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STUDY THE INFLUENCE OF ANISOTROPY ON THE DRAWING CYLINDRICAL PART

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ABSTRACT

An investigation was carried out about the possibility of increasing the material utilization coefficient by excluding the flange rimming operation after the first drawing process. The dependency of the earing height on the drawing ratio and anisotropy was determined by means of the «AutoForm» simulation tool. The simulation results allow one to determine the necessity of cutting the flange depending on the required tolerance for the drawn part. Sensible anisotropic parameters, which take essential influence on the materials earing behavior, are determined. Furthermore, connections between the earing height and anisotropic parameters are built.

1. Introduction

Nowadays it is impossible to project new technological processes without the use of recently appeared innovations from the branch of sheet metal forming [1–3]. For this reason, it is required not only to produce parts without visible defects, but also achieve the required material texture and accuracy. Consequently, the priority objective is to increase the quality of the forming product. Most metals used in sheet metal forming possess anisotropic properties. In the present more and more scientists try to analyze the influence of anisotropic values on the stamping process [4, 5]. To analyze the plastic flow of anisotropic materials correctly, is important to consider material anisotropy in the chosen computational modeling method to receive adequate results from the simulation.

For a correct analysis of the process of plastic flow of anisotropic metal important methodology of computer modeling of technological processes taking into account the anisotropy of stamped material [6–8], which allows to get adequate results during the simulation.

An investigation is made about receiving the requested material texture and the materials anisotropic behaviour with respect to the rolled sheet metal blank. The work of [9] analyses the influence of the material texture and anisotropy on the plastic flowing behaviour of low carbon steels during deep drawing.

In the present plenty of research has been published, such as [10–13, 14–16], focusing on the influence of anisotropy on the drawing process. However, not many investigations exist, which explore the influence of anisotropy on the shape accuracy of the resulting part. Particularly, so-called «earings» develop during the drawing process of a cylindrical part [13]. After the deep drawing process the earing defect always appears in rolling or transverse direction for steel blanks. In the direction of 45° to the rolling direction the valleys of the earings can be observed. This can result in the necessity of rimming the part [17–21].

Hereby it is clear that for isotropic materials and small drawing ratios, the earing height is negligible, so the rimming process can be avoided. This allows one to increase productivity, exclude an additional technological process and decrease material usage. For this reason the investigation of the influence of anisotropy and the drawing ratio on the size of earnings is a current topic.

2. Method

The task in this work is to determine conditions under which rimming is not needed. The difference between the minimum and maximum earing height is defined as U.

The results for different drawing ratios lack of consistency due to the varying cup height. For the sake of comparable results, the dimensionless size $u = U/h_{th}$ is defined as the "earing ratio". Hereby h_{th} is the theoretical height of the cylindrical cup and calculated by Equation 1.

$$h_{th} = 0.25(d_0\beta_0 - d_1) + 0.43\frac{r_P}{d_1}(d_1 + 0.32r_P). \quad (1)$$

The following part investigates the influence of the drawing ratio $\beta = d_0/d_1$ – with d_0 being the specimen diameter and d_1 the diameter of the drawn cylindrical cup — on u.

The numerical model for the deep drawing process of a cylindrical cup was performed and simulated in «AutoForm» with the following geometrical parameters: $d_1 = 70$ mm; $r_p = 8$ mm and $s = 1$ mm.

The blank material consists of the steels DC03, DC04 and DC05, which are similar to the Russian steel «steel 08».

The according material characteristics have been provided by "AutoForm".

Table 1. **Tool parameters**		
Tool	Parameter	Size
Lubrication	Friction Coefficient	0.15
Punch	Tool Contact	Upper Side of Blank
	Support Type	Rigid
Die	Tool Contact	Lower Side of Blank
	Support Type	Rigid
Blankholder	Tool Contact	Upper Side of Blank
	Support Type	Force Controlled
	Displacing Tool	Die
	Cushion Stroke, mm	350
	Tool Stiffness, MPa/mm	50
	Loading Condition	Uniform
	Initial Pressure, MPa	5

Table 2. **Tool parameters for deep drawing setup**				
Punch Diameter, mm	Punch Radius, mm	Punch Height, mm	Die Diameter, mm	Die Radius, mm
38.8	2.5	41.2	41.2	2.5

Table 3. **Material properties of Steel 08**							
Basic Properties							
Material Type		Young's Modulus, MPa		Poisson's Ratio, [-]		Specific Weight, MPa/mm	
Low strength steel		$2.1{\cdot}10^5$		0.3		$7.8{\cdot}10^{-5}$	
Hardening Curve				Anisotropy			
φ_0 [-]	n [-]	a, MPa	α [-]	r_0 (= r_{90}) [-]	r_{45} [-]	r_m [-]	Δ_r [-]
0.002	0.130	375.0	0	2.14	1.30	1.72	0.84

As an example, the material characteristics of DC03 are presented in the following.

Hardening curve by Swift:

- $C = 559$ MPa;
- $\varepsilon_0 = 0.00648$ MPa;
- $n = 0.176$.

Hardening curve by Hockett-Sherby:

- $\sigma_i = 232$ MPa;
- $\sigma_{sat} = 443$ MPa;
- $a = 6.94$;
- $p = 0.768$.

The combination factor hereby equals 0.25.

Anisotropy coefficients (r-values):

- r_0=2.09;
- r_{45}=1.47;
- r_{90}=2,44.

The parameter r_m was used in the first row to evaluate the material anisotropy and its influence on the earing height (2).

$$r_m = \frac{r_m + 2r_{45} + r_{90}}{4}. \qquad (2)$$

The analysis of the result showed that the earing height decreases from DC03 to DC05. However, r_m has its minimum value for DC04 which can be seen in the simulation results in **Fig. 1**.

For this reason, the parameter Δr will be used for further investigations.

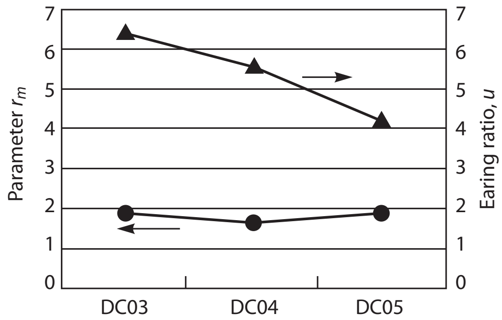

Fig. 1. Dependence of *u* and r_m on the steel grade

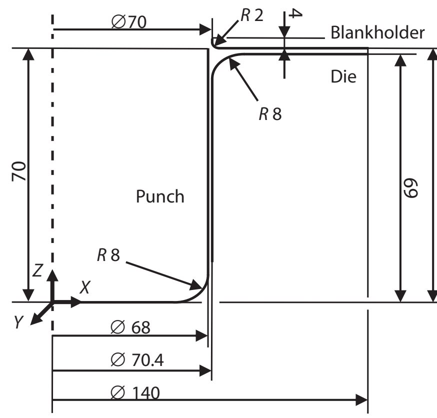

Fig. 2. Deep drawing setup with geometrical specifications

$$\Delta r = \frac{r_m - 2r_{45} + r_{90}}{2}. \qquad (3)$$

The numerical model was built with the geometrical parameters represented in **Fig. 2**.

The used tool parameters in the numerical model illustrated in **Table 2**.

3. Experiment

Experimental results will be compared with a numerical model which is analogous to the one previously presented. The Russian "Сталь 08" (Steel 08), which is a construction steel comparable to the German DC01, was chosen and round specimens with a sheet thickness of 1 mm were used. The following diameters were used in the experiment, given in the order of experimental performance from first to last: 63.55 mm; 63.6 mm and 63.5 mm; 51.5 mm and 51.55 mm. The geometric parameters presented in **Table 2** differed from the previously presented model.

The radius of the die was lubricated with Litol-24. The specimen was placed on the die and locally fixated with an outer ring of which the thickness equalized to the one of the specimen. To guarantee play between specimen and blank holder when applying the binder force, an additional ring with a thickness of 0.5 mm was placed on top of the outer ring.

The material parameters are summarized in the **Table 3**.

Five points in rolling direction and five further coordinates were defined in transverse direction to de-

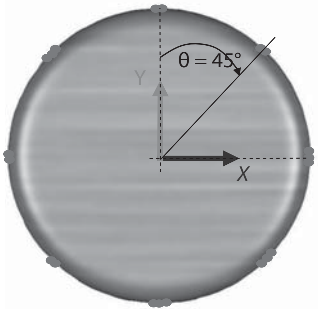

Fig. 3. Measuring Technique in “AutoForm”

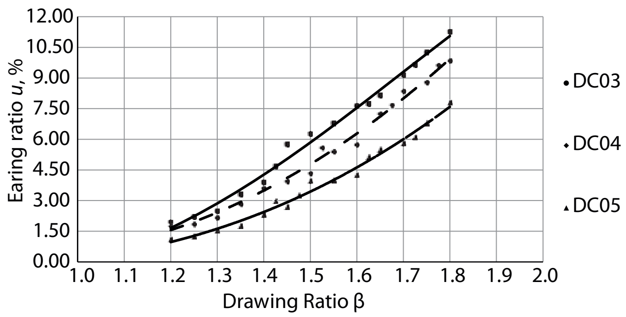

Fig. 4. Deep drawing setup with geometrical specifications

termine the maximum absolute earing height (**Fig. 3**). Ten point coordinates in total were measured in diagonal direction (θ = 45°). Thus resemblance between the measurements from the experiment and the simulation was assumed.

3. Results

Firstly, the dependency of the earing ratio on the drawing ratio was determined for different DC-steels. The simulation results for DC03, DC04 and DC05 are summarized in **Fig. 4**.

From the figure 4 has been concluded that the steels with the largest discrepancy between the r-values and a consequently high Δr-value show the strongest earing defect.

Most produced deep drawing parts fulfill the tolerance range of the IT14-quality.

For a size of 70 mm the tolerance defined by GOST 25346-89 is 0,74 mm. In the case of DC05, for example, if β < 1,5 additional material for rimming is unnecessary as the process can be excluded and no second draw is needed to form the part.

Furthermore, simulative studies have been carried out about the influence of the drawing ratio and the anisotropy on the earing size. The results are shown in **Fig. 5.**

From Fig. 5 it can be seen that an increase in the drawing ratio end planar r-value can lead to a significant increase in the earing height. Therefore, it is necessary to check whether the difference in diameters between the protrusion and the earing cavity falls into the accuracy class in the height of the stamped part or not.

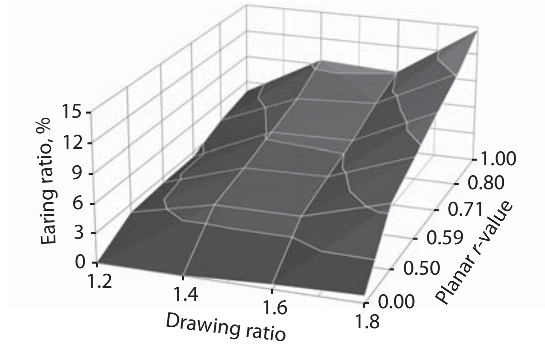

Fig. 5. Dependence of earing ratio on drawing ratio and planar *r*-value

5. Conclusions

The following conclusions can be drawn on the deep drawing simulations of a cylindrical cup and the carried out experimental studies:

- The proposed mathematical model allows one to determine the earing height and their dependence on Δ_r and β;
- Maximally allowed drawing ratios and anisotropic coefficients have been determined. Overstepping these will lead to the necessity of an additional rimming process;
- The proposed method can be used for other materials than DC and Steel 08.

A method of determining the technological process is given in order to increase the material utilization ratio and to decrease the amount of operations for the deep drawing process.

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