STUDY OF THIN WALLED CONE BY USING OF FINITE ELEMENT ANALYSIS IN DEEP DRAWING

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ABSTRACT

In this research paper the study has been carried on proposes modeling of deep drawing tool geometry for thin sheet metal. Steel grade TS230 material has been taken and cone thickness (thin walled 0.155 mm) has been considered. Tooling with influential parameters is modelled and analyzed with ABAQUS 6.10 software haven been used for analysis. Minimum drawing force necessary for selected tool geometry and overall tool behavior is investigated during study. Heat generation of selected tooling of deep draw process and its influence on thin sheet metal deformation is also being considered. Optimization of process is achieved by elimination of errors that appear in form of wrinkling, excessive thinning or fracture.

I. INTRODUCTION

Deep drawing process is constantly subjected to sheet metal forming process. In this research paper in order to achieve higher efficiency and reduce the production cost of deep drawing process of thin walled tinplate is evaluated. The evaluation of deep drawing process is regarding mechanical properties and consists of achieving minimal process force, determination of optimal blank shape, optimization of forming steps, product stability, and minimal thickness in product, wrinkling, spring back and prediction of defects. Changes in material properties reflect to the final product geometry, in this study it is assume that the same tooling geometry and work conditions are used. Defects that occur in deep drawing process can be considered and their causes have been analyzed. The process requires deep understanding of thin walled tinplate products production and deep drawing process. The state of stress and their component and strain and their component flow in the product requires is determined by tool radii, material properties, temperature generated in process etc. and these cause of wrinkling, tearing and reduced formability [1,7].

II. MATERIAL

Thin walled plate, electrolytic tinplate is a cold rolled low carbon mild steel sheet or coil coated on both surface with in layer that is applied in continuous electrolytic operation. This 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 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 *Rm*= 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
0.04-0.08	0.03	0.18-0.35	0.08	0.02	0.02	0.08	0.02	0.008	0.08	0.08	0.02	0.02

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

$$k_f = C.\varphi^n \qquad (1)$$

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:

$$k_f = 394.96.\varphi^{0.083} \qquad (2)$$

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 = *rd*·(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 work piece form first step and execute finished product. The thin walled sheet metal blank has a single grain structure, so the stresses can influence the final result of specified product design. In factory conditions typical working temperature of thin walled 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 $d_n = 70\ mm$ by equation (3) the ideal height$h_n = 34mm$.

$$D_o = \sqrt{d_n^2 + 4h_n d_n} \qquad (3)$$

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

$$F_{d,max} = n.\pi.D_o.S_0.UTS \qquad (4)$$

where *Fd,max*- drawing force, D_o- 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 fig. 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 linearbrick, reduced integration, hourglass control. Number of nodes used in simulation: 3290, number of elements used in simulation: 1591.

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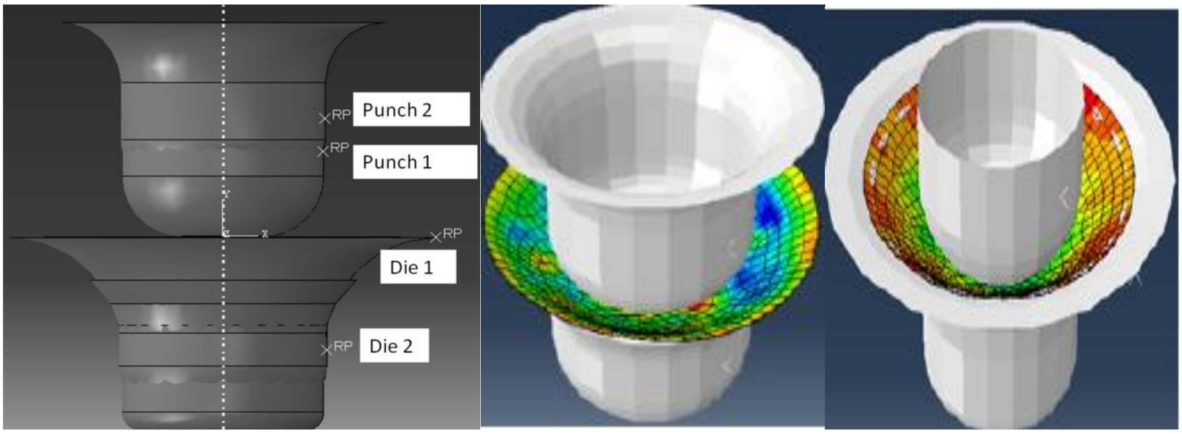

Fig. 2: Assembly of two step tooling setup in ABAQUS of Die and Cone

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 *rd*= 38 mm was used in combination with punch radius of *rp*= 20 mm. In second step problems occurred with connecting with first step, *rd*= 18 mm and *rp* =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.

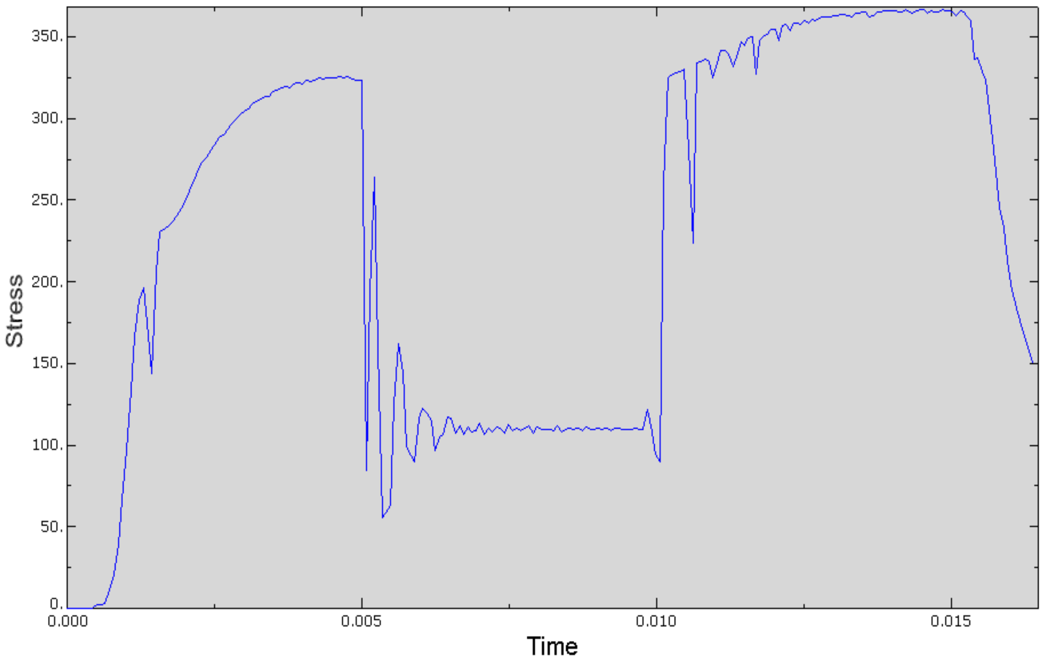

Fig. 3: Von Misses stress

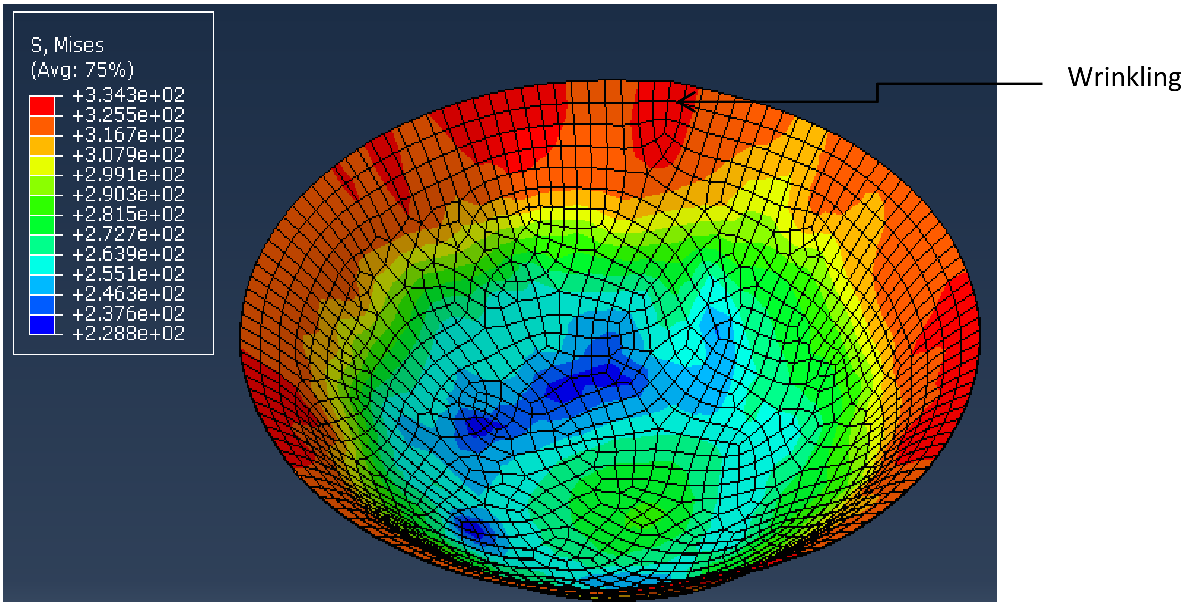

Fig. 4.1: Results of first step

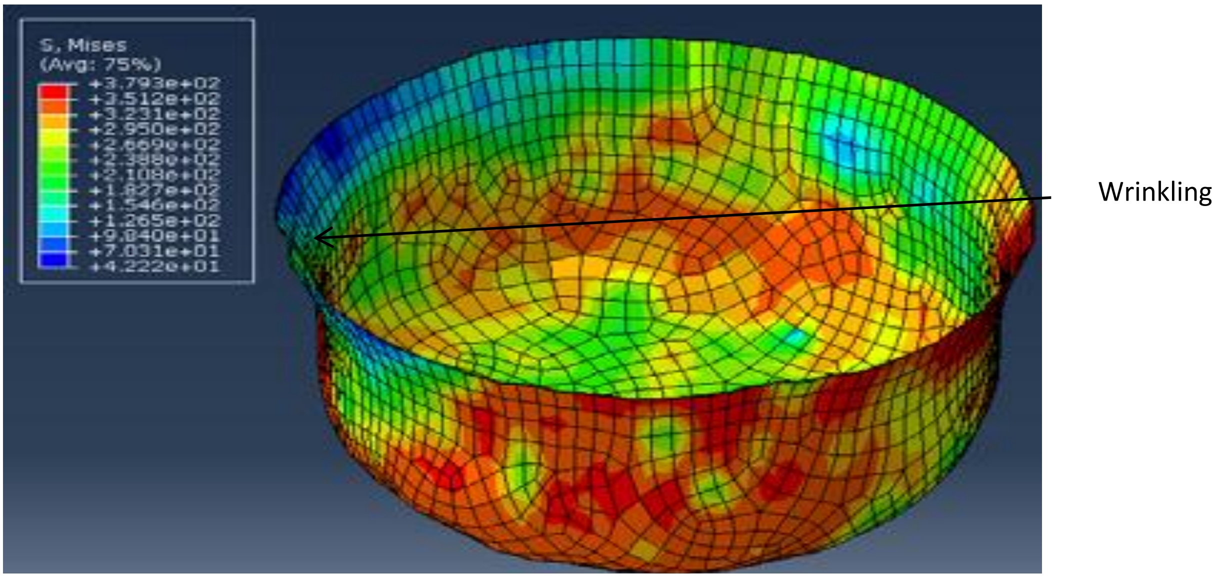

Fig. 4.2: Results of second step

III. 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 *rd*= 38 mm was used in combination with punch radius of *rp*= 20 mm in order to achieve depth of 25 mm, wrinkling was eliminated. In second step *rd*= 18 mm and *rp* =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.

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