# SOME CONSIDERATIONS ON A MOLDING SIMULATION FOR A POLYETHYLENE PRODUCT

G. Gregov[1], S. Žic[2], M. Kršulja[2], B. Barišić[2] and J. Kudlaček[3]

[1]University of Rijeka, Faculty of Engineering, Department of Mechanical Engineering Design, Croatia

[2] University of Rijeka, Faculty of Engineering, Department of Industrial Engineering and Management, Croatia

[3] CZU in Prague, Faculty of Mechanical Engineering, Department of Manufacturing technology, Czech Republic

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**Abstract.** A number of considerations must be taken into account while designing a plastic product. Use of simulations facilitates creation of defect free products while taking in consideration its final use. In this paper an investigation of filling time, cycle and considerations of design geometry, material flow, mold and product cooling are discussed. An example of a tap used as insert into chairs with tube frame is shown and its production analyzed. Cycle times are tested in real production and results discussed. Mold flow simulation is used for prediction and control of runner balancing.

### Introduction

Several steps and considerations are needed to be done in order to create a plastic product such as industrial design, mechanical design and lastly production [1]. Simulations are used in order to create a digital factory where multiple processes can be monitored. Simulation benefits us to determine where the defects are most likely to occur while there are still many options available to correct it. Also, it allows us to create multiple designs and calculations of the most profitable solution. More material inserted into the process than necessary can require more time to cool and can result with bigger shrinkage that can cause sinking of plastics [2]. After such errors occur in real production line reparation of used dies is needed. Reparation of mold by welding is undesirable as it can cause lower lifecycle of the mold, it can break in production and it causes additional expenses. Another problem that can be simulated is shear test analysis, control of the design that calculates week spots. Shear test is useful because parts can be manufactured without surface errors but they unexpectedly fail to perform their function when put under load conditions [3-12]. With simulation the runner balancing can be solved and ensure optimal filling of cavities with same quality.

Injection molding process needed for creation of selected polypropylene product is investigated in the paper. Material selection together with mixing ratios and their preparation for production process are shown. Influence of material composition on the quality of the product is discussed. Several parameters used in the process are analyzed and a solution of a robust process for specified product is given. Temperature of the material and the liquefying – solidifying process of the melt is monitored and final shape errors discussed. The material required for each shot and molding cycle is analyzed and improvements implemented into design.

A CAD design of mold is given and cycle time analyzed. Mold flow simulation with MoldflowXpress that is included in Solidworks 2007 was also used in presented investigation.

### Product

Stacking chairs and other chairs with steel tubing frames use taps in order to facilitate contact between various floor materials to prevent them from scratching or snagging on the floor. The product on Fig. 1 shows investigated model with ending as Oval of 30 x 15 mm. The ribs as shown in figure are created in order to accommodate the variations in tube wall dimensions for oval tubes 30 x 15 x 1.2 mm (the thickness is varying in range from 1.0 mm - 1.5 mm). The ribs are created accordingly and have to perform a tight fit into the tube opening.

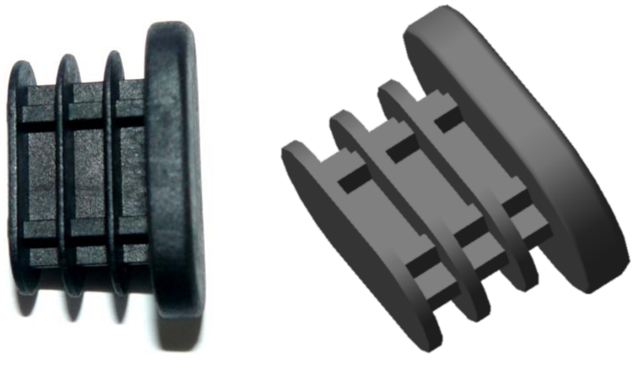

Fig.1 Foot tap for chair and 3D model of foot tap for chair

Chair frames in our example use powder coated tubing and their quality is measured by The Business and Institutional Furniture Manufacturer's Association (BIFMA). BIFMA defines standard X5.1 [13-15], for testing of commercial-grade chairs. It specifies following requirements:

- chair back strength of 68 kg
- chair stability if weight is transferred completely to the front or back legs
- leg strength of 34 kg applied on 25 mm from the bottom of the leg
- seat strength of 102 kg dropped from 150 mm above the seat
- seat cycle strength of 100.000 repetitions of 57 kg dropped from 50 mm above the seat.

The specification further defines heavier "proof" loads that chairs must withstand. Under these higher loads, the chair may be damaged, but it must not fail catastrophically. It increases lifespan of the chair. Well balanced chairs will last longer with an equal weight distribution through all legs. Chair taps can be used for balancing, thus increasing durability.

**Material**

In this research polyethylene PE is used for production with composition of 98 % of polyethylene (PE) and 1.5 to 2 % of master. The mixing ratio of recuperation is 70 % percent of primary mixture and 30 % of recycled material (Fig. 2). The primary mixture consists of 1.5 - 2 % of comonomer (master) and the rest is Polyethylene (PE)

Polyethylene (PE) - The term polyethylene describes a huge family of resins obtained by polymerizing ethylene gas, H2C = CH2, and it is by far the largest volume commercial polymer [1 - 9]. This thermoplastic is available in a range of flexibilities and other properties depending on the production process, with high density materials being the most rigid. Polyethylene can be formed by a wide variety of thermoplastic processing methods and is particularly useful where moisture resistance and low cost are required (PE properties Tab. 1). Low density polyethylene typically has a density value ranging from 0.91 to 0.925 g/cm$^3$, linear low density polyethylene is in the range of 0.918 to 0.94 g/cm$^3$, while high density polyethylene ranges from 0.935 to 0.96 g/cm$^3$ and above.

Fig. 2 Material commoner, mixed material, material waste prepared to be reused

Table 1. Standard PE properties [1 - 9]

| Property | PE low-high density | Property | PE |
|---|---|---|---|
| Nozzle Temperature | 160 - 246 °C | Crystallization temperature | 112 - 117 °C |
| Middle Barrel Temperature | 154 - 243 °C | Mold shrinkage | 0.0100 - 0.0300 cm/cm |
| Specific density (g/cm$^3$) at 20 (°C) | 0.924 - 1.05 g/cc | Flexural Modulus | 0.280 - 1.81 GPa |
| Mold Temperature | 10.0 - 65.6 °C | UnnotchedIzod impact strength (kJ/m) at 23 °C | 2.45 - 5340 J/cm |
| Injection Pressure | 2.76 - 103 MPa | Tensile elongation at break | 3.20 - 2080 % |
| Melting point (°C) | 121 - 136 °C | Tensile strength (MPa) | 10.0 - 43.0 MPa |
| Melt flow | 0.0250 - 1610 g/10 min | Base Resin Melt index | 2.00 - 20.0 g/10 min |
| Spiral flow | 15.5 - 53.8 cm | Hardness Rockwell | 33.0 - 52.0 |

**Parameters, molding cycle and temperature**

Injection molding machine Plastic metal Mod PM 135 is used in this investigation. Injection molding is a cyclic process (Fig. 3) where each cycle compromises several operations feeding, melting, homogenization of polymer grains, mold closing, injection under pressure, cooling or heating the polymer inside the mold, mold opening and ejection of molded part. Control over process variables can be more precise by proper selection of barrel temperature, screw speed, mold temperature, cooling or heating and injection pressure.

In Table 2 total cycle time and other times are presented. The times were calculated and modified until the specified product gave satisfying quality. Improvement for cycle time can be obtained in cooling time as the process will yield a good product even for 10 seconds; however this time was proven to be sensitive to temperature changes and therefore for a more robust process cooling time of 11.8 seconds was selected.

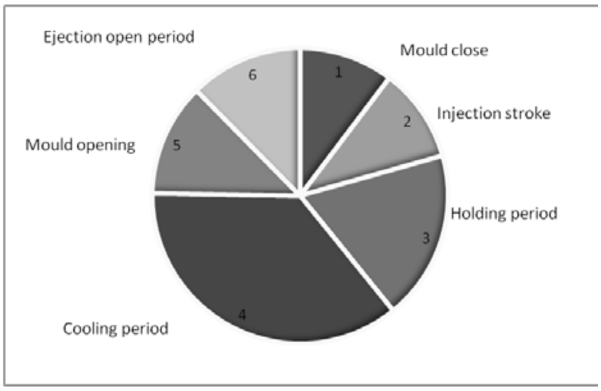


Fig. 3 Cycle times diagram [2]

Table 2. Cycle times and pressures

| Activity | Period [s] | Pressures | MPa |
|---|---|---|---|
| Alarm | 52.8 | Clamping low | 13 |
| Recycle | 0.3 | Injection speed | 90 |
| Injection | 9.0 | Lower injection speed | 60 |
| Cooling time | 11.8 | Counter-pressure | 16 |
| Screw delay | 0.5 | | |
| Flow molding | 0.2 | | |
| Carriage retract delay | 0.3 | | |
| Ejector out delay | 0.4 | | |
| Ejector retract delay | 0.5 | | |
| Total cycle time | 23.0 | | |

Alarm represents the setting time that activates in case of failure and stops the pump for selected duration. Setting time must be higher than overall cycle time. Recycle is the time necessary for ejection of molded part. Injection represents screw rotation that starts to supply the preselected material into the mold. Cooling time is the selected time necessary for cooling of the part. Screw delay by delaying the shot volume it prevents the nozzle from drooling. Flow molding controls quantity of material to be introduced in the mold. Carriage retract delay, ejector out delay and ejector retract delay are used for part and runner ejection.

Temperature of the tooling used for specific PE material was 65 °C and the melting points used in the process were 180 °C for initial preheating then 190 °C for melting and mixing in the screw and 200 °C before entering into the die cavity. Pressure used for injection speed in the specified process was 90 Mpa. Tooling used in the process can be seen on Figure 5.

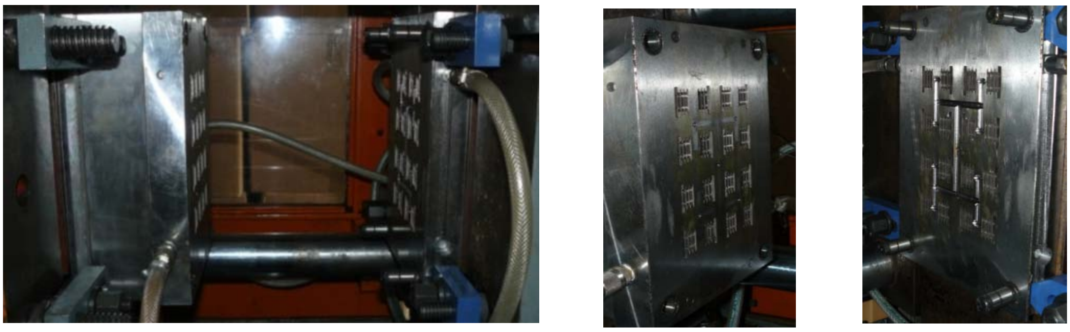

Fig. 5 Tooling used in production process

**Mold simulation with MoldflowXpress software**

Mold simulation has also been made by the use of the software MoldflowXpress (Solidworks 2007). MoldflowXpress is an introductory version of Moldflow Plastics Advisers (MPA) for SolidWorks. For 1 kg of material 165 parts are produced, 6 grams per part. One shot has 97 grams for parts and additional 5 grams for runner making total of 103 grams per shot.

Figure 6 shows the runner concept. Considering the real works regime and material characteristic, chosen material is Polyethylene (PE), melt temperature 200 °C and mold temperature 70 °C. Injection location has been chosen in the center of foot tap for chair, the same as in the real process. The simulation demonstrated that for the chosen mold material and the temperature the cavity of mold tool is completely filled without residual volume. The total time necessary for filling 6 grams into the mold was 2 second in simulation and 8 seconds for all 103 grams of total shot needed for production of all parts. In real process 9 seconds were used for 103 grams at the pressure of 90 MPa in order to keep the process more robust. Results of simulated filling of a single part of the mold capacity are shown in the Fig. 7. Considerations of balanced filling of all parts were taken into consideration and the model has shown good performance.

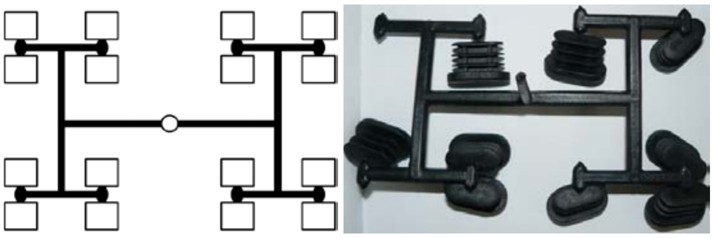

Fig. 6 Runner concept and final production

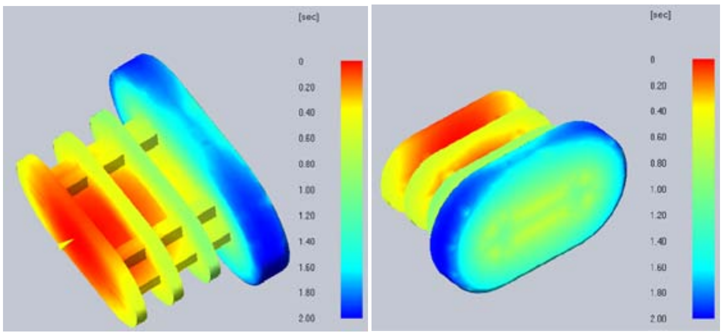


Fig. 7. 3D model of product with critical areas

**Conclusion**

Influential parameters for injection molding have been presented with emphasis on cycle calculation for given product. CAD mold simulation has shown adequate results that can allow preparation of new production and give better correlation between influential process parameters. By simulation we have obtained the necessary data needed for creation of a mold design and critical points. Experimental production has shown that simulation does not give a good enough robust process because of unpredicted parameter behavior such as temperature variation, cooling cycle and material mixing. Several recommendations based on simulation results have been made in order to maintain an error free production. Further investigation will be concentrated on use of different material and its adaptability to given mold design. Several equations will be investigated such as production rates, behavior runners, selection of optimal melt temperatures and mold temperature etc.

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