Finite Analysis of Deep Drawing Tool Geometry for Thin Walled Tin Can

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Keywords: deep drawing, FEM, sheet metal, deformation, TS230 (1.0371)

Abstract. This investigation proposes modeling of new deep drawing tool geometry for thin sheet metal. TS230 (W. nr. 1.0371, T50HF) D2,8/5,60 41 ST/Fin thin walled (0.155 mm) material properties are investigated and results are put in numerical simulation. Tooling with influential parameters is modelled and analyzed with ABAQUS software. Minimum drawing force necessary for selected tool geometry and overall tool behaviour is investigated. Heat generation of selected tooling of deep draw process and its influence on thin sheet metal deformation is also considered. Optimization of process is achieved by elimination of errors that appear in form of wrinkling, excessive thinning or fracture.

Introduction

Deep drawing process is constantly subjected to new and thinner materials. in this paper for given example in order to achieve high process efficiency and reduce the production costs deep drawing process of thinwalled tinplate is evaluated. The evaluation of deep drawing process is based on reliable information regarding mechanical properties and consists of achieving minimal process force, determination of optimal blank shape, optimization of forming steps, product stability, minimal thickness in product, wrinkling, springback and prediction of defects. Changes in material properties reflect to the final product geometry, if we assume that the same tooling geometry and work conditions are used. Defects that occur in deep drawing process can be traced and their cause analyzed. The process adjustment requires deep understanding of thinwalled tinplate products production and deep drawing process. Combination of different stresses that the product requires is determined by tool radii, material properties, temperature generated in process etc. and as such cause wrinkling, tearing and reduced formability [1]. In this paper potential problems will be analyzed in FEM analysis applying ABAQUS Explicit code, in order to study feasibility of proposed model.

Material

Thinwalled plate, electrolytic tinplate is a cold rolled low carbon mild steel sheet or coil coated on both surface with tin layer that is applied in continuous electrolytic operation. Thin can be applied equally or differentially where one surface carries heavier tin coating than other. Tinplate is produced in sheets or strips of a thickness from 0.100 to 0.49 mm, with a carbon content up to 0.13 % C, table 1. Tinplate surface is therefore covered on both sides with a thin layer of primer tin, minimum purity 99.85 %, this gives it the white color and thus it is called white or tin plate. In this paper simple reduction tinplate material TS230 (W. nr. 1.0371) [2] is investigated. TS230 has non-ageing quality and is suitable for the fabrication of deep drawn products. Standard ultimate tensile strength for material TS230 is R_m =325 ± 50 MPa, while Rockwell hardness HR 30 Tm: 52.

Table 1. TS230 (1.0371) material composition % [3]

C	Si	Mn	Ni	P	S	Cr	Mo	N	Al	Cu	As	Sn	Others	-
0.04 - 0.08	max 0.03	0.18 - 0.35	max 0.08	max 0.02	max 0.02	max 0.08	max 0.02	max 0.008	0.02 - 0.08	max 0.08	max 0.02	max 0.02	total 0.02	Type A

The flow curve of material can be described in the form of hardening law:

$$k_f = C \cdot \varphi^n, \tag{1}$$

where: k_f is the true stress, φ is the true plastic strain, n is the strain-hardening exponent, C is the strength coefficient. Experimental results of uniaxial tensile test in order to obtain C and n was conducted in angle of 0°, 45°and 90° in regards to rolling direction of sheet metal strip. The resulting flow curve that will be used in simulation has a form of:

$$k_f = 394.96 \cdot \varphi^{0.083}. \tag{2}$$

Experimental setup

Metal can is produced in three steps, disc cut from sheet, drawing into shallow can and forming of flanges. At each tool station the press cycle cuts a circular disc (blank) from the metal and whilst in the same station draws this in to a shallow can (cup). During the drawing process the metal is reformed from flat metal into a three-dimensional can without changing the metal thickness at any point. After this single draw, the can may be already at its finished dimension. However, by passing this cup through a similar process with different tooling, it may be re-drawn into a can of smaller diameter and greater height to make a draw–redraw can (DRD) [4]. Figure 1 shows basic schematic in creation of can.

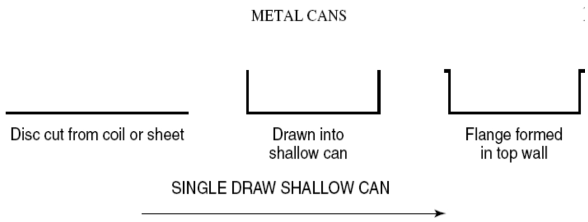

Fig. 1 Drawing of can in three steps

One of occurring problems in can design is the calculation of die and tooling radius. In this paper such tooling is investigated for material of thickness 0.155 mm. Thin sheet causes sudden wrinkling and usual formula r_d =(5 -10)· s_0 (where r_d is die radius, s_0 sheet thickness) and r_p = r_d·(2-5) (where r_p is punch radius) don't work properly, the necessary radius are much bigger [5]. The process consists of two steps and they have to be planed accordingly. Second tool in process must be made to take the workpiece form first step and execute finished product. The thinwalled sheet metal blank has an single grain structure, so the stresses can influence the final result of specified product design. In factory conditions typical working temperature of thinwalled products was measured to be around 35 °C. Therefore care of the grain orientation and anisotropy must be minimized. Initial blank size used in investigation is 120 mm, finish product radius is $\boldsymbol{d_n}$=70 mm by equation (3) the ideal height $\boldsymbol{h_n}$ = 34 mm.

$$\boldsymbol{D_0} = \sqrt{\boldsymbol{d_n^2 + 4d_n h_n}} \tag{3}$$

The maximum drawing force can be calculated by equation (4):

$$F_{d,max} = n \cdot \pi \cdot D_0 \cdot s_0 \cdot UTS, \tag{4}$$

where $F_{d,max}$ - drawing force, D_0 - cup diameter, s_0 - sheet thickness, UTS - ultimate tensile strength, n - drawing coefficient for metal (0.7 - 0.95). For material TS230 $F_{d,max}$ =0.95· π·120·0.155·395 = 21916 N. Friction between material and die was tested [6] and for investigation in simulation penalty friction μ = 0.25 was used. in simulation for the low carbon steel of thickness 0.155 mm a Young's modulus 210 GPa, mass density 7.85 gm/cc and Poisson's ratio 0.30 was used. In figure 2 the assembly of two step tooling setup is shown, each step has specific radii used in order to reduce wrinkling and earring [5]. In simulation C3D8R elements are used, C3D8R represent an 8-node linear brick, reduced integration, hourglass control. Number of nodes used in simulation: 3290, number of elements used in simulation: 1591.

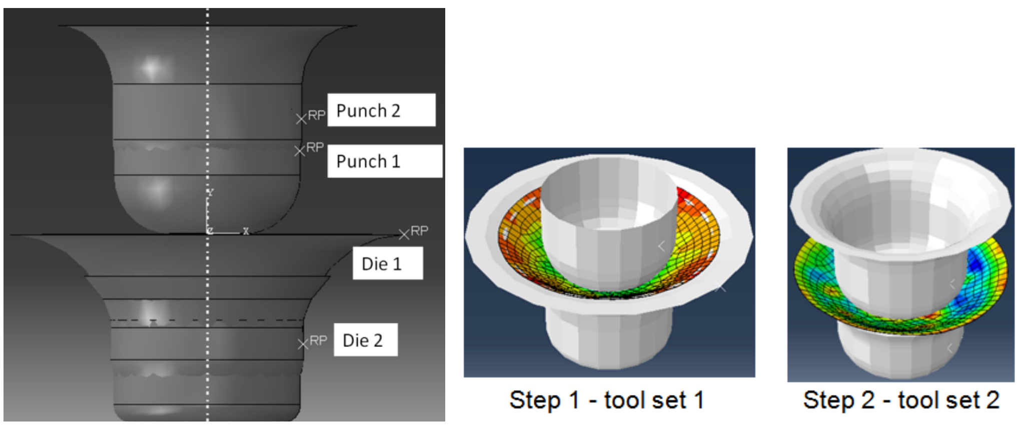

Fig. 2 Assembly of two step tooling setup in ABAQUS

Results of first step is max Von Misses stress 334 MPa and depth of 25 mm, while second step approached max limit with 380 MPa and obtained the target depth of 34 mm, figure 3 and 4. In first step the radii of punch and die were changed until the wrinkling was eliminated final die radius was selected of r_d = 38 mm was used in combination with punch radius of r_p = 20 mm. In second step problems occurred with connecting with first step, r_d = 18 mm and r_p =14 mm was used. The die should come into effect immediately after the first step is finished, however simulation showed most errors in connecting with second step. For second step final product geometry was used, results showed small error in the form of wrinkling and earring in comparison to expected behavior of material in work condition.

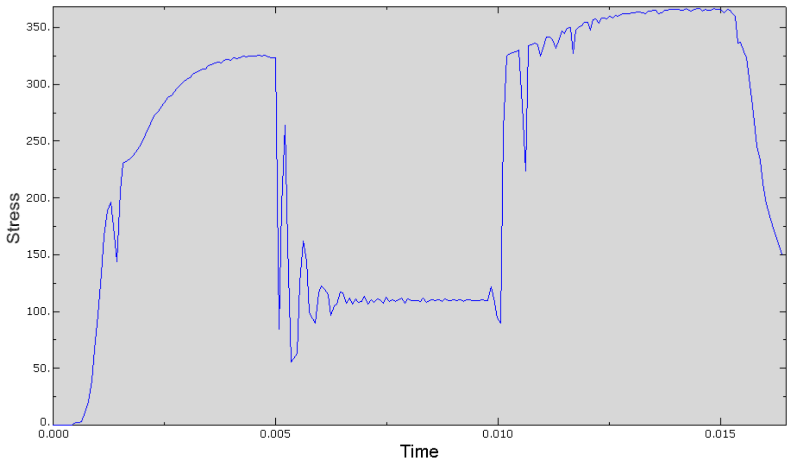

Fig. 3 Von Misses stress for combined first and second step

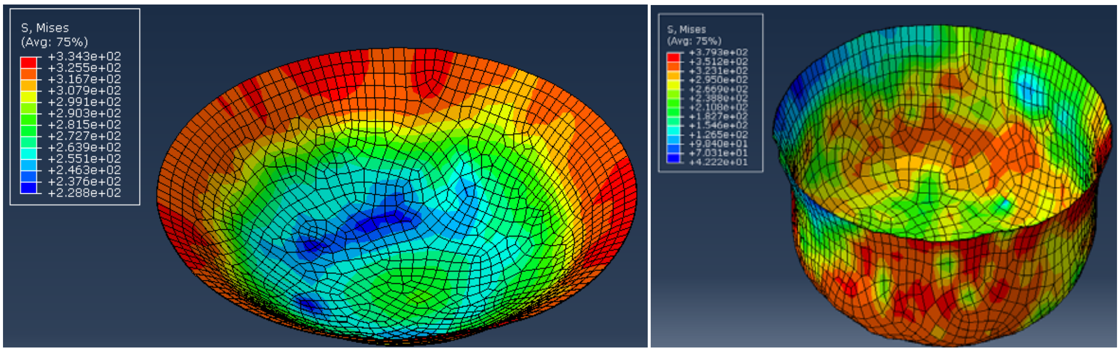

Fig. 4 Results of first and second step

In figure 5 tool path displacement is shown, in simulation smooth path was selected for tool movement.

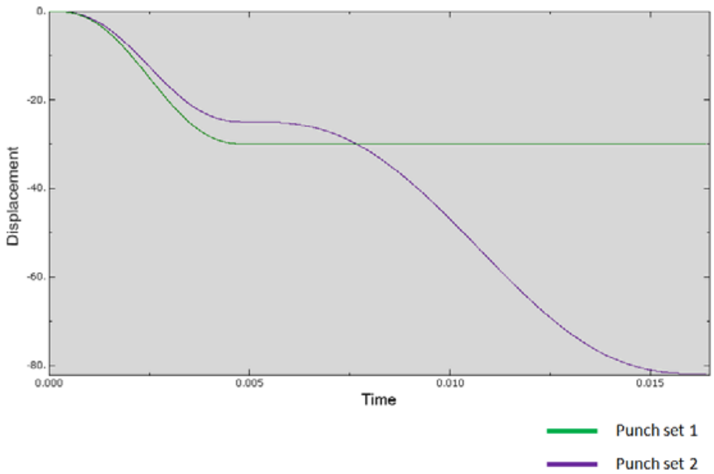

Fig. 5 Results of first and second step

Conclusion

By simulation the necessary data needed for creation of optimized tooling design was obtained and critical points have been analyzed. In first step die radius of r_d = 38 mm was used in combination with punch radius of r_p = 20 mm in order to achieve depth of 25 mm, wrinkling was eliminated. In second step r_d = 18 mm and r_p =14 mm was used in order to obtain final product geometry was used, results showed small error in the form of wrinkling and earring in comparison to expected behavior of material in work condition. Tooling design for first and second step was created with control of stress according to hardening law in order to eliminate fracture and wrinkling occurrence. By radii variation final maximum stress in first step was 334 MPa while in second step it was 380 MPa which is lower than allowed by hardening law of 395 MPa. Further research will be focused on implementation of temperature in simulation, construction of prototype and real industry implementation.

Acknowledgment

The authors would also like to acknowledge the support provided by the University Foundation of Rijeka, http://www.zaklada.uniri.hr.

The authors would also like to acknowledge the support provided by the National CEEPUS Office of Croatia, National CEEPUS Office of Slovenia and National CEEPUS Office Czech Republic, which helped the research through mobility in the frame of the CEEPUS II HR 0108 project, http://www.ceepus.info. The authors would also like to acknowledge the support provided by Metalplast, Croatia company that supported investigation of their product.

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