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Earing evaluation of DC06 using finite element method

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--***ABSTRACT***--
This paper deals with the simulation of deep drawing steel DC06 with a thickness of 0.7 mm and the influence of the blank holding force on the deep drawing process using the Hill48-Hollomon models. The simulation of the technological process is an integral part of engineering production. The deep drawing is a complex process, the quality of which is affected by several factors including friction, blank holding force, punch velocity or die and punch radius. In this paper earing of DC06 were evaluated using Simufact forming software.
Keywords *– deep drawing, DC06, simulation, FEM, Simufact*

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I. INTRODUCTION

Deep drawing is defined as a tensile/compressive forming process in which sheet metal blank is formed into a hollow part open on one side (direct drawing) or an open hollow part is formed into another hollow part with a smaller cross-section (re-drawing). Deep drawing is based on productionparts with simple or complex shapes throughlarge plastic deformation of flat metal sheets[1], [2].

Deep drawing is one of the most widely used sheet metal forming processes. In addition to being used in many other industries, it finds its greatest application in the automotive industry in the production of car body parts[3].

Optimization of deep drawing process parameters in sheet metal forming is a critical task to reduce manufacturing cost. Todetermine the optimum values of the process parameters, it is necessary to find their influence on the deformationbehaviour of the metal sheet. The significance of blank holding force parameter on the deep drawing characteristics of a cup from DC06 steel sheet will be determined[4], [5].

With the development of computer aided engineering, numerical simulation has become widely used in themetal plastic forming process. In predicting the change of thickness of the thickness of the blank, distributions of stress and strain in the workpiece during forming process computer simulation has great achievements and provides effective data flow analysis and optimization design[6].

In this paper a finite element model is developed for 3-D numerical simulation of a circular cup from DC06 material in the Simufact forming finite element software. The properties and design parameters of the tool were used as input parameters for the simulation.

II. MATERIAL, MODEL AND INPUT DATA

In this experimental research, Simufact software is used to simulate deep drawing process of material DC06. Circular cups with diameter of 36.6 mm were deep drawn from material DC06 using different blank holding forces.In this experimental research metal sheet from DC06were used. Mechanical properties and chemical composition of material are shown in Tab.1 and Tab. 2.

Tab. 1Mechanical properties of the material DC06

Material	**Density [kg/m^3]**	**Young´s modulus [MPa]**	**Yield strength [MPa]**	**Ultimate strength [MPa]**	**Ultimate strain [%]**	**Strain hardening [-]**	**Poisson´s ratio [-]**
DC04	7850	212000	140	279	48.3	0.261	0.282

Tab. 2 Chemical composition of DC06

	C_{max}	**P_{max}**	**S_{max}**	**Mn_{max}**	**Ti_{max}**	**Si_{max}**	**Al_{min}**
Percentage by weight % max.	0.02	0.030	0.020	0.25	0.3	-	-

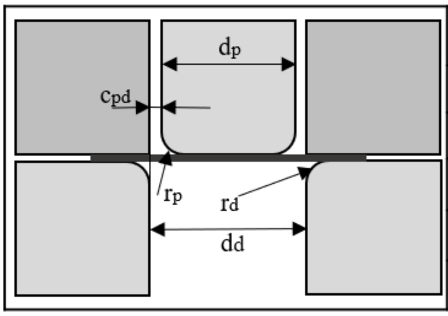
The Hill48 yield criterion was chosen as the anisotropic model with Hollomonhardening model. Hill48 criterion requires parameters that can be obtained from a uniaxial tensile test. Anisotropy values of materials DC06 are shown in Tab.3.

Tab. 3Anisotropy values of DC06

Parameters	**r0° [-]**	**r45° [-]**	**r90° [-]**	**Δr[-]**	**y0° [MPa]**	**y45° [MPa]**	**y90°[MPa]**
Value	1.67	1.6	2.0	1.71	138	142	141

Parameters of deep drawing tool are shown in Tab.4.

Tab. 4 Deep drawing tools parameters



Parameters	**Length [mm]**
Die diameter - d_d	35
Punch diameter - d_p	36.6
Clearence between punch and die - c_{pd}	0.8
Punch radius - r_p	5.5
Die radius - r_d	5.5

Numerical simulation was performedwith die and punch radius of 5.5 mm with different coefficient of friction 0.2 using Coulomb friction law. Parameters of deep drawing process are shown in Tab.5.

Tab. 5 Parameters of deep drawing simulation using Simufact forming

Parameter	**Value**
Punch velocity	20 mm/s
Blank holder force	5.9, 7.6, 9.2 kN
Punch/die temperature	20°C
Blank temperature	20°C

CAD model of the deep drawing tool was made using Solidworks software is shown in Fig. 1.

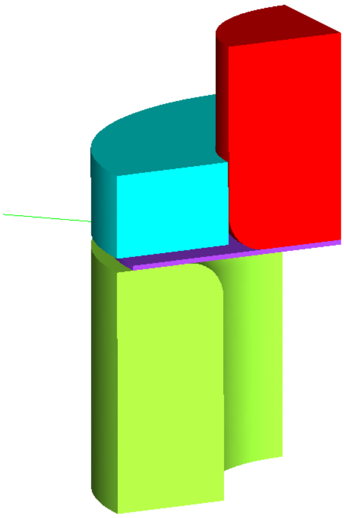


Fig. 1 CAD model of deep drawing tool in Simufact forming

The mesh was created with hexahedral elements with the size of 0.1 mm. Seven elements per thickness were used (Figure 2). Software automatically remeshed metal sheet if accumulated strain of any element reached value 0.2.

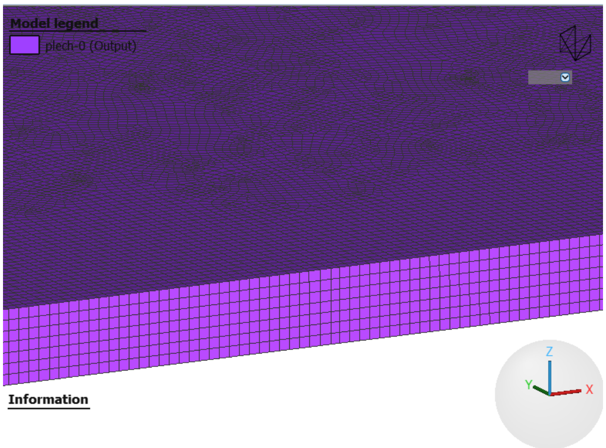


Fig. 2Hexahedral mesh of the 3-D model

To reduce computational time two symmetry planes were used (Fig. 3).

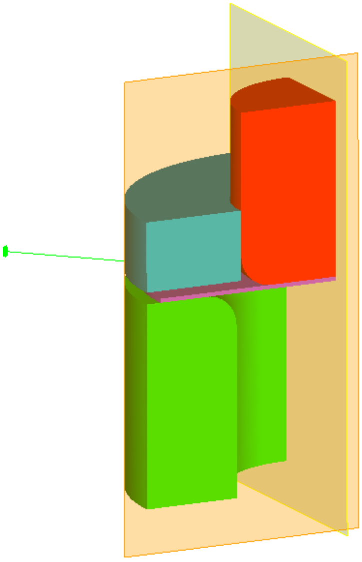


Fig. 3 Symmetry planes

According to the value of Δr, it is possible to determine the susceptibility of the sheetto form earing during deep drawing. Ears are formed in sheet directions in which thevalue of the normal anisotropy ratio Δr is maximum.

If:
- $\Delta r > 0$ – ears will form in 0° and 90° direction
- $\Delta r = 0$ – ears will not form
- $\Delta r < 0$ – ears will form in 45° direction

Earing of the cups was evaluated bymean ear heigh. The values of mean ear heigh is calculated from the relation (1).

$$\Delta H = \frac{1}{2}(H_0 - 2.\, H_{45} + H_{90}) \tag{1}$$

Where, H_0, H_{45}, H_{90} are cup heights in the direction of 0°, 45° and 90°, with respect to the rolling direction.

III. RESULTS

Based on the parameters mentioned above, three simulations(Fig. 4) were performed with the BHF of 5.9, 7.6 and 9.2 kN. Measured heights of the cups are shown in Fig. 5-7.

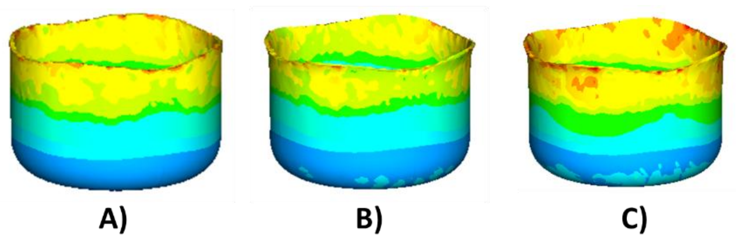


Fig. 4 Deep drawing results using A) BHF = 5.9 kN, B) BHF = 7.6 kN, C) BHF = 9.2 kN

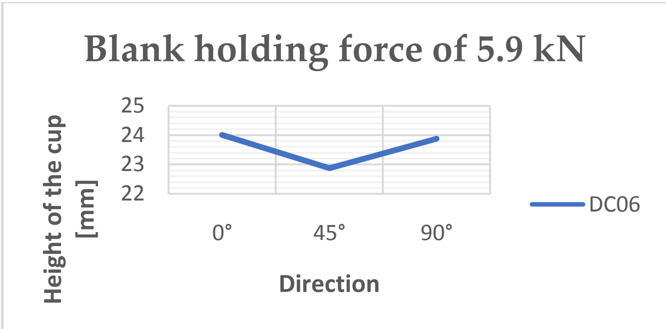


Fig. 5Heights of the cup using BHF = 5.9 kN

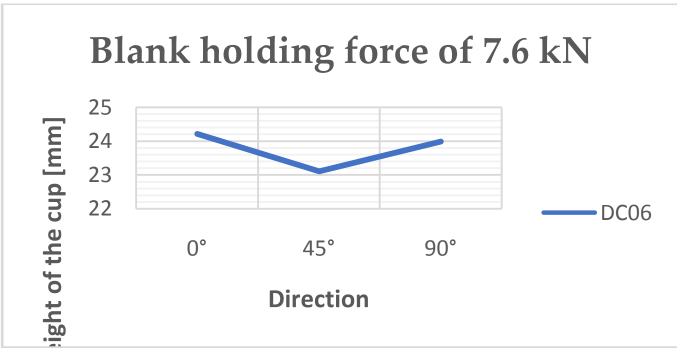


Fig. 6Heights of the cup using BHF = 7.6 kN

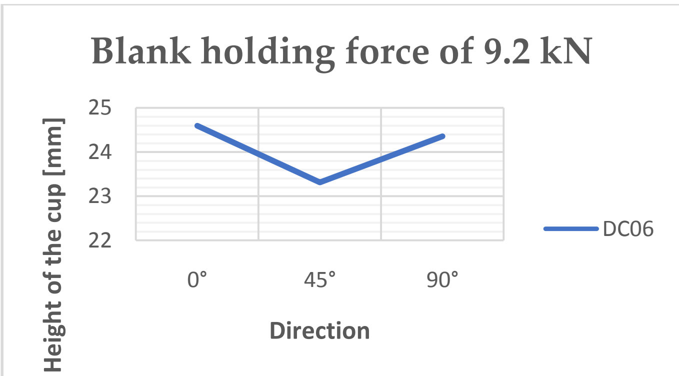


Fig. 7 Heights of the cups using BHF = 9.2 kN

Height comparison with different BHF is shown in Fig. 8.

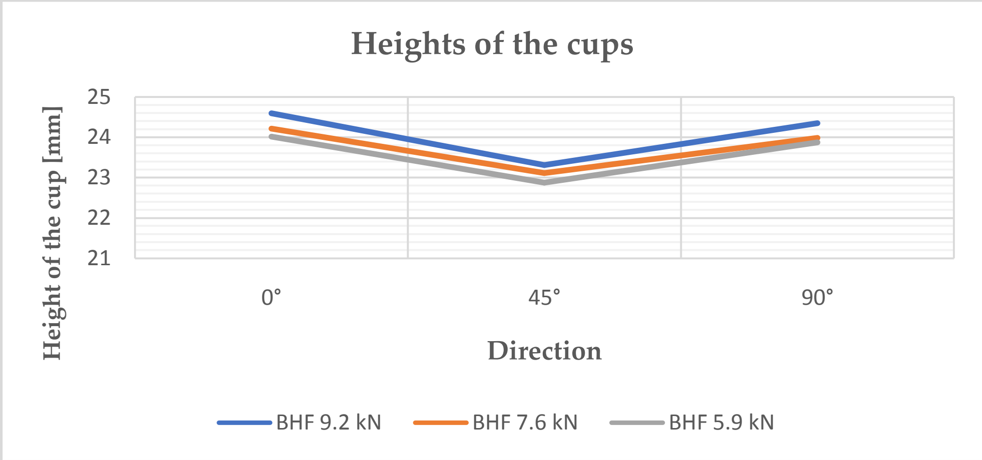


Fig. 7 Height comparison of the cups with different BHF

Values of mean ear height were calculated from the relation (1).

Tab. 6 Values of mean ear height

BHF [kN]	H_0 [mm]	H45 [mm]	H90 [mm]	ΔH [mm]
9.2	24.592	23.312	24.35	1.159
7.6	24.212	23.109	23.983	0.9885
5.6	24.011	22.875	23.875	1.068

In conclusion, deep drawing simulations were conducted using BHFs of 5.9, 7.6 and 9.2 kN. It was observed that earing occurred in the direction 0° and 90° with the respect to the rolling direction. As the planar anisotropy was positive the formation of earing appeared at 0° and 90° direction, which correlated with the theoretical knowledge.

The results showed (Figure 8) that the height of ears, increased with the increase of BHF. A increase of earing height was observed at 0° and 90°with the larger BHF.

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