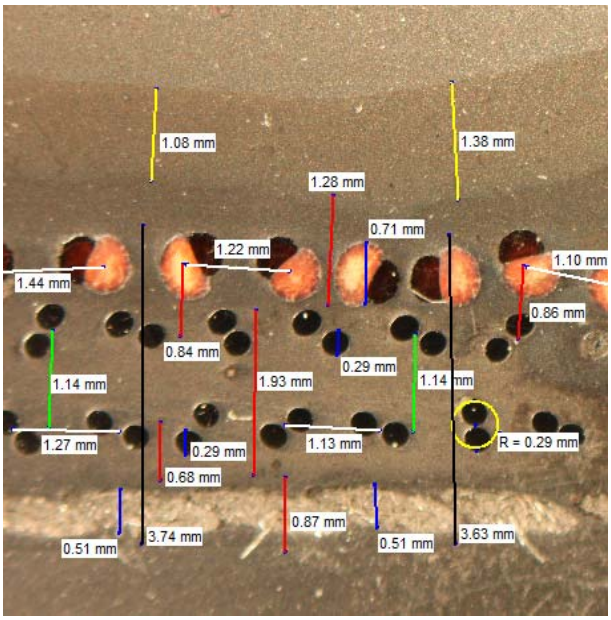

Figure 3 The image analysis of part of tyre-casing 245/40 R18

4 FUTURE WORKS

The test machine Autograph AG-X plus 5 kN – Schimadzu has temperature chamber allows the tests from -70 to + 180 °C and from +20 to + 80 °C it is possible change humidity from 30 to 95 %. In the future the cyclic loading of composites at different temperatures will be possible.
The experiment results can be used for the optimization of the deposition angle of textile reinforcement in composites.

***ACKNOWLEDGEMENT**: The contribution was suported by the Cultural and Educational Grant Agency of the Slovak Republic (KEGA), grant No. KEGA 005TnUAD-4/2016 and the project „Centrum pre testovanie kvality a diagnostiku materiálov“ ITMS code 26210120046 of the Operational Program Research and Development funded from European Fund of Regional Development.*

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THE EFFECT OF LOW-TEMPERATURE PLASMA ON PP NONWOVENS SURFACE

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Abstract: *Low-temperature plasma treatment has been used in the last years as a useful tool to modify the surface properties of different materials, in special of textiles. In the present work low-temperature plasma was used to treat surface of polypropylene (PP) nonwoven. The innovative plasma source based on Diffuse Coplanar Surface Barrier Discharge (DCSBD) generates homogeneous plasma at atmospheric pressure was used in this study. Extremely high power density of plasma up to 100 W/cm^{-3} allowed short plasma exposure times. The main aim of this work was to study the influence of the exposure time (30 - 120 s) at power 389 W supplied to atmospheric air plasma on selected properties like hydrophilicity/wettability of PP nonwovens. Characterization of the functional changes due to the plasma treatment has been carried out by means of Fourier transform infrared spectroscopy (FTIR–ATR). Plasma treatment on PP nonwoven results in contrast of untreated PP nonwoven the formation of new bands that corresponds to a carbonyl and hydroxyl groups. These functional groups are responsible for improved hydrophilic properties. The surface morphology of the untreated and plasma-treated PP nonwovens was analyzed by scanning electron microscopy (SEM). The SEM clearly showed that low-temperature atmospheric plasma modified the surface of PP fibers.*

Keywords: *polypropylene, plasma, DCSBD, SEM microscopy, IR spectroscopy*

1 MATERIALS AND METHODS

The PP nonwovens (surface weight: 0.176 kg.m^{-2}, thickness: 0.95 mm) was selected for the study. All experiments were carried on using laboratory equipment for application of low-temperature plasma under atmospheric pressure KPR 20 (Fig. 1).

Figure 1 Plasma laboratory equipment KPR 20

Plasma reactor using DCSBD (Diffuse Coplanar Surface Barrier Discharge) plasma systems. Time of plasma PP surface treatment was 30 - 120 s and power 389 W. Distance between nonwoven surface and active plasma area (plasma electrodes) was 1.15 mm.
Low-temperature plasma treatment modified the surface of PP nonwovens.

2 SCANNING ELECTRON MICROSCOPY (SEM)

The surface morphology of PP fibers was examined by the VEGA3, TESCAN Scanning Electron Microscope, with an accelerating voltage of 0.20 kV to 30 kV and probe current of 1 pA to 35 μA at a high magnification between 1000x – 50 000x. The basic PP nonwoven and treated sample can be seen from the SEM-images in Fig. 2. The SEM images of plasma treated samples showed that PP nonwoven surface has been roughened.

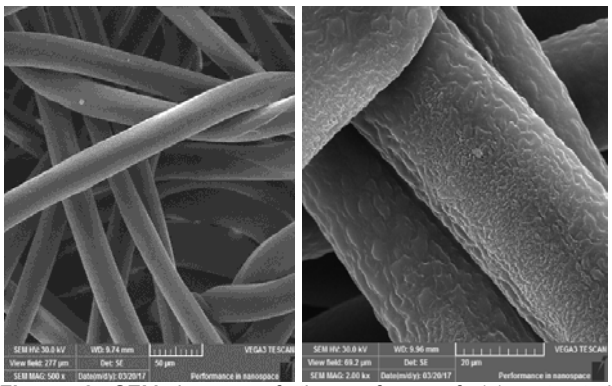

Figure 2 SEM images of the surfaces of (a) untreated (magnification 500x) and (b) treated DCSBD plasma PP fibers at nonwoven fabrics (magnification 2000x)

ACKNOWLEDGEMENT: *The contribution was suported by the Slovak grant agency KEGA, project No. 005 TnUAD-4/2016, VEGA 1/0589/17 and the project „Centrum pre testovanie kvality a diagnostiku materiálov" ITMS code 26210120046 of the Operational Program Research and Development funded from European Fund of Regional Development.*

THE EVOLUTION OF THE MICROSTRUCTURE OF CANE CELLULOSE MICROFIBRILS DURING COLD CAUSTIC EXTRACTION

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Abstract: *Cellulosic fibrous fillers can be used in the preparation of biocomposite materials. A method of cold caustic extraction from a cane was used. Determined the character of distribution changes of cellulose fibers by transverse dimensions, depending on delignification process conditions.*

Keywords: *biocomposite polymeric, structure, cellulose, extraction.*

1 INTRODUCTION

Application of renewable natural resources is one of the strategic directions of the modern technologies development. This is due to the environmental problems and the need to create materials that are safe for the environment. While obtaining biocomposite polymeric materials as functional fillers, tend to use different substances of natural origin. The most common and eco-safe filler among synthetic polymers is cellulose, which is traditionally derived from wood of different breeds. At the same time intensively studied and other "non-wood" source of fiber cellulose semi products. One of the popular directions of the before mentioned research is using bamboo (*Bambúsa*) as rapidly renewable resource of fibrous cellulose with high physical and mechanical characteristics.

2 MATERIALS AND METHODS

Plant cane (*Phragmites communis*), like a bamboo, belongs to the grass family (*Gramíneae*). This determines viability of performing studies in application of this plant as feedstock for obtaining eco-safe micro-fibrillar cellulose fillers. Isolation of cellulose micro-fibrils performed by cold caustic extraction. The main technological parameters that affect this process are the concentration of alkali and the process duration. Investigation of the cellulose fibers structure was performed by polarization light microscopy (Figure 1), followed by image analysis and statistical data processing.

The following study describe the influence of the concentration of alkali solution (NaOH) and treatment time on the cellulose yield, structure and dimensional characteristics of the fibers.

3 RESULTS AND DISCUSSION

Determined the dependence of the cellulose yield of the NaOH concentration and treatment duration. Established that increasing of the concentration of alkali from 2 % to 10 % results in almost linear decrease in the cellulose yield from 79 % to 66.5 %. With further concentration increasing from 10 % to 18 %, changes in cellulose yield is not significant. Increasing of steeping time from 1 to 7 days also reduce cellulose yield from 78.8 % to 66.5 %.

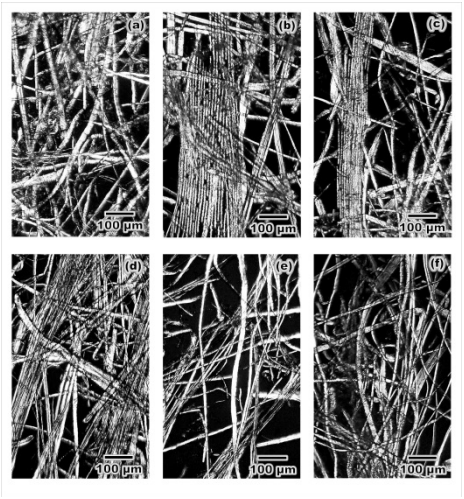

Figure 1. PLM image with crossed polars of cane cellulose microfibrils, extracted from cane (NaOH, 10 wt %; 20˚C). Time processing (day): (a) 1; (b) 2; (c) 3; (d) 4; (e) 5; (f) 6.

Modelled the extraction process by the resulting data of bivariate interpolation method. The best value of NaOH solution concentration (12-13 %) and treatment time (3.5-4 days). Experimental verification of the cellulose yield at specified process parameters showed that the resulting value (67.8 %) is consistent with model representations.

4 CONCLUSION

Determined the character of distribution changes of cellulose fibers by transverse dimensions, depending on delignification process conditions. It was shown that reducing the mean value of fibers cross size to 9.3 mkm may be due to increased concentrations of NaOH to 18 wt %. Increased duration from 4 to 7 days has no influence on the average size of the fibers, but increases the uniformity of their distribution by size.

DEPENDENCE OF WATER VAPOR PERMEABILITY OF KNITTED SAMPLES ON THEIR WETTING LEVEL

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Abstract: *Along with the development of the new fiber materials, improvements of the knitting technology and new testing methods & instruments of fabric comfort evaluation are created. In the study, a new property of knitted structures, their water vapor permeability in the wet state, was experimentally determined. The evaluation of drying rate of the wetted samples together with the measurement of water vapor permeability of the samples shows the almost linear dependence of these parameters on wetting level of the all tested structures including single jersey, rib and interlock with different fabric construction.*

Keywords: *knitted fabric, water vapour permeability in wet state, measuring method, Permetest instrument.*

1 INTRODUCTION

To analyze successfully the effect of water vapor permeability of knitted structures in wet state, it should be noted that a knitted fabric has a different mechanical behavior in different directions. Various constructions of structures cause different structural parameters in wale-wise and course-wise directions and together with the structural properties of multifilament (count, number and cross section of fibers, bending properties) they influence the water vapor permeability [1].
Firstly, relative water vapor permeability (RWVP) under standard (dry state) conditions of 11 weft knitted samples was determined. RWVP is the ratio between the cooling heat flow q_{fab} passing through the tested fabric inserted in the PERMETEST instrument and the cooling heat flow q_o passing through the measuring head of this instrument without any fabric covering the measuring surface, see the Eq. (1)

$$RWVP = 100 \; q_{fab} / q_o \qquad (1)$$

The aim of the study is to measure the effective relative water vapor permeability ERWVP of wet fabrics. However, determination of the ERWVP of wet fabrics is not easy [2]. The total heat flow (q_{tot}) transferred through the boundary layer of the fabric surface is given by the sum of heat flow passing from the skin through the permeable fabric $q_{fab\ w}$ and heat flow $q_{fab\ surf}$ caused by temperature gradient between the skin and fabric surface, which is cooled by evaporating of water from the fabric surface

$$q_{tot\ w} = q_{fab\ w} + q_{fab\ surf} \qquad (2)$$

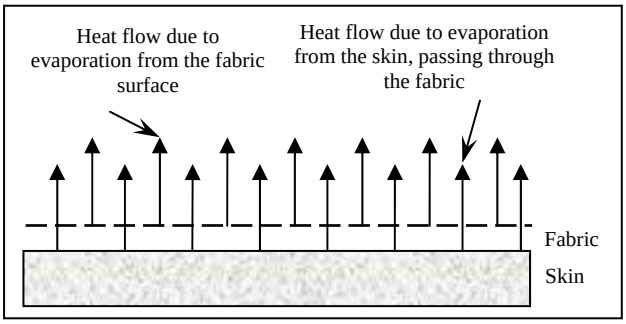

Figure 1. Cooling flows from a wet fabric

In order to determine the effective RWVP by means of the PERMETEST instrument, it is necessary to execute 2 different measurements on the same sample. In the first step, the relative cooling heat flow $q_{tot\ w}$ (Eq. 1) passing through the wetted sample and the generated by the wet sample surface is measured. In the next step, the measuring head of the PERMETEST instrument is covered by an impermeable foil, which stops the effective relative cooling flow $q_{fab\ w}$ through the wet fabric. Thus, we would determine the relative cooling flow $q_{fab\ w}$ from the wet fabric surface only. The difference between both these measurements yields the required relative cooling flow $q_{fab\ w}$, which also presents the effective RWVP.

2 MATERIALS AND METHODS

D Different 11 samples in single jersey rib and interlock weft knitted fabric structures (100% PP multifilament) were produced for the purpose of this study and testing. In order to determine the ERWVP in wet state by using the PERMETEST apparatus, it is necessary to carry out several different measurements on the same wet knitted sample. As already explained, at first the relative cooling heat flow passing through the wet sample together with the cooling flow generated by the wet sample surface are measured. In the second step, the measuring head of PERMETEST instrument is covered by an impermeable foil. Thereafter, we measure the relative cooling flow from the wet fabric surface only. Then the sample is a little dried up and the measurement continues with the same way to the 20 % of wetting level (7 times) [3].

.

3 RESULTS AND DISCUSSION

The water vapor permeability is the ability of the fabric to transmit water vapor (WV) from the body. If the evaporation resistance is too high for the WV transmission and simultaneously the thermal resistance of the textile layers covering our body is high, then the body is not enough cooled by the evaporated sweat, heat generated in the body cannot be dissipated and causes an uncomfortable feeling [4,5].
It can be seen that relative water vapor permeability values in dry state RWVP of weft knitted rib fabrics (different structures) increases with the fabric density.

The effect of the knitted construction on relative water vapor permeability is statistically significant.

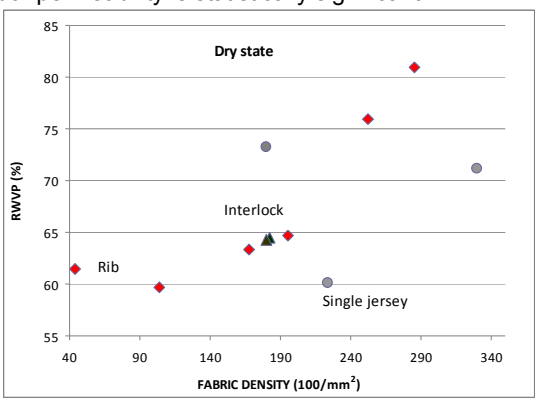

Figure 2. Dependence of the relative water vapor permeability of all samples in dry state on fabric density

The Figure 3 indicates the dependence of the wetting level on the relative water vapor permeability. All samples exhibit similar behavior during the process of drying and measurement of the RWVP in wet state, but the values differ from each other.

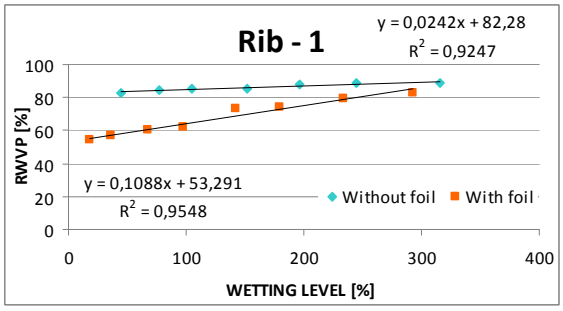

Figure 3. Dependence of the wetting level on the RWVP of weft knitted samples with rib structure. The upper curve shows the total relative cooling flow (total RWVP), whereas the lower line Presents the relative cooling flow q_{fab} evaporated from the wet fabric surface.

The differences of ERWVP are plotted in the Figure 4. With the increasing mass of the weft rib knitted samples the ERWVP values are decreasing.

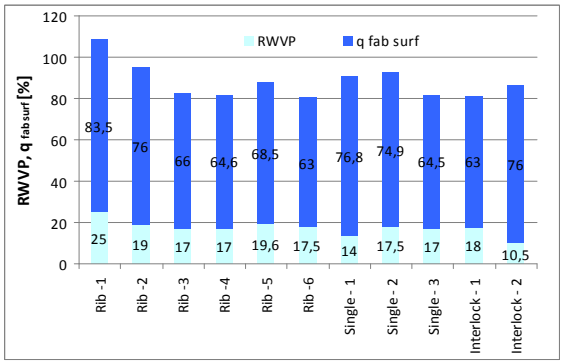

Figure 4 Substantial reduction of the total relative water vapour permeability RWVP of various knitted structures caused by the 50 % relative moisture content in the fabrics. The effective RVWP or effective cooling flow for the Interlock - 2 is only 11% of the total cooling flow.

***ACKNOWLEDGEMENT**: We express our thanks the MOIRA company from Strakonice Czech Republic for providing their unique samples for our testing.*

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STUDY ON MECHANICAL PROPERTIES OF JUTE FIBER REINFORCED JUTE-RECYCLED POLYESTER RESIN EPOXY COMPOSITE

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Abstract: *The effects of alkali treatment and mixing proportion of recycled and virgin polyester resin on the mechanical properties of jute fiber reinforced Jute-Polyester resin hybrid epoxy composite had been studied. To improve the mechanical properties of jute fabric reinforced composites, jute fabric was treated with 5% alkali (NaOH) solution for different time durations (3 hrs. 5 hrs. 7 hrs.) at room temperature followed by used as reinforcing material to produce jute/unsaturated polyester resin epoxy composites. Recycled (R-UPR) and virgin (V-UPR) unsaturated polyester resin were used at different combinations (100%V-UPR, 100%R-UPR, 50%V-UPR and 50% R-UPR) as epoxy. The effect of alkali treatment and mixing proportion of recycled and virgin polyester resin on tensile strength, tensile modulus, flexural strength and flexural modulus of the composites were studied and characterized as referred as in corresponding ASTM standards. Results indicated that, due to better adhesion of polyester resin with alkali treated fiber matrix present in jute fabric shows an improvement on tensile strength and flexural strength compared to untreated composites. Besides, higher tensile and flexural strength on the composite produced by using recycled polyester resin compared to the composite produced by using virgin polyester resin also been perceived in the consequences..*

Keywords: *Alkali treatment; Recycled Polyester Resin; Epoxy composites; Mechanical properties; Jute fabric;*

1 INTRODUCTION

Most of the natural fibres are very strong and they are relatively cheap. Among the natural fibres jute fibre has high tensile strength than other natural fiber like flax, sisal, coir fibers which can be used as reinforcement in composites.[1-3] Unsaturated polyester resin usually synthesized from recycled PET in the form of flakes was obtained by crushing PET beverage bottles.[4] An advantage of recycled polyester resin is reduce plastic waste, improve the environmental performance, good adhesion properties with jute reinforcement, reduce the cost of the raw material, minimize usage of petroleum product, low density and Minimum water absorption. In this work, an attempt made to produce low weight modified alkali treated Jute reinforced composite using 100% virgin unsaturated polyester resin (V-UPR), 100% recycled unsaturated polyester resin (R-UPR) and combined 50% V-UPR / 50% R-UPR.

1.1 Materials

The jute woven fabric (260 GSM, 11 EPI, 10 PPI, warp and weft count of 8 Ne and fabric width 44 inches) was procured from Chetty & Co. Ltd. (India). Sodium Hydroxie (NaOH, 97%,mw-40 gm/M), recycled (density 1.12g /cc, Viscosity 220-300 CPS, Acid value 13-14, Gel time 5-6°C/min) and virgin unsaturated polyester (PET) resin (density 1.14g /cc, Viscosity 260-320 CPS, Acid value 20-21, Gel time 6-7°C/min), Methyl ethyl ketone peroxide ($C_8H_{18}O_6$) and Cobalt octate ($(C_8H_{15}O_2)_2Co$) were procured from Aiswarya Polymers (India) with analytical grade, and used as received without further purification.

1.2 Methodology

The required jute fabrics were pretreated with alkaline solution at 30°C maintaining a liquor ratio of 20: 1. Composites were produced by hand lay-up technique for prepreg preparation and a tailor made mold was used to produce the composite of size (25 x 25 x 0.4) cm.

2 RESULT AND DISCUSSION

Effect of alkali treatment on jute fiber and behavior of tensile and flexural properties were studied.

2.1 Effect of alkali treatment on weight loss of jute fabric

In this process, hemicellulose and lignin were removed from the fabric; hence the fabric loses its weight. Figure 1 illustrates the Weight loss % of jute fabric after alkali treatment. It has been found that, the difference between weight loss at 3 hours and 5 hours treatment periods is 1% only. But at 7 hours treatment period the weight loss is nearly double compared to the 5 hours treatment period.

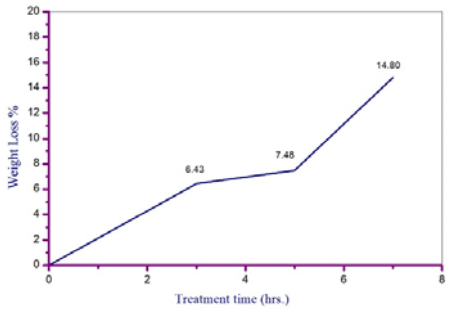

Figure 1 Weight loss % of jute fabric on different alkali treatment time.

2.2 Improvement of tensile properties

All alkali treated fabric composites compared with control sample (0h). Composite consist of 5 hrs treated jute reinforcement shows the higher tensile strength and modulus composite with 3 hrs treated fabrics shows the decreased in the modulus and tensile strength. This is because of the loss of the structural integrity in the amorphous cellulose and contribution to withstand the applied load. It has clearly observed that the NaOH treatment improves the tensile strength and Energy to Break Point. An improvement in the tensile strength of the composites consists of untreated fabric and fabric treated with 5% NaOH for 3 hrs has increased from 59.576 MPa to 81.976 MPa for composite produced by combined 50% Virgin unsaturated polyester resin and 50% recycled unsaturated polyester resin. This can be understood that the removal of the hemicellulose and a part of the lignin by alkali treatment can increase the interfacial adhesion between the matrix and NaOH treated fabric.

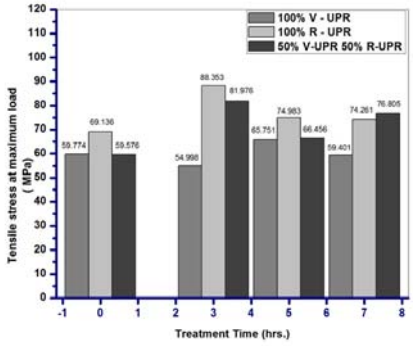

Figure 2 The comparative tensile strength analysis of composite prepared by 100% virgin unsaturated polyester resin (100%V-UPR), 100% recycled unsaturated polyester resin (100%R-UPR) and combined both 50%V-UPR and 50% R-UPR

2.3 Improvement of flexural properties

The flexural behavior of composites having 4plies of 0hr, 3hrs, 5hrs and 7hrs treated and untreated jute fabric reinforced composite prepared by combined 50% Virgin-unsaturated polyester resin (V-UPR) and 50% Recycled-unsaturated polyester resin (R-UPR) found similar with the trend of tensile strength. It is evident that alkali treated jute fabric laminates consistently improved the flexural strength compared to the untreated jute fabric laminates. The flexural strength and modulus were consistently better for 3hrs, 5hrs and 7hrs alkali treated jute fabric laminates compared to untreated jute fabric laminates. Maximum flexural strength and modulus values were consistently obtained from 3hrs alkali treated jute fabrics laminates composite in comparison to the 5hrs and 7hrs alkali treated jute fabrics laminates.

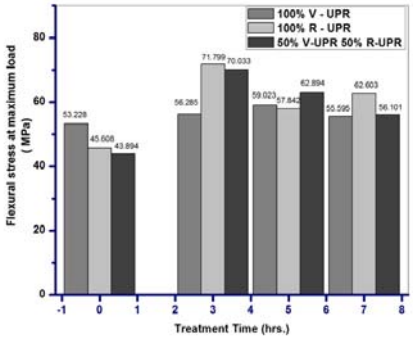

Figure 4: The comparative flexural strength analysis of composite prepared by 100% virgin unsaturated polyester resin (100%V-UPR), 100% recycled unsaturated polyester resin (100%R-UPR) and combined both 50%V-UPR and 50% R-UPR

2.4 Conclusion

The composites produced presented a brittle behaviour with higher tensile and flexural properties. The fibres were finer after treatment of fabrics, having less hemicellulose content, increased crystallinity, reduced amount of defects resulting in superior bonding with the unsaturated polyester resin. The mechanical properties were maximum when reinforced around 3–5 h treated jute fabric. The results showed that the mechanical properties are varied indicating the possibility of two different failure modes before 2h and after 5h treatment.

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IMPACT OF MULTIPLE HOUSEHOLD WASHINGS ON THE PROPERTIES OF REUSABLE NAPPIES

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Abstract: *The impact was investigated of household laundering on the properties of reusable nappies. After performing multiple washings of nappies, secondary laundering effects were evaluated as decrease in breaking strength, stiffness and colour characteristics. The sorption characteristics were also evaluated of both unwashed and washed nappies. The results of the investigation shows that the overall characteristics of reusable nappies after 200 washing cycles in a household washing machine are surprisingly good. Analyses of the obtained results helped to define the optimum laundering protocol and conditions for household washing of highly absorptive textiles.*

Keywords: *textile laundering, household washing machine, reusable nappies, laundering effects*

1 INTRODUCTION

Since the 1960s, when the first children`s nappies were introduced, their main function has remained unchanged, to absorb and retain body fluids while keeping the skin dry and heathy. By 1990, disposable nappies were used in more than 90% of households in most European countries. Today, disposable nappies (for children or adults), are a still growing fraction of municipal waste in the EU28 and, thus, create additional pressures on the environment [1,2]. The highest amount of generated waste in the EU28 was noted in the year 2014 (2,598 million tons), where households share 8.1% or 209 million tons [3]. It is estimated that around 2-3% of household waste is disposable nappies (approx. 4.1 to 6.3 million tons/year). Therefore, the use of reusable, (or cloth), nappies could contribute to the reduction of household waste. The aim of this research was to evaluate the impact of multiple washings on the properties of the reusable nappies. The laundering effects and sorption characteristics were carried out in accordance with valid Standards and guidelines.

2 EXPERIMENTAL PART

2.1 Materials

A cotton ballast load (3.5kg, consisting of sheets, pillow cases, towels), and reusable nappies (Kiss, Knof so.op., SI), which are composed from multi-layer knitted fabric was used in the research. The knitted fabric consisted of 100% cotton in the outer and inner layers, while the middle layer (absorption layer) was a blend of bamboo and PES (77%/23%).

2.2 Laundry equipment

Multiple washings of nappies were performed in a household washing machine SensoCare W7643L Gorenje d.d. (SLO) (capacity of 7kg, drum volume of 54 L). The classical laundering procedure (Cotton/Normal), which was optimised in a previous stage of the investigation (laundering phase duration, agitation), was performed 200 times according to SIST EN 60456. Each laundering cycle began with loading the washing machine with ballast fabric and reusable nappies, followed by automatic dosing of water (conduct < 10 µS/cm; TWH 2.5±0.2 mmol/L = 14±1.12 ^{o}n; pH = 7.3–7.7, T= 15±2 ^{0}C) and laundering agent IEC A*(basic powder, SPT, TAED). Main washing at 60 ^{0}C was followed by the rinsing phases. The last step was water extraction by centrifuge (1200 rpm).

2.3 Determination of laundering effects

The unwashed and 5, 25 and 200 times washed reusable nappies, which were decomposed before evaluation, were subjected to stiffness measurements according to the DIN 53362 method. The breaking strength of unwashed and washed layers of nappies were determined by the DIN EN ISO 13934-1 method, respectively. The colour characteristics were determined by measuring the reflection values and calculations of CIELAB values and CIE whiteness indexes WI_{CIE} [7]. The methodology for determining the secondary laundering effects has been described briefly in [8]. The sorption characteristics of unwashed and washed nappies were obtained by the tensiometric method. The contact angles and adsorptions of layers of nappies were measured with a tensiometer K12 Kruss (D) as is described in [9].

3 RESULTS AND DISCUSION

The characteristics of reusable nappies washed 5, 25 and 200 times are presented in Tables 1 and 2, whilst the influence of multiple household washings on water absorption of nappies are shown in Figures 1 and 2.

It is evident from Table 1 that the stiffness values increase with the number of performed laundering cycles. As was expected, the higher stiffness differences occur at the outer layer of a nappy, which could be attributed mostly to the mechanical action of the laundering process and detergent`s oxidation ability. This was also reflected in a decrease in breaking strength. The 200 cycles of washing caused higher mechanical damage on the outer layer

($Z_{Out\ 200}$= 16.41%) than on the middle ($Z_{Mid\ 200}$= 9.78%) or inner layers ($Z_{In\ 200}$= 10.39%) of nappies.

Table 1 Characteristics of the layers before and after multiple household washings (Out-Outer layer, Mid- Middle layer, In- Inner layer)

Sample\ Laundering		Stiffness	Breaking strength Z_n
		(cN·cm^2)	(%)
Out	Unwashed	0.17	--
	25 cycles	0.32	8.01
	50 cycles	0.54	10.79
	200 cycles	0.64	16.41
Mid	Unwashed	0.15	--
	25 cycles	0.41	6.73
	50 cycles	0.47	7.94
	200 cycles	0.58	9.78
In	Unwashed	0.20	--
	25 cycles	0.31	8.28
	50 cycles	0.50	9.15
	200 cycles	0.52	10.39

The oxidative ability of the laundering detergent caused almost equal increase of whiteness on all layers ($WI_{CIE\ average}$= 24.43). As shown in Fig. 1, values for contact angle decreased with increasing laundering cycles, meanwhile the sorption characteristics (Fig. 2) of the middle layer are surprisingly high, even after 200 washing cycles.

Table 2 Colour characteristics of the layers before and after multiple household washings (Out-Outer layer, Mid- Middle layer, In- Inner layer)

Sample\ Laundering		Colour characteristic (D65/10)			
		*L**	*C**	*h*	WI_{CIE}
Out	Unwashed	92,52	3,61	99,69	65.30
	25 cycles	93,49	1,05	288,51	88.64
	50 cycles	93,36	1,34	284,50	89.72
	200 cycles	93,17	1,48	278,55	90.05
Mid	Unwashed	92,84	3,47	101,31	66.82
	25 cycles	93,85	0,86	287,91	88.67
	50 cycles	93,87	1,37	283,05	91.22
	200 cycles	93,12	1,48	278,76	89.97
In	Unwashed	92,55	3,73	101,34	64.89
	25 cycles	93,46	0,92	288,21	88.04
	50 cycles	93,43	1,30	283,74	89.74
	200 cycles	93,12	1,55	278,83	90.27

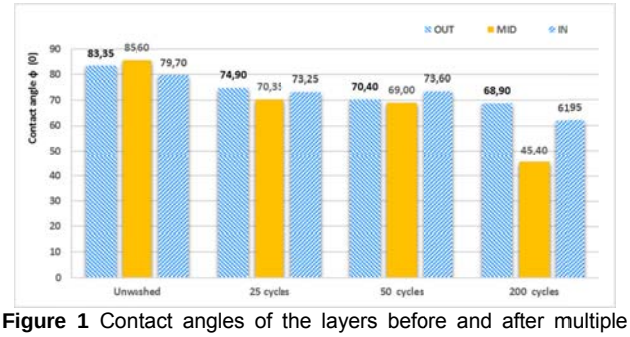

Figure 1 Contact angles of the layers before and after multiple household washings

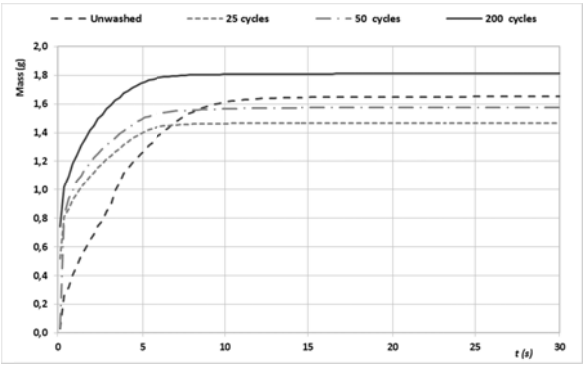

Figure 2 Water uptake characteristics of middle bamboo/PES layer before and after multiple household washings

4 CONCLUSIONS

The results of the investigation show that the overall characteristics of reusable nappies after 200 washing cycles in a household washing machine are surprisingly good. Analyses of the obtained results helped to define the optimum laundering protocol and conditions for household washing of highly absorptive textiles.

ACKNOWLEDGEMENT: *We are grateful to the Zavod Knof s.po. for the support of the project. We want to acknowledge Shelagh Margaret Hedges for the final proof-reading.*

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ANTIMICROBIAL EFFECTIVENESS OF CELLULOSE BASED FABRICS TREATED WITH SILVER NITRATE SOLUTIONS USING PLASMA PROCESSES

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Abstract: *In order to obtain antibacterial properties, the possibility of deposition of silver particles from silver nitrate solutions by Plasma Deposition Process using argon as a carrier gas (PDP-Ar) was explored. Hexamethyldisiloxane and acrylic acid were used as precursors and were deposited by Plasma Enhanced Chemical Vapor Deposition (PE-CVD). The processes were carried out on Lyocell and Modal fabrics and antimicrobial efficacy was determined on E. coli and S. aureus using time kill assay method. Results of minimal inhibitory concentration show that higher antimicrobial efficacy on E. coli exhibits the solution of silver nitrate in ethylene-glycol rather than in ethylene. Overall, the best antibacterial effect for both samples is achieved with the treatments with precursors (AAC and HMDSO) and $AgNO_3$ in ethylene-glycol as solvent, with prolonged incubation time against E. coli.*

Keywords: *cellulose fabrics, plasma processes, $AgNO_3$, quantitative microbiological method, antibacterial efficacy*

1 INTRODUCTION

Plasma technology and its application in the field of textile technology are known as ecologically friendly processes. Textile materials exposed to plasma undergo through chemical and physical transformations in the surface layer. Using different gasses and reagents in the process of plasma finishing of textile materials, a variety of functional properties can be obtained. Those include flame resistance, antistatic, hydrophobic, antibacterial properties etc. The ultimate effect depends on many more factors such as plasma type, type of materials, plasma parameters, treatment conditions and the process used [1, 2].

The application of low-pressure plasma in order to improve the property modification of Lyocell and Modal fibers and to achieve antibacterial properties by deposition of silver particles was studied. Antimicrobial treatments are carried out in order to control the growth and reproduction of microorganisms. This prevents the spread of infection, allergic and respiratory problems as well as degradation of textile materials in the form of discoloration, staining, odors and degradation of the fibers. Such textiles are used in medical technology, health, hygiene products, home textiles, water treatment systems, as well as clothes for everyday use and personal protection [3, 4].

Physical sputtering and Plasma Enhanced Chemical Vapor Deposition (PE-CVD) under low-pressure plasmas are dominant techniques used in textile finishing [1]. In this study, a relatively new method was used for the deposition of antibacterial agent called Plasma Deposition Process using argon as carrier gas (PDP-Ar). The process consists of reagent bottle with antibacterial agent, which is from one side connected to the supply of argon gas and the other side to plasma system. Argon is used as a carrier gas, which assists the transfer of reagent to the plasma system and on the textile substrate.

2 MATERIALS AND METHODS

2.1 Textile Samples and Chemical Agents

Plain wave Lyocell (CLY) and Modal (CMD) fabrics (Lenzing, Austria) were used in this study. They were industrially prepared (desized and scoured) and weaved at the textile company Čateks, Croatia.

By dissolving $AgNO_3$ (Sigma Aldrich) in absolute ethanol (Carlo Erba) and ethylene-glycol (Fluka Analytical), 0.1 M solutions were prepared and used for processing the fabrics in order to achieve antibacterial properties. Hexamethyldisiloxane, HMDSO (Sigma Aldrich, ≥ 98.5 %) and acrylic acid, AAC (Acros Organic, 99.5 %) were used as precursors. Applied bacterial species were *Escherichia coli* ATCC 10536, *Staphyloccocus aures* ATCC 6538 and Müeller-Hinton Broth (BBL™ Müeller-Hinton Broth – BD, USA) was used for mentioned bacterial species.

2.2 Plasma Treatments

Treatments were done using Low-pressure Plasma System type NANO LF-40 kHz, by Diener. To ensure enhanced binding of silver particles on textile surface, activation process was carried out for 5 minutes using O_2 gas (purity of 99.99 %, Messer) under optimized process parameters – pressure 0.34 mbar, power 300 W, frequency 40 kHz and gas flow 40 cm^3/min. The pretreatments with HMDSO and AAC were conducted in order to enhance binding of silver particles onto cellulose using PE-CVD process. The process was conducted for 20 minutes at 0.18 mbar and 150 W. $AgNO_3$ solutions were applied on activated and pretreated samples using PDP-Ar process and argon plasma as a medium for deposition. The process was carried out for 20 minutes at pressure 1.5 mbar, gas flow 400 cm^3/min and power 150 W.

2.3 Testing Methods

Antimicrobial efficacy of $AgNO_3$ solution was determined by known broth microdilution technique, which specifies minimum inhibitory concentration (MIC), i.e. the minimum concentration of antimicrobial agent that inhibits growth of a microorganism after a specific time of incubation.
Antibacterial efficacy of treated materials was determined by *time kill assay* method, a quantitative method that defines the rate at which a microorganism is killed as a function of time. Treated samples (1cm x 1cm) were inoculated with 50 µl of microorganism suspension. The antibacterial effectiveness against *E. coli* and *S. aureus* was investigated at the moment of contact of the sample with a suspension of microorganisms (0 h) and after incubation time of 6 h and 18 h at 37 °C. Solution from inoculated samples was then serially diluted and aliquots of the dilutions series were spread-plated on an agar medium to allow for enumerating the colonies of the bacteria. Quantification of the number of colony forming units of microorganisms was done after incubation at 37 °C for 24 hours.

3 RESULTS AND CONCLUSIONS

Minimal inhibitory concentration of the solution of $AgNO_3$ in ethanol for bacterial species *E. coli* and *S. aureus* is 0.13271 µg/ml. MIC values of the solution of $AgNO_3$ in ethylene-glycol for *E. coli* is 0.06635 µg/ml and for *S. aureus* is 0.13271 µg/ml. Based on the obtained data for MIC it can be concluded that silver nitrate is an excellent antimicrobial agent that exhibits excellent antimicrobial effectiveness even at very low concentrations, especially against bacteria species *E. coli*.

Testing results of antibacterial effectiveness of treated samples for bacterial species *E. coli* and *S. aureus* are shown in Fig. 2 - Fig. 5.

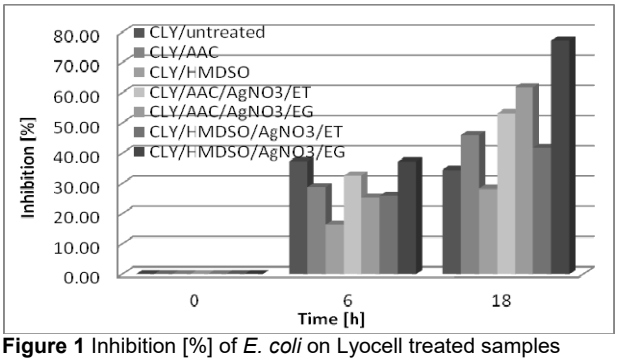

Figure 1 Inhibition [%] of *E. coli* on Lyocell treated samples

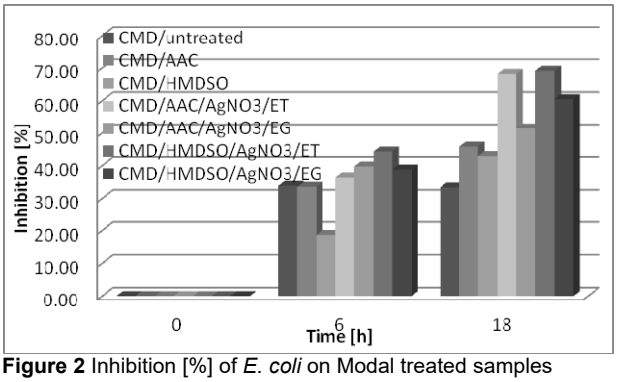

Figure 2 Inhibition [%] of *E. coli* on Modal treated samples

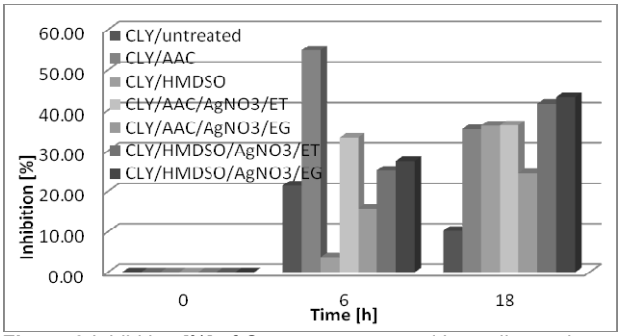

Figure 3 Inhibition [%] of *S. aureus* on treated Lyocell samples

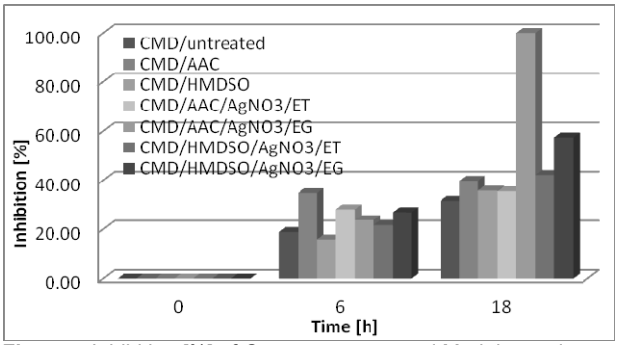

Figure 4 Inhibition [%] of *S. aureus* on treated Modal samples

From the results presented above a positive effect of all treated samples for tested bacterial species is visible and it grows with the incubation time. Untreated textile samples as well as those treated only with HMDSO and AAC show some antibacterial effect in time.
Higher antibacterial effect on both Lyocell and Modal samples has been obtained against *E. coli* where the highest inhibition exhibit samples pretreated with HMDSO. Highest results are visible after 18 hours of incubation and the reason may be the formation of polymer film on the fiber surface so longer time is required to achieve antibacterial effect.
In addition, the concentration of deposited polymer and silver nitrate using plasma processes is lower and the required time for inhibition of both tested bacterial is more prolonged.
Results of antibacterial effect against *S. aureus* (fig. 4 and 5) are not so uniform for tested samples; inhibition is lower, what is in correlation with MIC of solutions for S. aureus. Such bacteria are greater than *E.coli* and it requires more agents for its reduction.
Generally, the best antibacterial effects for both samples is achieved at the treatments with precursors (AAC and HMDSO) with $AgNO_3$ in ethylene-glycol as solvent, with prolonged incubation time against *E. coli*.

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DYNAMIC ANTHROPOMETRY – DEFINING A PROTOCOLS FOR AUTOMATIC BODY MEASUREMENT

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Abstract: *Paper presents research on possibilities of protocol development for automatic computer-based determination of measurements on 3D body model, in defined dynamic positions. Initially, two dynamic body positions were defined for research on dimensional changes of targeted body lengths and surface segments, during body movement from basic static position into selected dynamic body position. The assumption is that during body movement, specific length and surface dimensions will change significantly from aspect of clothing construction and functionality of garment model. 3D body scanning of female test sample was performed in basic static and two defined dynamic positions. 3D body models were processed and measurement points were defined as a starting point for determination of characteristic body measurements. The protocol for automatic computer measurement was defined for every dynamic body position by the systematic set of activities, based on determined measurement points. Verification of developed protocols was performed by automatic determination of defined measurements on the test sample and by comparing the results with the conventional manual measurement.*

Keywords: *dynamic anthropometry, 3D body scanning, measurement protocol*

1 INTRODUCTION

Anthropometric human body measurement is the basis for obtaining accurate data on human body measures, which are necessary for construction of clothing block patterns [1]. Body measurements using conventional measuring instruments is increasingly being replaced by the use of modern computer technologies, such as various types of 3D body scanners [2,3]. In addition to determination of linear body measures, as the most commonly used data in the garment industry and on which the conventional garment construction is based, 3D scans are used to obtain body shape data, anthropometric relationships of individual body parts, deviations from normal proportions, and body posture [4,5]. This enables the relevant data, necessary for the computer construction and the adjustment of garment patterns according to the individual anthropometric body characteristics of particular subject [6,7]. International standard ISO 20685 was developed to ensure comparability of body measurements that are determined by standard ISO 7250 (Basic human body measurements of technological design) and ISO 8559 (Garment construction and anthropometric survey-body dimensions), obtained by using different types of 3D body scanners [8]. However, accompanying computer programs applied for measurement on the obtained 3D point clouds at the end of the scanning process, at this point enables automatic measurement procedure only available in the basic standing body position. If it is necessary to determine body measurements in any of the dynamic positions, it is performed interactively, with precision measurement being largely dependent on the user. Such a measurement method is not appropriate for serial measurements of the test subjects, since the positioning of the measurement points have to be repeated for each subject in order to determine measurements during which is very difficult to achieve the measurement precision and comparability of the measurement results for a sample of test subjects. In that sense, paper presents the method of defining the protocols for body measurement in two dynamic body positions, as a starting point for improvement of the clothing construction methods, as well as the design and development of functional garment models.

2 METHODOLOGY

2.1 Defining dynamic positions and 3D body scaning of female test subjects

Since the main objective of the research is to perform the analysis of the targeted lengths dimensions and body surface segments in the static position and dynamic conditions, two dynamic body positions were initially defined for 3D body scanning of female test subjects, Fig. 1.

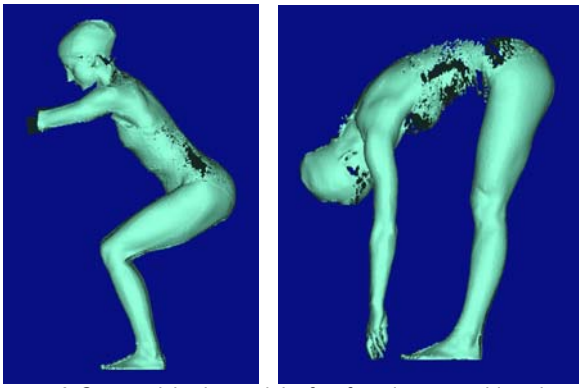

Figure 1 Scanned body model of a female test subject in two defined dynamic body positions

The test subjects were scanned with precisely positioned markers on the body, at defined measurement points. Total of 80 female test subjects, aged 20 to 30 years were scanned for the study, using laser 3D body scanned developed by Human Solutions. After the performed 3D body scanning, an automatic measurement procedure was performed and 152 body measurements were determined

for every test subject in the basic body position according to ISO 20685: 2010.

2.2 3D models computer processing

Every particular 3D point cloud, i.e. body model of every test subject in static and dynamic positions was computer processed using software Anthroscan 2016 (3.4.0.). Processing includes closing body models surfaces and creating one-layered closed polygonal model suitable for further analysis.

2.3 Defining of measurement points and characteristic body dimensions

Measurement points are defined at the position of recorded markers on the body, as a starting point for the development of measurement protocols in dynamic positions, Fig. 2. A total of 23 measurement points were defined for the dynamic body position 1 and 21 measuring points for the dynamic body position 2. Selected measurement points are specifically targeted for the purpose of determining measurements that are significant for clothing construction, from the aspect of achieving the garment model functionality in dynamic conditions.

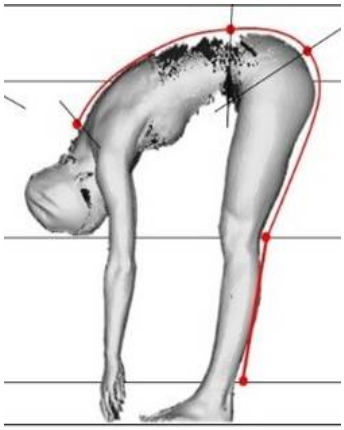

Figure 2 Dynamic position 2 with selection of defined measurement points

2.4 Defining protocol for automatic measurement of body in dynamic position

When defining a protocol for automatic measurement, it is primarily necessary to load each scanned 3D body model in dynamic position into the same file with the appropriate 3D model in the static position and to store created file as a protocol configuration within the Anthroscan program. In this way, the connection between the scanned model in the dynamic position and the anthropometric points defined by the ISO 7520 standard is achieved. Loading of the created file into the program, enables defining of target dimensions in the dynamic position, whereby coordinates of anthropometric points between which the measurement will be performed, are defined directly on the 3D model. The positions of the defined anthropometric points are stored as a file of measurements within the defined protocol. The protocol must be defined separately for each selected dynamic position, after which automatic measurement of scanned body models in dynamic positions is enabled by selecting the desired protocol within the program menu. The protocol also enables an automatic creation of a measurement table, i.e. html file with measurements and coordinates of anthropometric points.

3 RESULTS

Verification of defined protocols for automatic body measurement in defined dynamic positions was performed by comparing the results with conventional manual measurement on a sample of test subjects.

4 CONCLUSION

Determined measurement values will be a starting point for analysis of changes on characteristic body measurements caused by particular dynamic position and which are affecting the clothing construction. Creating automatic measurement protocols for dynamic positions provides greater precision in defining anthropometric points compared to manual processing of individual models and also enables comparison of obtained measurement results, since measurement is always performed in the same manner according to the defined protocol.

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IMPACT OF ASPIRATION AIR PRESSURE IN THE SPINNING SHAFT ON THE FORMATION OF HOLLOW POLYAMIDE 6 FIBERS

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Abstract: *An influence of aspiration air pressure under spinnerets on properties of hollow polyamide 6 fully drawn multifilament yarns is presented in the article. Experiments were made on an industrial spinning machine. Aspiration air pressure in the spinning shaft of 50 Pa and 100 Pa influenced on decreasing of spinnerets temperature, on a quantity of monomer in yarns and breaking force, which both increased, but breaking elongation of hollow polyamide 6 fully drawn yarns decreased. The changes of mechanical properties are related with changes in supramolecular structure and ability of yarns for dyeing.*
Keywords: *hollow fibre, polyamide 6, fully drawn yarn*

1 INTRODUCTION

Polyamide 6 (PA 6) is a synthetic polymer, which is formed in a ring-opening polycondensation reaction of monomer ε-caprolactam [1, 2]. Unreacted monomer and acyclic/cyclic oligomers (low molecular weight fraction) are extracted from PA 6 chips in discontinuous process before using the polymer for spinning fibres. However, in PA 6 spinning melt always exists a certain quantity of monomer and low molecular weight fraction, which influence on rheological properties of melt, and later on final yarn's properties, particularly in regard to the tensile properties [3]. At high spinning temperatures monomer and low molecular weight fraction evaporate from jets at a length of a first 5–15 cm under spinnerets [4] and deposit on spinnerets and on spinning shaft walls, where a few millimeters thick layers in few days can be formed.
Deposited monomer and low molecular weight fraction can be removed by mechanical cleaning in regular time intervals. A vacuum suction in a spinning shaft is nowadays the most commonly used method of removing monomer and low molecular weight fraction. The method is not enough effective when the concentration of monomer and low molecular weight fraction is high [4].
The main deficiency of air suction is an additional air flow around the jets under the spinnerets, which can influence on the solidifying process. In our research an influence of aspiration air pressure under spinnerets on properties of hollow PA 6 fully drawn multifilament yarns was studied. Hollow PA 6 filament yarns have a potential as suitable thermal insulation material for clothing, in particular socks, pillows and T-shirts. Currently, hollow PA 6 yarns are not available on the market.

2 EXPERIMENTAL PART

2.1 Materials

Samples of fully drawn PA 6 yarns of expected linear density 44 dtex with ten hollow filaments were made on an industrial fully drawn yarn spinning machine Teijin Seiki (Japan) at different aspiration air pressures in a spinning shaft (Tab. 1). All the samples were made from the same polymer with 1.3% added TiO_2. Draw ratio was 1.35, winding velocity 4,410 m/min and application of a spinning preparation was 0.7%. Before winding the yarns were interlaced (Fig. 1). For each sample twelve bobbins were made on two spinning positions. Spinneret temperature was measured with a laser thermometer Raytek Raynger MX. Yarn stress was measured in the spinning line on five positions (Figure 1) using an on-line tensiometers.

Table 1 Designation of samples and average values of spinning conditions

Samples	Aspiration air pressure (Pa)	Aspiration air velocity (m/s)	Temperature of spinnerets (°C)
AP0	0	0	243
AP50	50	0.2–0.3	240
AP100	100	2.5–4.0	237

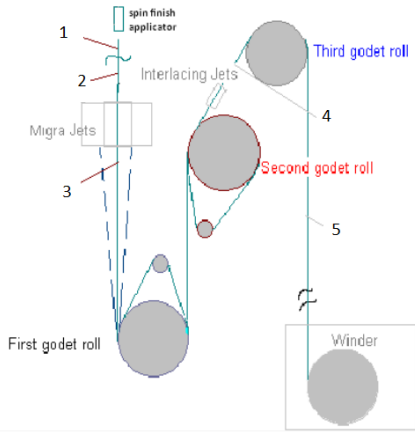

Figure 1 Positions 1–5 of measuring yarn stress in the spinning line

2.2 Methods

Yarn's linear density was measured gravimetrically in accordance with a standard EN ISO 1973:1999. Breaking force and elongation of yarns were measured on a dynamometer Statimat M Textechno according to standard EN ISO 2062:2010. Monomer and low molecular weight fraction were determined by a quantitative analysis of extracts, which were prepared by a treatment of fibres four hours in methanol at 95 °C. Extracts were analyzed by a HPLC method. Average molecular weight was determined from viscosity measurements of polyamide 6 solution in 0.1% sulfuric VI. acid.

3 RESULTS AND DISCUSSION

Aspiration air pressure under the spinneret had no influence on an average viscosity molecular weight of PA 6 fully drawn yarns. It was for all samples 15,185.89 g/mol. Aspiration air pressure of 100 Pa had a definite influence on the quantity of extract in methanol: it amounted 2.05% for sample AP100, 1.95% for sample AP50 and 1.92% for sample A0. From the Fig. 2 is seen that aspiration air pressure influenced on polymerization equilibrium of solidifying PA 6 jets with a significant increasing of monomer. Spinnerets temperature have decreased by 3–4 ºC with increasing aspiration air pressure (Tab. 2). Lower spinnete temperature accelerated the solidifying process of spinning jets. Consequently, higher yarn stresses (Tab. 2) in all positions 1–5 (Fig. 1) have been measured. Yarn stress at the measured position 5 before yarn winding on the bobbine increased the most at aspiration air pressure 100 Pa. Yarns made at aspiration air pressure of 50 Pa and 100 Pa showed much higher breaking force (Fig. 3) and lower breaking elongation as yarns, made at aspiration air pressure zero.

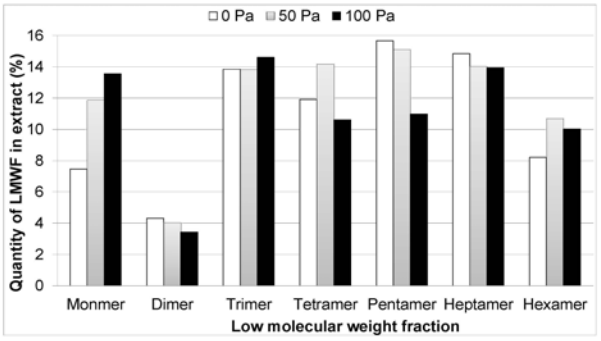

Figure 2 Influence of aspiration air pressure on a quantity of monomer and low molecular weight fraction of hollow PA 6 fully drawn yarns

Table 2 Spinneret temperature and yarn stress in spinning line

Sample	Average spinneret temperature (°C)	Average stress, measured in spinning line positions 1 to 5 Fig. 1 (cN/yarn)				
		1	*2*	*3*	*4*	*5*
AP0	243	3.5	6	8.3	3	4
AP50	240	3.7	6	8.5	3.5	4.2
AP100	237	3.9	6.2	9.3	3.8	4.9

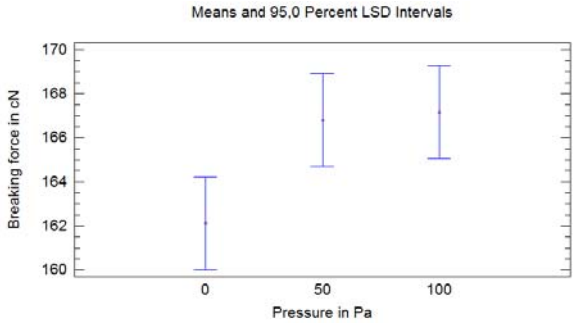

Figure 3 Influence of aspiration air pressure on a breaking force of hollow PA 6 fully drawn yarns

4 CONCLUSION

Using an aspiration air pressure in the spinning shaft in the range of 50 Pa and 100 Pa in a spinning process of polyamide hollow fully drawn yarns influences on:
- decreasing of spinneret's temperature,
- increasing of quantity of extract in methanol and monomer in yarns,
- increasing of breaking force and
- decreasing of breaking elongation of hollow polyamide 6 fully drawn yarns.

All these changes of yarn's properties are closely related with changes in yarns supramolecular structure, which is consequently demonstrated in changes in differences of colour tones of dyed yarns.

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TENSILE PROPERTIES OF BIODEGRADABLE FIBRES PREPARED FROM PLA AND PLA/PHB BLENDS

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Abstract: *Biodegradable polymeric blends based on polylactic acid (PLA) and polyhydroxybutyrate (PHB) were prepared by melt extrusion on co-rotating twin screw extruder. Created chips were spinned and fibres with different finnenes were prepared by drawing process. Tensile properties (fineness, elongation at break, tenacity and Young´s modulus) of prepared PLA and PLA/PHB fibres were evaluated and discussed.*

Keywords: *polymer blends, polylactic acid, polyhydroxybutyrate, fibres*

1 INTRODUCTION

Recent advances in biodegradable polymers have been spurred by intense interest in wide area of applications [1,2]. Biodegradable polymers break down in physiological environments by macromolecular chain scission into smaller fragments, and ultimately into simple stable end-products [3]. The degradation may be due to aerobic or anaerobic microorganisms, or biologically active processes (e.g. enzyme reactions) or passive hydrolytic cleavage [4,5,7]. The last two decades of polymer technology have seen a sharp rise in the development and commercial marketing of such new materials [6].
Polylactide acid (PLA) and blends of PLA with other biodegradable polymers are the most promising biodegradable materials owing to their mechanical properties profile, thermoplastic processibility and biological properties, such as biocompatibility and biodegradability.
The transformation of PLA into textile structures is complicated and depends on structural changes in the polymer during processing. Extrusion of the polymer into monofilament and multifilament may be achieved by melt spinning, dry spinning, wet spinning, and by dry-jet-wet spinning. There are distinct features of each of these processes that are subsequently reflected in fiber properties. Thanks to the thermoplastic nature of PLA, it is possible to melt the polymer under suitable conditions. Conversion of PLA to fiber by melt spinning usually has few advantages over wet spinning. Its a solvent-free process and more economical way. Production speed is higher than in solution spinning.
[8].

2 EXPERIMENTAL

2.1 Materials

The polylactic acid (PLA 4043D) from Nature Works (USA) and polyhydroxybutyrate (PHB) from Biomer (Germany) were used for preparation of blends for spinning process. Sample No.1 is fibre made from pure PLA and samples 2, 3 and 4 have different ratio of PLA: PHB. According to protection of intellectual property and patent procedure exact composition of blends is undisclosed.

2.2 Methods

The undrawn fibres were prepared by classical procedure of melt spinning from chips of blends using laboratory pilot plant with the screw ϕ = 16 mm at a temperature of 190°C. Metering of melt via spinneret nozzle with 13 orifices (ϕ = 0.5 mm) was 13g.min^{-1} and take-up speed at the spinning was 150m.min^{-1}. Pellets of PLA and PLA/PHB blends were dried to avoid the undesirable hydrolysis during processing. The prepared undrawn fibres were drawn at vertical laboratory drawing machine at two different drawing ratios (λ=2 and λ_{max}) for following of changes during drawing procedure at temperature of 110°C. Maximum drawing ratio was chosen with aim to investigate ability of prepared fibres reach highest possible tensile properties. This drawing ratio is different for all mentioned samples.

2.3 Mechanical properties

The Instron 3343 equipment was used for evaluation of the mechanical properties (tenacity and elongation at break, Young's modulus) of pure PLA and blended PLA/PHB fibres. The mechanical characteristics of the fibres were determined in accordance with STN EN ISO 139, STN EN ISO 2060, STN EN ISO 2062.

3 RESULTS

The fineness and mechanical properties of PLA and PLA/PHB fibres drawn at two drawing ratios are given in Tables 1-4. The fineness of the prepared fibres is positively influenced by content of PHB in blends (Table 1). According to observation content of PHB in blends has positive influence onto feeding of pellets into

spinning extruder which is automatically regulated via pressure sensor in spinneret nozzle. Fineness of PLA and PLA/PHB fibres is decreasing with higher drawing ratio for all samples.

Table 1. Fineness of the PLA and PLA/PHB fibres

Sample	Fineness [tex]					
	Drawing ratio					
	undrawn fibres	*CV*	*2*	*CV*	*max.*	*CV*
1	39.4	15.1	24.1	10.6	22.6	8.0
2	100.6	17.2	45.6	11.4	33.5	9.1
3	109.2	22.3	53.5	14.3	49.4	8.6
4	106.1	18.5	52.2	12.1	-	-

Table. 2 represents the elongation at break properties of undrawn and drawn PLA and PLA/PHB fibres. Addition of PHB in different amount have positive influence onto of elongation at break of undrawn fibres. With increasing drawing ratio elongation at break decreasing because of orientation is still higher. Content of PHB in blends improve more than two times elongation at break fibres drawn at maximum drawing ratio.

Table 2. Elongation at break of the PLA and PLA/PHB fibres

Sample	Elongation at break [%]					
	Drawing ratio					
	undrawn fibres	*CV*	*2*	*CV*	*max.*	*CV*
1	121	14.6	39	17.6	17	11.8
2	257	13.2	67	36.7	43	18.2
3	216	8.8	33	41.6	37	32.0
4	241	6.7	47	20.6	-	-

Table 3. Tenacity of the PLA and PLA/PHB fibres

Sample	Tenacity [cN/tex]					
	Drawing ratio					
	undrawn fibres	*CV*	*2*	*CV*	*max.*	*CV*
1	13.0	13	10.0	13	21.6	7
2	3.5	21	4.4	19	7	20
3	4.7	9	3.4	32	3.7	30
4	4.3	18	7.6	15	-	-

Different situation occurs in case of the tenacity and Young´s modulus of PLA and PLA/PHB fibres. Any content of PHB in blends cause significant decrease of tenacity values of prepared fibres in comparison with tenacity of fibres made from pure PLA (Table 3 and Table 4).

Table 4. Young´s modulus of the PLA and PLA/PHB fibres

Sample	Young´s modulus [N/tex]					
	Drawing ratio					
	undrawn fibres	*CV*	*2*	*CV*	*max.*	*CV*
1	3.6	19	4.4	16	4.7	16
2	0.6	42	0.2	19	0.3	23
3	1.1	14	1.0	25	0.9	28
4	1.4	24	1.7	17	-	-

4 CONCLUSION

The tensile properties of fully biodegradable fibres prepared from PLA and PLA/PHB blends, were investigated. Addition of PHB into PLA have positive effect onto fineness of prepared fibres. Also, elongation at break of prepared PLA/PHB fibres is much higher in comparison with fibres prepared from pure PLA polymer. Contrary these results is decrease of tenacity and Young´s modulus values in PLA/PHB fibres in comparison with fibres from pure PLA. This decrease of tenacity is 3 times higher for undrawn PLA/PHB. In spite of lower tensile strength, PLA/PHB blends have better biodegradable properties in comparison with PLA caused by presence of PHB in blend [9].

Acknowledgement: *This work was supported by the Slovak Research and Development Agency under contract No APVV-14-0175.*

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WHITENESS – ONE TASK, DIFFERENT WAYS, DIFFERENT RESULTS

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Abstract: *There is a range of opinions how to define whiteness. In geometrical view, surface defined as white is surface, which reflects diffusely in all directions. White color is characterized by constant absorption between 400 and 700 nm. Whiteness can be described as an aspect of color corresponding to high luminosity and an absence of hue and greyness. A range of technologies exist for achieving samples with brilliant whiteness. This article compares three methods of bleaching. The samples obtained by Pad-Batch technology, bleached in bath by common technology (hydrogen peroxide and water glass is used) and bleached by the help of modern bleaching agent were compared. Dependence of using brightening agents and effect of using a small amount of blue or violet dyestuff (shading) on final whiteness is described. Final whiteness was evaluated by the CIA whiteness formula. Experiment shows, that better whiteness provides samples with optical brightener (this is expectable), as like as fact that whiteness can be improved by using of small amount of well-chosen dyestuff – blue e.g.*

Keywords: *whiteness, bleaching, brightening, shading, styling*

1 INTRODUCTION

Numerous indices of whiteness exist to characterize whites. In physical terms, a white surface is the one that reflects strongly (>50%) throughout the visible spectrum. The higher and more uniform the spectral reflectance, the whiter is the appearance of the object. White is called an achromatic color and is characterized by constant absorption between 400 and 700 nm. Experience shows that when a white is slightly pinkish or greenish, the eye easily classes the examined surface in the category of 'non-whites'. On the other hand, it is much more difficult to find agreement when the whites studied are on the blue–yellow axis (axis b*). The main aim of this study is focused on measurement and assessment of whiteness for cotton fabric. Following experiments are based on bleaching and brightening. After this pretreatment, the samples were dyed by different direct dyes. Whiteness of samples was evaluated by CIE whiteness formula. [1,2]

2 MATERIAL AND METHODS

2.1 Textile material

In this study, 100% cotton fabric plain structure (1x1 warp and weft) were used. The fabric has 124 g/m2.

2.2 Experiments

Three technologies for bleaching were used and compared. Samples for bath bleaching were desized firstly by Texamil NU (commercial desizing agent).

- **Pad-batch process** was carried out to the desized fabric with different pressure (1 bar, 1.25 bar, 1.50 bar, 1.75 bar, 2 bar).

- **Bath bleaching with water glass**
  Fabrics were processed bleaching with common exhaust bleaching process, bleaching with optical brightener proceed in parallel. This process was made with different concentrations of H_2O_2.

- **Bath bleaching with combined bleaching agent**
  Used product Serafil is 3-in-one bleaching compound (stabilizer, detergent, sequestering agent), which provide excellent stabilization of H_2O_2 in bleaching bath. This process was made with different concentrations of H_2O_2.Five sort of samples were obtained by this technology.
  1) Pre-bleached without brightening (No. of samples 0305, 0325)
  2) Full–bleached without brightening (No. of samples 0410, 0440)
  3) Pre-bleached with brightening (No. of samples 0510)
  4) Full-bleached with brightening (No. of samples 0625, 0640)

2.3 Shading method

After bleaching, These fabrics were dyed with C.I. Direct Red 99 and C.I. Direct Blue 86 (0.0005%, 0.001%, 0.0020% and 0.0025% concentration).

3 EVALUATION

Instrumental evaluation of whiteness is generally carried out by a two-step method: the measurement of spectral reflectance of samples; and the evaluation of whiteness from the resultant data by various graphical or numerical methods. In 1979, the CIE (Commission Internationale de l'Eclairage) recommended a whiteness index based on research by Ganz. This formula was incorporated into an

ISO standard in 1987 (ISO 11475, ISO/DIS 11476) and an AATCC (American Association of Textile Chemists and Colorists) standard two years later (AATCC 110). This formula calculates whiteness, W, and is based on illuminant D65 and either standard observer.

The CIE WI are restricted by eq.1 :

$$40 < W < (5Y - 280) \qquad (1)$$

where Y is the lightness.

Consequently, the white samples that satisfy the aforementioned limitations could be evaluated by the CIE whiteness formula. The validity of the CIE whiteness index in comparison to visual evaluations has been reported by different researchers.
The CIE formula represents a very useful harmonization of the methods of evaluating whiteness, as none of them shows any real superiority in the current test conditions. It is complicated by the condition $40 < W < (5Y - 280)$, which limits its application by not allowing the use of results outside these limits of whites. [3]

4 RESULTS AND DISCUSSION

Selected results of whiteness measured are shown in tables 1 and 2.

Table 1 Bath bleaching with combined bleaching agent – whiteness before dyeing

Sample	CIE Whiteness
0305	18
0325	20
0410	70
0440	78
0510	70
0625	86
0640	91

Table 2 Bath bleaching with combined bleaching agent – whiteness after dyeing

Sample	Concentrace of dye	CIE Whiteness	
		CI Direct Blue 86	***CI Direct Red 99***
0305	0.0005%	31,93	30,88
0305	0.0025%	38,40	32,59
0325	0.0005%	34,55	33,06
0325	0.0025%	40,18	35,47
0410	0.0005%	77,46	75,78
0410	0.0025%	82,94	74,40
0440	0.0005%	83,76	81,39
0440	0.0025%	87,19	82,21
0510	0.0005%	79,44	75,61
0510	0.0025%	79,77	75,21
0625	0.0005%	88,83	87,97
0625	0.0025%	96,71	86,08
0640	0.0005%	93,72	87,11
0640	0.0025%	96,80	88,58

Treat the bleached material with a very small amount of blue or violet dye an operation known as bluing to boost the visual impression of whiteness. These dyes absorb light in the green yellow portion of the spectrum that reduces lightness. CI Dırect Blue 86 gave the best CIE Whiteness. This is related to the groups of chromophores. CI Dırect Blue 86 has phthalocyanine chromophore group and CI Dırect Red 99 has double azo chromophore group. According to these results the choromophore group is giving higher whiteness to those of phthalocyanine.

5 CONCLUSION

In this study, bleaching and scouring were made with optical brightening and without optical brightening. At the same H_2O_2 concentration, when optical brightening was used, better CIE Whiteness than without optical brightening are obtained.
Bleaching alone can't remove all traces of yellowish cast. Therefore, dyestuff (green, violet, red, blue) can be used. These dyes absorb light in the green yellow portion of the spectrum that reduces lightness. Since, at the same time, they shift the shade of the yellowish material towards blue, the eye records an increase of whiteness.
For example, if a small amount of blue dye is added, the addition of blue dye will decrease the luminous reflectance of the sample, making it finally bluish. Although this way also leads to increasing of whiteness, measured values are lower than in case optical brightening. But, it is method which can be use in cases when brightening agents are not available or its using is unsuitable.

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EXAMINATION OF THE THERMO-MECHANICAL PROPERTIES OF E-GLASS/CARBON COMPOSITES

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Abstract: *In this study, eight-plied E-glass, carbon and E-glass/carbon fabric reinforced hybrid composites are manufactured by vacuum bagging system. Dynamic mechanical analysis, thermogravimetric analysis and differential scanning calorimetry analysis are conducted to examine the thermo-mechanical properties of composite samples.*

Keywords: *textile reinforced composites, dynamic mechanical analysis, thermogravimetric analysis, differential scanning calorimetry*

1 INTRODUCTION

Fiber-reinforced composites are one of the favoured materials in many sectors owing to their properties such as high specific strength and stiffness, low thermal expansion, good fatigue performance and processing advantages at low cost [1].
Dynamic mechanical analysis (DMA) is a method which applies sinusoidal force to samples to investigate their viscoelastic properties and structures. It measures the modulus and damping properties of materials [2-4]. Differential scanning calorimetry (DSC), is a thermal analysis method that measures heat flow rate as a function of time and temperature, while thermogravimetric analysis (TGA) shows the weight loss of materials with increasing temperature [5,6].
In this study, thermo-mechanical properties of composite samples are investigated by DMA, TGA and DSC analysis methods.

2 MATERIALS & METHODS

2.1 Materials

E-glass and carbon fabrics are used as reinforcement material while polyester resin is used as matrix material. Both fabrics are plain woven and have a basis weight of 300 g/m^2. Matrix system contains accelerator (cobalt) and hardener (Methyl ethyl ketone peroxide-MEKP) together with polyester resin. The ratio of polyester:cobalt:MEKP is 1:0.00175:0.002 by weight.

2.2 Methods

Vacuum bagging system is used as the production method of composite laminates. Fabrication is realized at the room temperature (20ºC ± 2ºC). Four composite samples one of which has 8 plies of E-glass fabric (GGGGGGGG), one of which has 8 plies of carbon fabric (CCCCCCCC) and two of them have both E-glass and carbon fabrics with different stacking sequences (GGCCCCGG, CCGGGGCC) are manufactured. CNC milling machine is used for cutting the samples at required dimensions.
For dynamic mechanical analysis of composite samples RMI DX04T dynamic mechanical analyzer with three-point bending configuration is used. Samples of dimension 10mm x 50mm are cut from composite plates and tests are performed at a frequency of 1 Hz and the temperature programs are run from 30 to 150ºC under a controlled sinusoidal strain, at a heating rate of 3ºC/min.
For thermogravimetric analysis, Mettler Toledo TGA/SDTA851e Analyzer is used. Samples that have weight between 6-7 mg are heated from 25°C to 600°C with a heating rate of 5°C/min in nitrogen atmosphere.
For differential scanning calorimetry, DSC-6 Perkin–Elmer differential scanning calorimeter is used. Samples of about 8 mg are heated from 25 °C to 200 °C at a heating rate of 10 °C /min and wait 1 minute at 25 °C and then they are cooled to 25 °C at a rate of 10 °C /min.

3 RESULTS

3.1 Dynamic Mechanical Analysis

Fig. 1 shows the storage modulus results of the samples. Storage modulus shows the elastic behavior of material and it is proportional to the energy stored in one cycle [7].

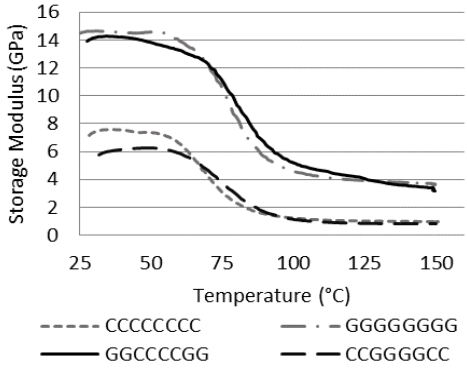

Figure 1 Storage Modulus results of samples

It is seen that E-glass reinforced composite samples and hybrid sample which has E-glass fabric plies at the outer layers have the highest storage modulus values. Fig. 2 shows the loss modulus results of the samples. Loss

modulus shows the viscous behavior of material and is proportional to energy dissipated in one cycle [7]. It is seen that E-glass reinforced composite samples and hybrid sample which has E-glass fabric plies at the outer layers have the highest loss modulus values.

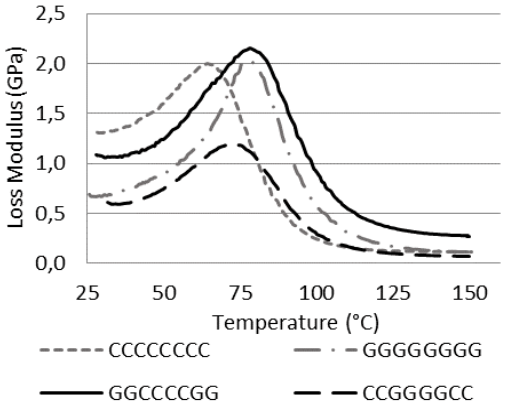

Figure 2 Loss Modulus results of samples

Fig. 3 shows the tangent delta results of samples.The ratio of loss modulus to storage modulus is known as tan delta and the peak point of the lines show the glass transition temperature (T_g) of material [7]. It is observed that GGGGGGGG and GGCCCCGG samples have higher T_g values than the other samples.

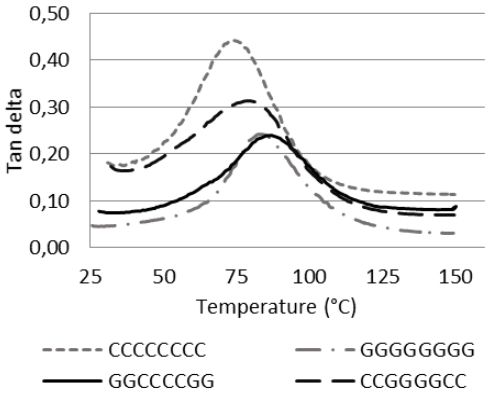

Figure 3 Tangent delta results of samples

3.2 Thermogravimetric Analysis

TGA results (weigth loss and onset temperature) are given in Table 1. It is seen from the Table 1 that onset temperatures of all samples are approximately at same level while weight loss of hybrid samples are lower than the other samples.

Table 1 Thermogravimetric analysis results of samples

Sample	Initial Weight (g)	Final Weight (g)	Weight loss (%)	Onset Temperature (°C)
CCCCCCCC	6.32	4.20	33.54	317.70
GGGGGGGG	6.59	4.51	31.56	309.91
CCGGGGCC	6.61	4.72	28.59	311.62
GGCCCCGG	6.54	4.89	25.22	309.64

3.3 Differential Scanning Calorimetry

DSC analysis results of samples are given in Fig. 5. It shows that none of the samples show any endothermic or exothermic reactions between 25 - 200°C.

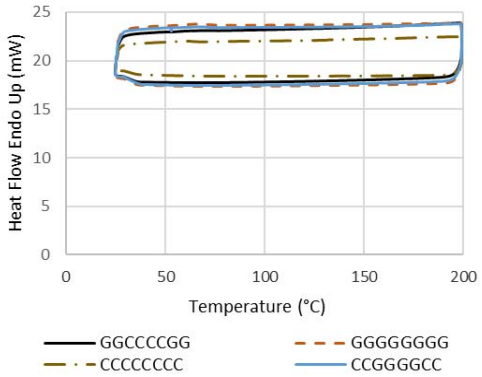

Figure 5 Differential scanning calorimetry results of samples

4 CONCLUSION

As a conclusion, it is observed from DMA results that E-glass reinforced sample and hybrid sample which has E-glass fabric at the outer layers are both more viscous and elastic than the other samples, while DSC analysis indicate that composite samples do not show any phase changes till 200°C. Moreover, TGA results demonstrates that hybrid samples have lower amount of weight loss than the other samples.

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STRUCTURE AND PROPERTIES OF POLYPROPYLENE FIBRES MODIFIED WITH PHOTOLUMINESCENT PIGMENT AS TOOL FOR THE PROTECTION OF ORIGINAL PRODUCTS

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Abstract: *Special photoluminescent inorganic pigment was used as protective tool of polypropylene (PP) fibres originality. The influence of pigment content and uniaxial deformation on the supermolecular structure together with basic mechanical properties of PP fibres modified with above mentioned pigment was investigated as well as its color performance under UV lamp. Supermolecular structure parameters as birefringence, sound velocity in fibres, crystallinity and crystallinity index of undrawn and drawn modified PP fibres prepared by discontinuous technological process were studied. Mechanical properties as fineness, Young´s modulus, tenacity at break and elongation at break of undrawn and drawn modified fibres were evaluated. The obtained experimental results of modified PP fibres were compared with the supermolecular structure and mechanical characteristics of standard non-modified PP fibres prepared under same technological conditions.*

Keywords: *protective photoluminescent pigment, modified PP fibres, structure, mechanical properties*

1 INTRODUCTION

In recent years there are a huge number of counterfeits of original products in all industry areas. It is practically impossible to distinguish original products from fakes. One of the cost acceptable solutions for the protection of original products represents an application of photoluminescent pigments [1-4]. In this study, the influence of content pigment and uniaxial deformation on the supermolecular structure together with basic mechanical properties of polypropylene (PP) fibers modified with photoluminescent pigment of company Tailorlux was investigated as well as its different colour performance before and after illumination with UV lamp.

2 EXPERIMENTAL AND METHODS

2.1 Materials

Isotactic polypropylene (PP) produced by Slovnaft Company, with MFR=27.6 g/10 min, PP masterbatch of photoluminescent inorganic pigment of company Tailorlux GmbH developed by Research Institute for Man-Made Fibres, a.s. Svit with pigment content 1.0 wt %, MFR=10.0 g/10 min and with Filter index<50 MPa.kg^{-1} were used.

2.2 Fibres preparation

The modified PP fibres were prepared from the PP and PP masterbatch of pigment using the discontinuous process of spinning and drawing. The laboratory line has an extruder with diameter of D=32.0 mm, with a discontinuous one-step drawing process. Processing conditions with the spinning temperature of 220°C, spinning die plate of 2x25 holes with diameter 0.3 mm, final spinning process speed of 1500 m.min^{-1}, drawing ratio λ=2.0, drawing temperature of 130°C and final drawing process speed 100 m.min^{-1} were used.

2.3 Methods used

The fibre's birefringence - total orientation of fibres

The fibre's birefringence was evaluated by polarization microscope DNP 714BI by compensation method.

The sound velocity in fibres

The sound velocity in fibres was measured by Dynamic Modulus Tester PPMSR.

Crystallinity index (FT-IR)

Crystallinity index of PP fibres was evaluated by FT-IR spectrophotometer 8400 Shimadzu.

Crystallinity of fibres

For the evaluation of thermal properties PP fibres, DSC 4 apparatus Perkin Elmer was used according to the STN EN ISO 3146/AC.

Mechanical properties of fibres

Mechanical properties of fibres (tenacity at break, elongation at break and Young's modulus) were measured using Instron 3343 equipment according to the Standard ISO 2062:1993 and fineness according to the STN EN ISO 1973.

3 RESULTS AND DISCUSSION

Stability of the spinning and drawing process of the studied system PP/ photoluminescent pigment in whole evaluated concentration range of pigment (0.005 – 0.5 wt %) was comparable with stability non-modified PP standard. For limited scope, the supermolecular structure parameters and basic mechanical properties only non-modified and modified drawn PP fibres were evaluated in this abstract (see Tab.1).

Table 1 The birefingence (Δn), sound velocity (c), crystallinity index (I_k FT_{IR}), crystallinity (β), fineness, tenacity, elongation and Young's modulus of drawn non-modified and modified PP fibres with drawing ratio λ=2.0

Pigment content [%]	Δn . 10^3	c [km/s]	I_k (FT_{IR})	β	Fineness [dtex]	Tenacity [cN/dtex]	Elongation [%]	Young's modulus [cN/dtex]
0.00	31,2	2,61	1,25	0,461	247,1	3,9	79,7	40,9
0.005	30,2	2,54	1,27	0,478	248,5	4,0	81,4	42,2
0.01	30,0	2,56	1,25	0,471	247,0	3,9	77,6	42,0
0.05	30,2	2,50	1,24	0,443	246,8	3,9	90,9	40,3
0.10	29,6	2,42	1,26	0,453	247,6	3,7	89,8	37,9
0.20	28,4	2,40	1,25	0,447	248,1	3,4	106,0	33,8
0.30	27,2	2,26	1,05	0,439	251,5	3,3	105,5	30,7
0.40	27,2	2,19	1,00	0,425	249,8	3,2	113,2	29,6
0.50	25,8	2,07	0,90	0,407	249,5	2,8	111,6	22,9

The increased pigment content in the drawn modified PP fibres result in the decrease of total macromolecular chains orientation in fibre (birefringence), orientation of macromolecular chains in surface layers (sound velocity), conformational regularity arrangements of crystalline regions (crystallinity index) as well as crystallinity (β) in comparison with drawn non-modified PP standard fibre. It is caused by a fact that higher pigment content in drawn fibres lead to the steric braking effect of inorganic pigment particles in polymer matrix. The content of pigment in the evaluated range has no significant effect on the fineness modified PP fibres (see Tab.1).

The addition of pigment in the modified PP fibres decreases the regularity of macromolecular chains arrangement in drawn composite systems. This was reflected by decrease in their tenacity (up to 28 %) and the Young's modulus (up to 44 %) in comparison with drawn non-modified PP fibre and slight increase in their elongation (up to cca 30 % absolute) with increased pigment content in the drawn PP fibres (see Tab.1). It is related to the decrease in all evaluated supermolecular structure parameters with increased pigment content in the drawn modified PP fibres. As can be seen from above mentioned fact the obtained values of the basic mechanical properties of modified PP fibres are in good correlation with determined values of their supermolecular structure parameters.

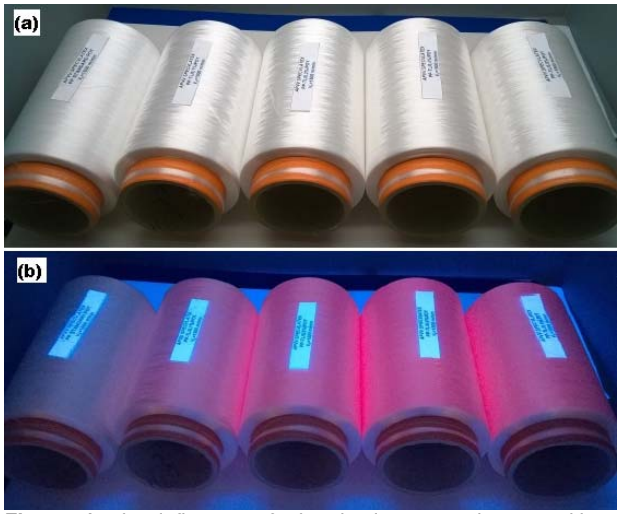

Figure 1 The influence of photoluminescent pigment with a content of 0,10 wt %; 0,20 wt %; 0,40 wt % and 0,50 wt % on the color performance modified PP fibres in comparison with non-modified PP rd fibre (first from left) under daylight D65 (a) and under UV lamp (b)

Fig. 1a show that under the daylight (D65) are all prepared modified PP fibers white. Under the UV lamp (Fig. 2b) there is white only non-modified PP fibre (first from left) while the modified PP fibres pass into red colour. The color intensity rises with increased content of pohotoluminescent pigment in PP fibres.

4 CONCLUSION

The results of the study PP fibres modified with photoluminescent inorganic pigment presented in this article showed that the system PP/pigment is fibre forming in discontinuous technological process across whole range (0.005-0.50 wt %) of the pigment content. The technological conditions for stable spinning and drawing modified PP fibres were found. It was found, that the particles of pigment inhibit orientation of PP macromolecular chains into the direction of the fibre axis in the process of uniaxial deformation. This was revealed by a reduction of orientation supermolecular structure parameters of drawing fibers and mechanical parameters (tenacity and Young´s modulus) of drawn modified PP fibres due to increased content of pigment in PP fibres.

From the procedural technological aspect, the evaluated photoluminescent pigment can be used as tool for the protection of original products, because already small content (about 0.10 wt %) of evaluated pigment provides clearly visible colour change under UV lamp. The lower contents of pigment (< 0.1 wt %) can be measured via equipments with UV detection e.g. hand held scan, Lab-Spectrometer where the optical excitation creates an individual spectral pattern that enables an unambiguous authentification.

***ACKNOWLEDGEMENT**: This work was supported by the Slovak Research and Development Agency under the contract No. APVV-14-0175.*

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SPATIAL ARRANGEMENT OF STAINLESS STEEL FIBERS IN THE STRUCTURE OF HYBRID YARNS DESIGNED FOR THE SHIELDING OF ELECTROMAGNETIC FIELD

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Abstract: *Yarns which contain in their structure, apart from classic textile fibers also very fine metal fibers are often used for the preparation of fabrics with increased electrical conductivity. The quality of the blending of the fiber components in a yarn significantly affects both the properties of the yarn and of the fabric. This reality creates a stimulus for exploring the arrangement of metal fibers in yarn structure, utilizing image analysis and spatial statistics methods. The aim of this work is to test and select a suitable method for obtaining the cross-section of a yarn, containing in its structure metal fibers, which will allow, through the utilization of image analysis, identification of both fibrous components and subsequent evaluation of their spatial arrangement. The work compares various approaches to the cross-cutting of yarns as applied to yarns containing metal fibers, including the use of micro-tomography. An algorithm is proposed for the objective segmentation of both fibrous components in the yarn cross-section, and a methodology is presented for the evaluation of the spatial arrangement of fibers using spatial statistics data. The results of the work show that the metal fibers in the cross-section of the yarn are arranged at random.*

Keywords: *hybrid yarns, stainless steel fibers, spatial arrangement of fibers, cross-section of fibers*

1 INTRODUCTION

Electrically conductive textile structures have obtained increased attention for electromagnetic shielding and anti-electrostatic purposes in recent years. This is mainly due to their desirable flexibility and lightweight.
High electrical conductivity and high magnetic permeability are two important parameters for production of electromagnetic shields. These characteristics are typical for metals. Fabrics for clothing should have low mass per unit area and be flexible to achieve high comfort of wearing and therefore fine staple length metal fibers are often blended with classic textile fibers (natural, synthetic). Since the mixed components have a very different density (e. g. stainless steel 8000 kg/ m^3 and polypropylene 946 kg/m^3), yarns are facing problems with uneven mixing, which negatively affects properties of the fabric (electrical conductivity, electromagnetic shielding ability).
The aim of the paper is to introduce suitable methodology for obtaining a cross-section of a yarn containing metal fibers, which will allow the use of image analysis to identify both fiber components for subsequent evaluation of spatial arrangement.

2 MATERIALS

Hybrid yarn was composed of conventional polypropylene (PP) fiber and staple BEKINOX stainless steel (SS) metal fibers (20 wt%). The diameter of the SS is 8 μm and the fiber length of the SS is 50 mm. In this study, TREVON polypropylene fiber with a fineness 2.2 dtex and 50 mm length was used as a non-conductive component. Properties of these fibers are given in Table 1. The two components were mixed at the drawing frame and a ring spinning system was used to produce blended yarns. Hybrid yarn had linear density 25 tex.

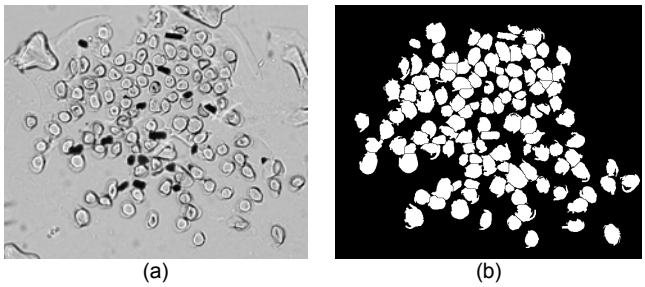
Table 1 Properties of fibers used for this study.

Fiber	Linear density [dtex]	Length [mm]	Tensile strength [cN/tex]	Elongation [%]
PP	2.20	49.79	37.29	73.29
SS	3.85	45.02	14.35	1.29

3 FIBERS SEGMENTATION

The aim of the image processing in this study is segmentation and identification of two types of fibers (PP and metal staple stainless steel fibers) in image area followed by spatial statistic for description of spatial arrangement of SS fibers in the area of yarn. Original images of size 1024×1360 px (real size is 0.855×0.643 μm) were taken by optical microscope Olympus BX51 in RGB color space. Representative original image can be seen in Fig. 1(a), where black cross section of fibers represents SS fibers and lighter objects PP fibers. From 100 m of hybrid yarn 15 images were taken in circa 7 m distance for analysis.
The individual steps of the image processing include conversion RGB image to grayscale followed by global thresholding (threshold was set experimentally) for conversion to binary image, where cross-section of fibers as objects are displayed by white (level=1) and background is displayed by black (level=0). Segmentation to a binary image simplifies subsequent image operations to the application of binary logical operation and in such images it is easier to measure characteristics of objects. Small objects (caused by random noise and imperfect segmentation) may also be visible in binary image; morphological opening is used to remove such small connected objects. Objects connected to image border represented incomplete objects were also removed [1].

In original image we can see that some objects are connected together. We used watershed segmentation for their division [2]. Identification of two types of fibers was based on value of mean grey level (130 in this case) corresponding to individual object. Results of watershed segmentation can be seen in Fig. 1(b) and identification in Fig. 2(a) in form of colored matrix superimposed transparently on original, where blue represent PP fibers and green color SS fibers.

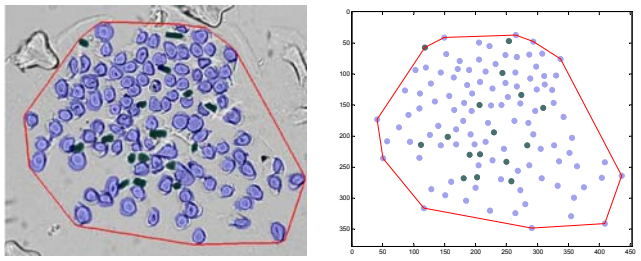


(a) (b)

Figure 1 (a) Original grey level image of yarn cross section, (b) result of watershed segmentation.

4 SPATIAL STATISTIC

For spatial arrangement analysis of cross-section of stainless steel fibers in a point pattern we used the empirical *K*-function. As a point pattern centroids of stainless steel fibers from each processed images were taken, see Fig. 2(b).



(a) (b)

Figure 2 (a) Result of image processing operations, (b) event locations and boundary. PP fibers are displayed by blue, stainless steel fibers by green and convex hull by red color.

Empirical *K*-function is the cumulative average number of data points lying within a distance *r* of a typical data points, corrected for edge effects and standardized by dividing the intensity. The standardization and edge correction make it possible to compare point patterns with different number of points, observed in different windows. An edge corrected estimation of *K* function is given [3]

$$\hat{K}(d) = \frac{r}{n^2} \sum_{i \neq j} \sum \frac{I_d(d_{ij})}{w_{ij}}, \qquad (1)$$

where n is a number of events (centroids), d_{ij} is the distance between the i-th and j-th events, I_d is an indicator function that takes value of one if $d_{ij} \leq d$ and zero otherwise and w_{ij} is correction factor for edge effects. For more information, see monography [3].

Figure 3 summarize estimation of *K*-function for stainless steel fibers (black curve), theoretical Poisson *K* function (red curve) for completely random pattern ($K(d)=\pi d^2$), upper and lower envelope (gray curve) as critical values for a test of the hypothesis that $K(d)=\pi d^2$ taken from 50 simulation [3].

In Fig. 3 we can see that *K* estimation do not show departure from complete spatial randomness. In small distances up to circa 18 μm we can see regularity, because fibers cannot be close together due to their real size. Similar results can be observed for all 15 analyzed images so we can consider the arrangement of SS fibers as random [4].

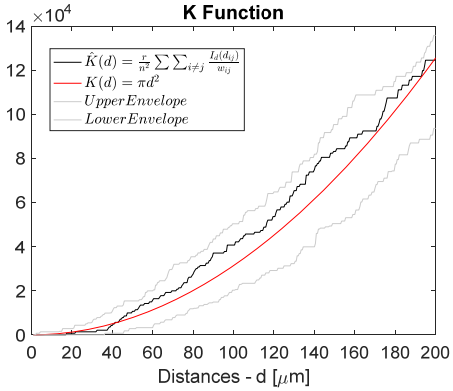


Figure 3 Results of testing for departures of PP fibers from CSR based on $\hat{K}$ with upper and lower simulation envelopes.

5 CONCLUSION

In this study hybrid yarns containing 20% of metal staple stainless steel fiber and 80% of polypropylene fibers were studied. In the next part an algorithm for fiber separation and identification of characteristics was prepared so that both the fiber components can be identified. Watershed segmentation methodology was used for this purpose. Position of fibers in the cross section of the yarn was extracted.

The spatial arrangement of the fibers was evaluated using spatial statistics. Graphical methods of yarn fiber arrangement (a dot map, quadrats map, kernel density estimation of cross-sectional fibers) were used along with statistical estimates (*G*, *F*, *K* function) of the spatial dependencies for assessment from which the model is in the point process of the fiber. For objective evaluation, hypothesis testing using the upper and lower envelope for *K* function, was used and assumes that the samples do not show departures from complete spatial randomness.

From the methods used above, it was found that the spatial arrangement of stainless steel fibers in cross section of yarn area is random.

***ACKNOWLEDGEMENT**: This work was supported by Faculty of Textile Engineering, Technical University of Liberec under the project SGS (no. 21199).*

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RHEOLOGICAL PROPERTIES OF THE PLA MASTERBATCHES FOR FIBRE PREPARATION

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Abstract: *Poly(lactic acid) (PLA) is a biodegradable polymer from renewable resources produced as potential alternative to the synthetic polymers. One of the alternative applications is a preparation of PLA fibres. The PLA fibres prepared by classical spinning technology do not have good mechanical properties, mainly elongation at the break. The prepared PLA fibres are very brittle with bad processability. The modification of the PLA fibres with nanoadditives is one of the perspective ways for improvement of processability of PLA fibres and increasing of multi-functional properties of these fibres. This work is focused on the evaluation of rheological properties of PLA and PLA/HNT masterbatches with various dispersants measured using capillary rheometer Reograph 75. Rheological characteristics such as Non-Newtonian deviation and viscosity are determined from the dependecies of shear stress on the shear strain. In this work there are compared rheological behaviour of PLA and PLA masterbatches with HNT and various of dispersants.*

Keywords: *polylactic acid masterbatches, rheological behaviour, viscosity*

1 INTRODUCTION

The perspective way how to assure special mono- and multifunctional properties of fibres for textile mentioned above is modification of the fibres by nanotechnologies[1]. Mainly, modification of the fibres with nanoadditives into bulk of fibres at the spinning is interested with chance of getting special mono- and multifunctional textiles even at low concentration of additives. Lower consumption of nanoadditives in comparison with the higher consumption of classic additives can add an economic benefit by introduction of new technology[1].

Rheological behaviour of the polymer melt at the PLA fibre spinning is the crucial factor that influences the whole processing to the final product. Generally, due to the origin and the structure used nanoadditives and dispersants for modification of PLA fibres have own specifications related to their melt processing. Halloysite $Al_2Si_2O_5(OH)_4$, naturally occurring aluminosilicate clay, exhibits, unlike currently used natural nanofillers, a range of morphologies and important properties for the polymer nanocomposites. The structure of halloysite strongly depends on the crystallisation conditions and geological occurrences. Halloysite has various morphologies as platy and spheroidal crystals, scroll and the hollow tubular structure that is very interesting for the application in synthetic fibres[2]. An important feature of halloysite is the different surface chemistry at the inner and outer sides of the tubes: silica layer is relevant to the outer surface of tube, while the alumina is in the inner surface. This can be interesting for their modification by substances for the preparation of multifunctional intelligent fibres[3]. At the current utilization of fluorescent dyestuffs has broad application, mainly their surface application in textile materials. An efficiency of surface application of fluorescent dyestuffs is decreased by washing of the textile materials during their useful life. The increase of efficiency and long-time utilization of these pigments and dyestuffs in polymer matrix of the textile materials is very actual question these days[4].

This work is focused on the evaluation of rheological properties of the polylactide acid (PLA) as well as PLA masterbatches with the inorganic additive Halloysite (HNT) and various dispersants measured using capillary rheometer Reograph 75.

2 MATERIALS AND METHODS

2.1 Materials

Polylactid (PLA) produced by NatureWorks, USA with the MFR = 22.8 g/10 min, inorganic nanoadditive of halloysite nanoclay (HNT) (Applied Minerals Inc.), dispersants - polymeric system based on the polyamide/polyether block amide (A22), ethoxylated alkyl amine (B38), compatibilizers based on maleic anhydride (C63), polyhydroxyethers phenoxy resins (D) and silicone oil (E350) were used for the preparation of the PP masterbatches and modified PP fibres.

2.2 Preparation of the PLA masterbatches

There were prepared the PLA masterbatches with the various contents of dispersants and their blends and with the same content of HNT (Table 1). The PLA were compounded with additives and pre-melted by twin-screw extruder Werner-Pfleiderer ZDSK ∅=28 mm at extrusion temperature 200 °C. The extrudate was cooled and pelletized.

2.3 Characterisation Methods

Measurement of the rheological properties was evaluated by the capillary rheometer Gottfert RG20 at the temperature 210 °C. There was capillary with circle diameter with L/D = 30/1 in the range of shear rates from 360 to 9000 s^{-1} with the pre-heating of the masterbatch

per 5 min. On the basis of the various rate of shifting of piston and the measurement of the pressure gradient there were generated incorrect dependencies of shear stress and viscosity on the shear rate for the evaluated masterbatches for the determination of flow consistency index K and flow behaviour index n from Ostwald de Waele power law.

Table 1 Characteristics of prepared PLA masterbatches

MBS	C_{PLA} wt %	Dispersant, wt %				
		A22	*B38*	*C63*	*D*	*E350*
1	100	-	-	-	-	-
2	85	-	5	-	-	-
3	85	5	-	-	-	-
4	86	-	-	4	-	-
5	86	-	-	-	4	-
6	84,5	4	-	-	-	1,5

All the masterbatches are materials with the Non-Newtonian behavior therefore all the measured rheological parameters were corrected using Rabinowitsch correction.

3 RESULTS AND DISCUSSION

Rheological behaviour of PLA and the PLA masterbatches is very important parameter of their processability at the preparation of the PLA and modified PLA fibres from melt. The rheological properties of PLA as well as the PLA masterbatches with 10 % wt. of the inorganic additive Halloysite (HNT) and various dispersants were measured using capillary rheometer Reograph 75. The obtained results are available in Figs. 1-2.

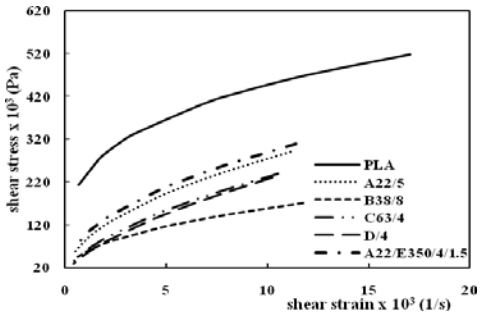

Figure 1 Dependences of shear stress on the shear rate of the PLA and the PLA masterbatches with Rabinovitsch correction

The dependences of shear stress on the shear rate with the Rabinowitsch correction for the PLA/HNT masterbatches with all dispersants are shifted to the lower shear stress in comparison with dependence of shear stress on the shear rate with the Rabinowitsch correction for PLA (Fig. 1). PLA masterbatches with the 5 wt % dispersant of the polymeric system based on polyamide/polyether block amide (A22) and with blended dispersant system consisting the 4 wt % of the polymeric system based on polyamide/polyether block amide (A22) and 1.5 wt % of silicone oil (E350) have the smallest shift. The PLA masterbatches with the 5 wt % dispersant of the ethoxylated alkyl amine (B38) has the highest shift. The higher shift of the dependence with the dispersants from pure PLA suggests the worse processability of these masterbatches.

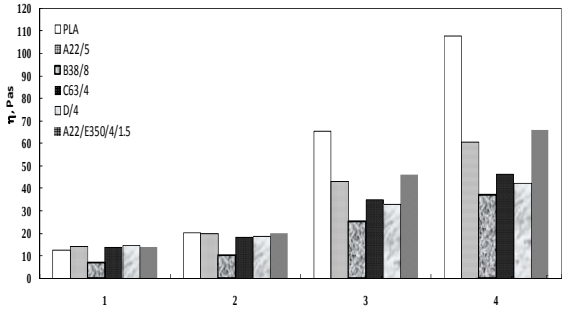

Figure 2 Viscosities of PLA and the PLA masterbatches at the various shear rates (1 – 10000 s^{-1}, 2 – 5000 s^{-1}, 3 – 1000 s^{-1}, 4 – 500 s^{-1})

The viscosities of the PLA/HNT masterbatches with all dispersants at the four shear rates are presented on the Fig. 2. Viscosities of PLA masterbatches at the higher shear rates (10000 and 5000 s^{-1}) are comparable to the viscosity of pure PLA besides of PLA/HNT masterbatch with the 5 wt % dispersant of the ethoxylated alkyl amine (B38). The decrease of shear rates (1000 and 500 s^{-1}) leads to the differences of viscosities of the PLA and the PLA masterbatches. The viscosities of all PLA/HNT masterbatch are lower in comparison with the viscosity of pure PLA. The highest differences of viscosities were observed at the PLA/HNT materbatches with the 5 wt % dispersant of the ethoxylated alkyl amine (B38) and the 4 % dispersant of polyhydroxyethers phenoxy resins (D). This means that at the lower shear rates the processability of observed masterbatches is not good for the preparation of modified PLA fibres. But at the high shear rates of the spinning could be used all PLA/HNT masterbatches without dispersant of the ethoxylated alkyl amine (B38).

4 CONCLUSIONS

This paper presents the observed rheological behaviour of the PLA and PLA/HNT masterbatches with various dispersants. The rheological behaviour is different in comparison with the rheological behaviour of pure PLA.

***ACKNOWLEDGEMENT**: This work was supported by the Slovak Research and Development Agency under the contract No: APVV-14-0175 and APVV-14-0301.*

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CARBON NANOTUBES AS FILLER FOR ELECTROMAGNETIC INTERFERENCE APPLICATIONS

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Abstract: *This work examines the electrical properties of composite made of thermoplastic polymer matrix and carbon nanotubes. Polypropylene was used as basic matrix to which nanoparticles in the weight percentage ratio were added. Multi-walled carbon nanotubes in various percentages by weight ratio were used as filler. The nanocomposite was made by the Arburg injection molding machine. For evaluation of electrical properties electromagnetic shielding effectiveness of the final composite with and without nanofillers was evaluated. In the paper, mechanical properties of the carbon nanotube-filled composites are also described. These results are compared and discussed. Influence of multi-wall carbon nanotubes amount on the electrical and mechanical properties of polymer composite is evaluated and predictor models are introduced in the conclusion.*

Keywords: *carbon nanotubes, nanocomposite, electromagnetic interference*

SIMULATION OF THERMAL INSULATION THROUGH AEROGEL BASED FIBROUS STRUCTURES

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Abstract: *Aerogel has super-insulating characteristics and the heat transfer phenomenon is associated with its complex nanoporous structure. Measurement of thermal properties of aerogel coated material is important to evaluate its usefulness under extreme weather condition. This study was focused on thermal insulation of nonwoven with and without aerogel fibrous materials. Modeling and simulation were used to study the heat transfer through porous aerogel materials using Ansys and Comsol. The results show that the fabric density and the aerogel present in the fabric have a significant effect on thermal properties of the overall structures. The heat retention in the nonwoven structure with aerogel was 67% higher than in the nonwoven structure without aerogel implying that aerogel hinders heat transfer, thus keeping the body warmer.*

Keywords: *Aerogel, Simulation, Thermal Insulation, Ansys, Comsol, Nanoporous*

1 INTRODUCTION

Combination of different types of fabrics, with various coatings and treatments, are being studied to understand and improve the effectiveness of materials as thermal insulators. Different kinds of fibrous materials such as traditional nonwovens are used as the middle thermal insulating layer. Nonwoven fabrics are important components for good thermal insulation from the surroundings, and they offer both space and weight savings[1]. The important constructive parameters are thickness, weight per unit area and packing fraction p.f., which is the ratio between the bulk density of fibrous structure samples and of the same sample if it was made up wholly from the same polymer [2]. Thermal insulation properties are determined by the physical parameters of fibrous structures as well as the structural parameters [3].
Heat is usually referred to in thermodynamics through the term “heat transfer”, which is consistent with the ability of heat to raise or lower the energy within a system. Since fabric is a heterogeneous system of air and fabric, conduction through air and fibers contributes to total thermal conduction of the fabric [4]. All three modes of heat flow rely on a temperature difference for the transfer of energy to take place. The greater the temperature difference the more rapidly will the heat be transferred [5].
Numerical methods are used due to its reliable accuracy and flexibility in different simulated conditions. For modeling, series of governing equations based on the energy conservation of law is normally used to depict heat transfer process in fabrics.
In this study, numerical simulation was used to evaluate the heat flux, temperature distributions, and convective heat transfer coefficients of fibrous insulating materials treated with and without aerogel.

2 MATERIALS AND METHODS

2.1 Materials

In this study, 50:50 ratio composition of polyester/polyethylene non-woven fabrics treated with aerogel were used. The type of aerogel used was hydrophobic amorphous silica aerogel. The aerogel particles were added during thermal bonding of the non-woven web. The samples were chosen ins as are widely used in most textile insulating applications. The non-woven fabric samples were characterized using SEM (VEGA TESCAN Inc. USA) at 30 kV. Modelling and simulation was done using ANSYS and COMSOL.

3 RESULTS & DISCUSSION

3.1 Microscopic Analysis of Samples

SEM was used for characterization of aerogel treated nonwoven fabric samples. A typical high resolution images for the aerogel-treated nonwoven fabrics are shown in Figure 1 which shows and confirms aerogel dispersion in between the fibers in the structure.

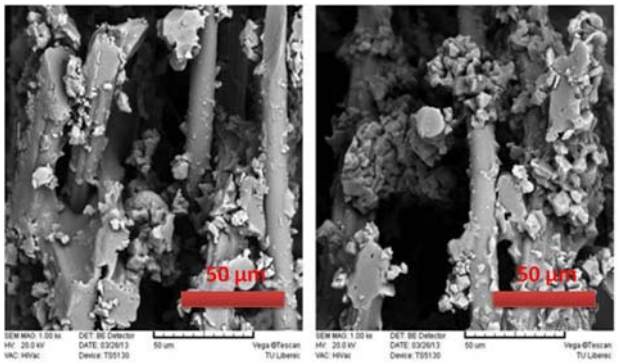
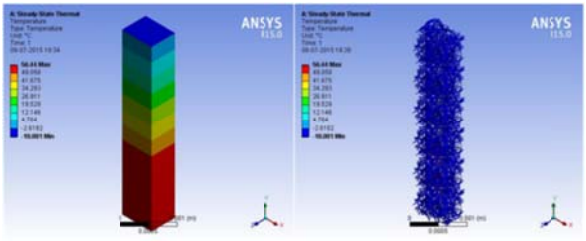


Figure 1. Scanning electron microscope images of aerogel-treated non-woven fabrics.

3.2 Modeling of Heat Transfer

During simulation in ANSYS, a constant ambient temperature of -10^{o}C was considered. Simulation was done so as to allow heat to flow along the thickness of the fabric (perpendicular to both the machine and the cross direction). As the heat flows under the temperature gradient provided, various levels of the fabric thickness settle down to different equilibrium temperatures which is depicted in the ‘Temperature’ diagram shown in figure 27. Apart from this, variations in the ‘Total Heat Flux’ and the ‘Directional Heat Flux’ (along the Y axis – because that is the major direction for heat transfer) have been shown. Clearly, the heat retention in the nonwoven structure with aerogel is 67% higher than in the nonwoven structure

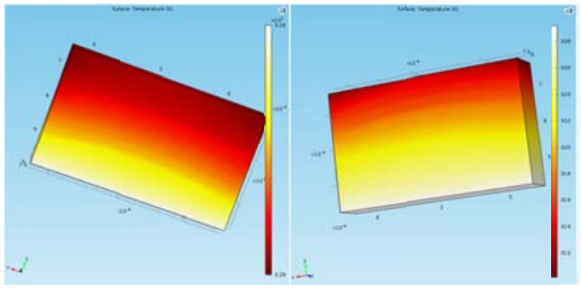
without aerogel implying that aerogel hinders heat transfer, thus keeping the body warmer.



(b)

Figure 2. Temperature gradient for aerogel treated nonwoven.

Using COMSOL, In the case of standard nonwoven without forced convection, the temperature at the surface exposed to outside air was 329.18955 K and the heat rate through the fabric was 2.185 e^{-8} W.



(a) (b)

Figure 3. Heat transfer through (a) aerogel treated nonwoven without forced convection (b) aerogel treated nonwoven with forced convection.

In the case of standard nonwoven with forced convection showed in figure 28(b), the temperature at the surface exposed to outside air was 318.04327 K and the heat rate through the fabric was 1.024 e^{-8} W. In the case of nonwoven with aerogel and without forced convection shown in figure 28(c), the temperature at the surface exposed to outside air was 329.18949 K and the heat rate through the fabric was 1.267 e^{-8} W. In the case of nonwoven with aerogel and with forced convection shown in figure 3, the temperature at the surface exposed to outside air was 310.16686 K and the heat rate through the fabric was 9.801 e^{-9} W. In the case of forced convection, the difference between the surface temperatures in case of air and aerogel for is almost 8 K even for such a small unit cell. When forced convection was not taken into account, the temperature difference was very less (6 e^{-5} K). But in both cases, the heat flow through air is higher than in case of aerogel. In the case with forced convection, the heat rate was around 5% higher and in the case without forced convection, the heat rate was more than 72% higher. That is, the heat loss through the air is 1.7 times the heat loss through aerogel, in the case without any forced convection. The total net heat rate is defined as the net incoming and outgoing heat fluxes through all the surfaces of the body. This value for forced convection case is seen to be less in both aerogel and air because the outgoing flux is much more when there is a forced convection. The temperature versus length plot was also made. This was a smooth curve for the cases of forced convections but in the cases with no forced convections, the graph obtained had steps maybe because of very less variation of temperature in those regions.

4 CONCLUSIONS

The modeling and simulation of heat transfer for aerogel-treated nonwoven fabric was carried out by ANSYS and COMSOL. The simulation results showed that thermal behavior of the fabric improved when treated with aerogel. This may be attributed to the nanoporous structure of the aerogel that hinders transfer of heat through its structure. The simulated data agreed well with experimental data. The numerical simulation of convective heat flow fabric can be considered a reliable method since there is a good agreement between simulation and experimental data. Aerogel may be considered a good insulator for improving thermal insulation of textiles. Further research has to be done to investigate convective heat transfer and the effect of aerogel's pore size and distribution on the thermal properties of fabric. The heat transfer properties of the fabric can be further optimized with assistance of this model..

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Title	**Book of Abstracts – 9th Central European Conference 2017**
Editor	Collective authorship
Publisher	Technical University of Liberec
Approved by	Rector´s Office of Technical University of Liberec
	Ref. no. RE 35/17, 30th August 2017
Date of Issue	August 2017
Edition	First
Number of Pages	169
Printed by	Vysokoškolský podnik Liberec, spol. s.r.o., Studentská 1402/2, Liberec
Publication Number	55-035-17

ISBN 978-80-7494-356-0

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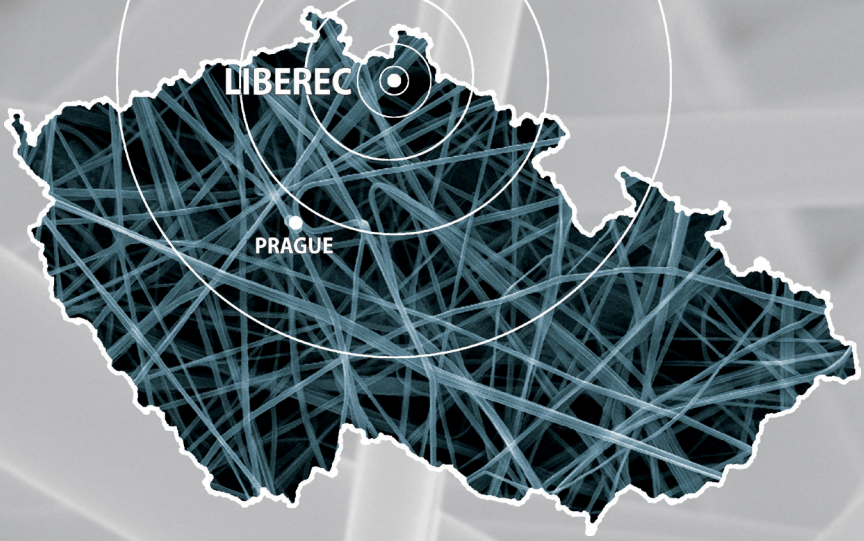

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