The International Journal of Engineering and Science (IJES)
|| Volume || 12 || Issue || 1 || January || Pages || PP 28-32 || 2023 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

Deep drawing of DC04 and dieload analys is using Simufactforming software

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ABSTRACT
This article deals with the 3D simulation of deep drawing steel DC04 with a thickness of 0.7 mm along with die load analysis of a deep drawing punch made from tool steel X16CrNiSi25-20. In numerical simulation of deep drawing process Barlat and GMT models were used. The simulation of the technological process is a key factor in engineering production in terms of efficiency, cost savings or inprediction of errors. In this paper, the basic outputs of deep drawing will be evaluated such as effective plastic strain, thinning, equivalent stress and contact pressure of a punch with the use of Simufact forming software.
Keywords *– deep drawing, DC04, die load analysis, FEM, Simufact*

Date of Submission: 01-01-2023 Date of Acceptance: 12-01-2023

I. INTRODUCTION

Deep drawing is a technological process of metal sheet forming in which a three-dimensional product - a hollow body - is created from a sheet metal material. The hollow part is open on one side (direct drawing) or an open hollow part is formed into another hollow part with a smaller cross-section (re-drawing) [1], [2].

Process of deep drawing, one of sheet metal forming methods, is very convenient method in industrial field because of its efficiency. The deep drawing is affected by many process variables including radius of punch, die, blank shapes or formability of materials[3].

Deep drawing is one of the most widely used sheet metal forming processes[4].This method is mostly used in the aerospace and automotive industries and in the production of kitchen utensil and cold drink cans[5].

The mathematical description of the deep drawing process is considerably complicated because ofvarying loading history and complex stress state in each point of material.The input parameters introduced in the mathematical model of deep drawing are normally taken from the simplest mechanical test, such as uniaxial tensile test[6].

In this paper a finite element model is developed for 3-D numerical simulation of a circular cup from DC04 material in the Simufact forming finite element software. The properties and design parameters of the tool were used as input parameters for the simulation.Part of the 3D simulation is also a punch load analysis of the punch made from tool steel.

II. MATERIAL, MODELAND INPUT DATA

In this paper, Simufactforming software is used to simulate deep drawing process of circular cup with diameter of 25 mm from material DC04 using Barlat-GMT models.

In this research metal sheet from DC04 and X16CrNiSi25 for the punchwere used. The mechanical properties of materials are shown in Tab.1.

Tab. 1Mechanical properties of the materials

Material	Density [kg/m^3]	Young´s modulus [MPa]	Yield strength [MPa]	Ultimate strength [MPa]	Ultimate strain [%]	Strain hardening [-]	Poisson´s ratio [-]
DC04	7850	210000	220	330	35	0.18	0.283
X16CrNiSi25-20	6810(>)	210000	371	976	24	0.19	0.27

Tab. 2 Chemical composition of materialsDC04

	C_{max} [%]	P_{max} [%]	S_{max} [%]	Mn_{max} [%]	Cr_{max} [%]	Ni_{max} [%]	Si_{max} [%]	Al_{min} [%]	Ti_{max} [%]
DC04	0.08	0.030	0.030	0.40	-		-	-	-
X16CrNiSi25-20	0.20	0.035	0.035	2.00	26.00	21.00	2.30	-	-

The Barlat yield criterion was chosen as the anisotropic model with GMT plasticity model. Barlat criterion requires parameters that can be obtainedonly from a uniaxial tensile test. The Simufact fortming software has this data (Tab.3) for material DC04 in its library.

Tab. 3 Parameters for Barlat yield criterion

Parameters	**m [-]**	**y0° [MPa]**	**y45° [MPa]**	**y90° [MPa]**
Value	1.6	200	190	205

Flow curves of the material DC04 are shown in Fig. 1.

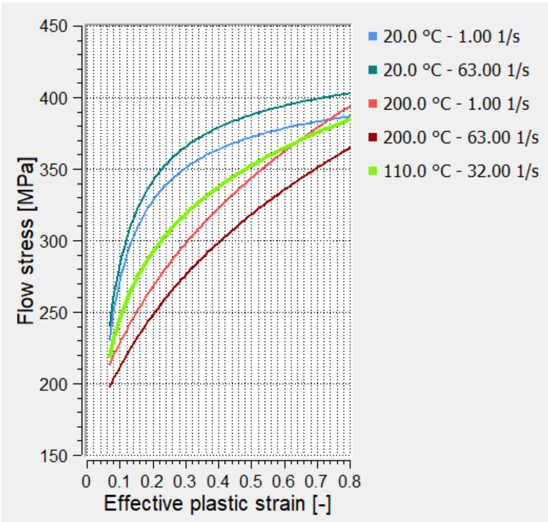
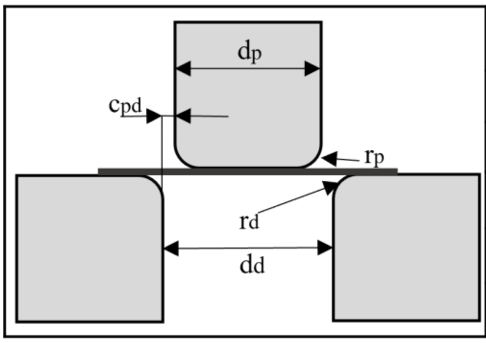


Fig. 1 Flow curves of the material DC 04

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

Tab. 4 Deep drawing tools parameters



Parameters	**Length [mm]**
Die diameter - d_d	41.6
Punch diameter - d_p	40
Clearence between punch and die - c_{pd}	0.8
Punch radius - r_p	5
Die radius - r_d	5.5

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

Tab. 5 Parameters of deep drawing simulation

Parameter	Value
Punch velocity	30 mm/s
Blank holder force	10 kN
Punch/die temperature	20°C
Blank temperature	20°C

To save time and reduce the number of elements, we used two symmetrical planes shown in Fig. 2.

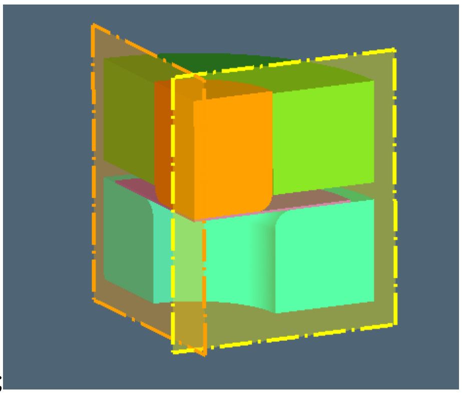

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Fig. 2 Symmetry planes of deep drawing tool and metal sheet

The mesh was created with solid mesh elements with an element size of 0.07 with ten elements per sheet thickness. If strain limit of 0.2 is reached, software will remesh the metal sheet.

III. RESULTS

Based on the above material and process parameters, the results of the deep drawing process are analysed. For the given technological parameters, the maximum effective plastic strain is 0.62 (Fig. 3).Maximum thinning is 10.22% of blank thickness (Fig. 4).

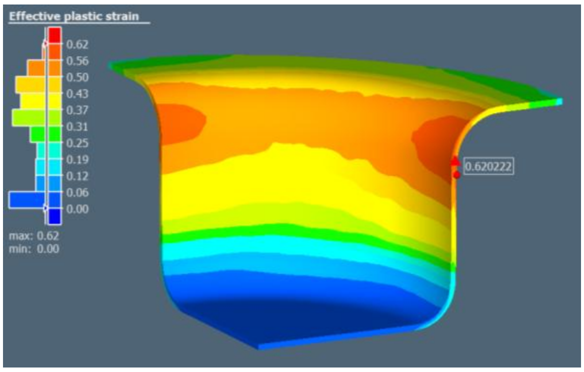

Fig. 3 Effective plastic strain

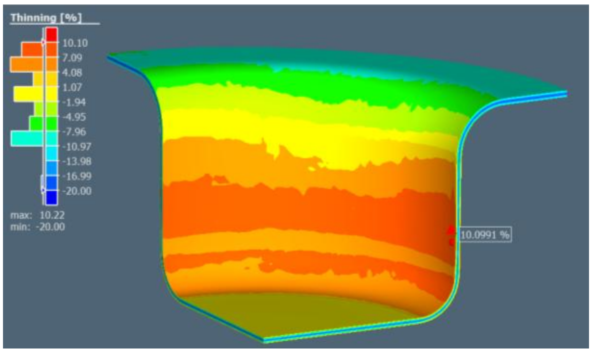

Fig. 4 Thinning of the cup during deep drawing

Additional simulation output data are shown in Tab. 6.

Tab. 6 Output data of deep drawing

Output data	**Value**
Equivalent stress (max)	251.87 MPa
Maximum principal stress	264.12 MPa
Thickness (min)	0.63 mm

For the punch load analysis tetrahedral (134) mesh type of element size 0.2 mm were used. Analysed parameters were contact pressure (Fig. 5) and maximal principal stress (Fig.6).

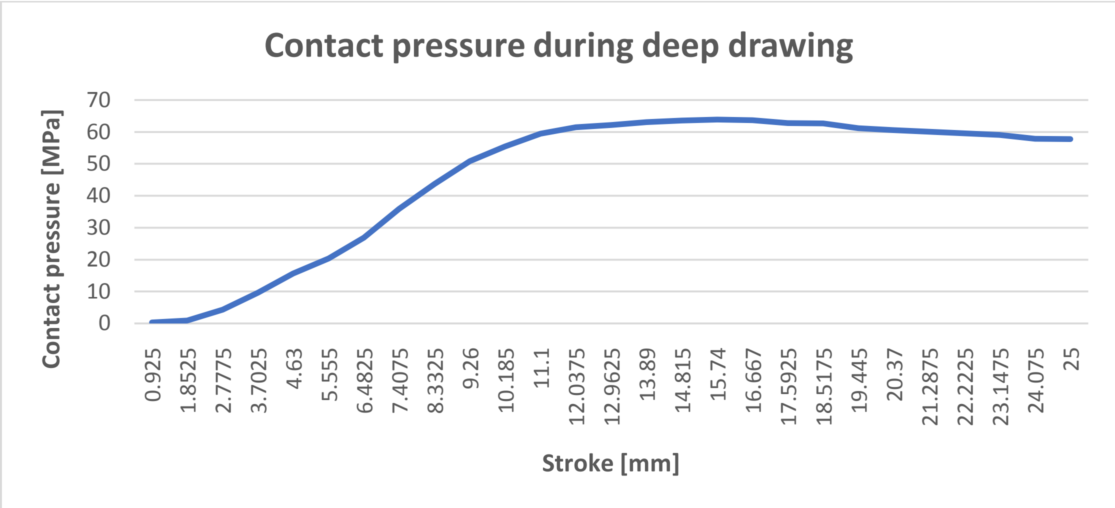

Fig. 5 Contact pressure of the punch

As a Fig. 5 shows the maximum contact pressure is 63.84 MPa at depth of 15.74 mm. After punch reaches the value of 11.1 mm, contact pressure is relatively constant with a slight decrease after maximum value. Maximum value of principal stress of the punch reached 175.24 MPa (Fig 6).

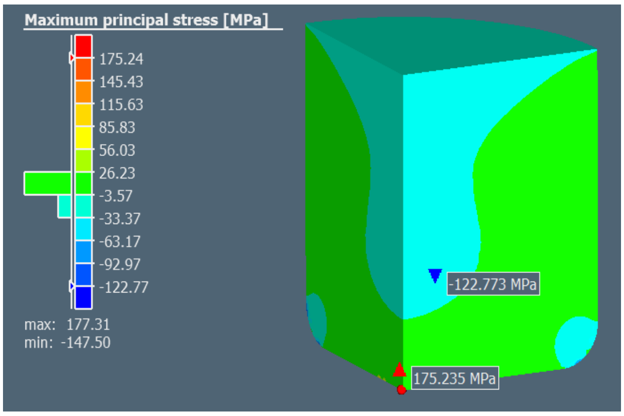

Fig. 6 Maximum principal stress of the punch

Elastic deformation of the punch reached very low values with the maximum 0.00112 (Fig. 7).

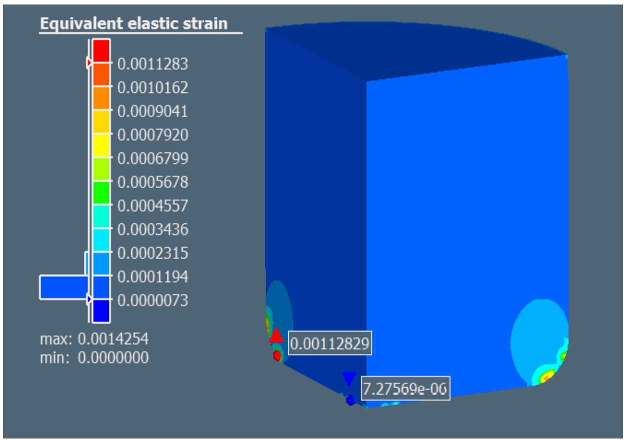

Fig. 7Equivalent elastic strain of the punch

The Z displacement describes the absolute displacement of the nodes in Z direction. In this case punch yielded by around 0.00421 mm.

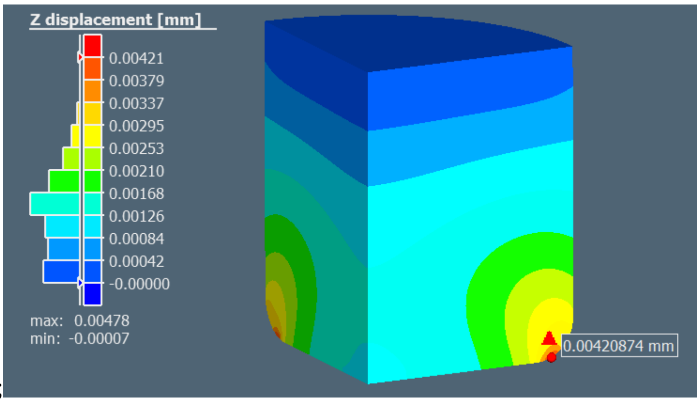

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Fig. 8 Displacement of the nodes in Z direction

IV. CONCLUSION

In this paper, deep drawing simulation of DC04 steel with a cup height of 25 mm were made. Simufactforming simulation software was used for the simulation. As part of the simulation, the main parameters were examined and evaluated, such as effective plastic strain, thinning, equivalent stress and maximum principal stress. The simulation also includes a die load analysis in which the parameters contact pressure, maximum principal stress, equivalent elastic strain and displacement in the Z axis were evaluated.

The values of equivalent stress and maximal principal stress did not exceed the maximum allowable stress. Thinning value of the wall thickness reached a maximum of 10%. The values of the elastic deformation of the tensioner did not reach high values and for this reason we consider them irrelevant.

ACKNOWLEDGEMENTS

The authors are grateful to VEGA 1/0384/20 and KEGA 036TUKE-4/2021.

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