ISSN No:-2456-2165

Numerical Simulation on the Combined Drawing Technology in Fabrication of Cylindrical Details from Sheet Metal

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Abstract:- At present, the cylindrical details with a bottom thicker than wall made from sheet metal manufactured according to the traditional technological processes: deep drawing in the first step in order to reduce the diameter of the workpiece, then reduced wall thickness by the ironing (while almost no change in the diameter of product). For technology process being applied that has a lot of steps leads to reduced productivity, increased cost of tools manufacturing, increased energy costs and labor. To improve the efficiency of the drawing process, the paper conducted research and proposed combine drawing method. Combine drawing is the process of deformation while reducing the diameter and wall thickness of the workpiece or the product. By using 2D Deform simulation software, the article has simulated the first step of combine drawing technology in the process in fabrication of cylindrical details from sheet metal, which have wall thickness thinner than bottom. The simulation results are verified by empirical survey process. The simulation results show a similarity with the theoretical calculations and experimentation process. From this, it confirms the rationality of the combined drawing technological process and the usefulness of simulation tools in the calculation and design of the combined drawing technological processes in order to minimize the testing process, increase productivity and reduction in production costs.

Keywords:- *Drawing, Combine drawing, Forming, Deformation, Simulation.*

I. INTRODUCTION

At present, the cylindrical details with a bottom thicker than wall made from sheet metal of national defense and economic manufactured according to the traditional technological processes: deep drawing in the first step in order to reduce the diameter of the workpiece, then reduced wall thickness by the ironing (while almost no change in the diameter of product) [1]. For technology process being applied that has a lot of steps leads to reduced productivity, increased cost of tools manufacturing, increased energy costs and labor.

To improve the efficiency of the drawing process, the paper conducted research and proposed combine drawing method [2]. This method allows receiving detailed with higher precision, increased reliability of wall, achieve greater deformation compared with other methods of deep drawing and ironing. This leads to reduce the number of steps of technological processes. Combine drawing is the process of deformation while reducing the diameter and wall thickness of the workpiece or the product (Figure.1a, 1b, 1c).

In the first of combine drawing process, it is possible to divide the deformation process into four stages (Figure 2), including: phase 1 – deep drawing; phase 2 - pull the embryo through the radius (the cone) and begin to move to the cylinder of die; phase 3 – ironing process; phase 4 - descending force and end the process stamping [2].

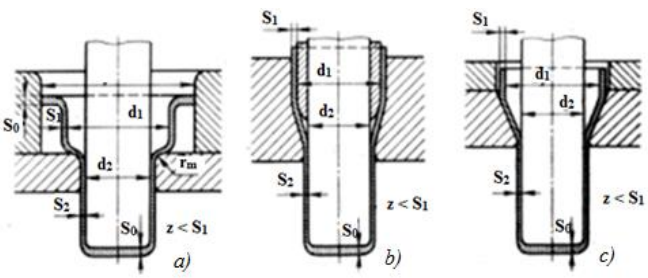


Fig 1:- The combine drawing process.

The degree of deformation and degree of deformation of step i is calculated by the following formula [3,4]:

$$\psi=1-mdms \quad (1)$$

$$i=1-mdimsi \quad (2)$$

Where ψis a degree of deformation when combine drawing, $m_d$is drawing ratio (characterize the workpiece diameter reduction), $m_s$is Ironing ratio (characterize the workpiece thickness reduction).

The height of the part of the first step received in the combine drawing process with a small radius at the bottom die was calculated [5,6]:

$$Hdi=Hidi=0.25msi1mdi2-1 \quad (3)$$

The combine drawing force is calculated by the formula as follows [5,6]:

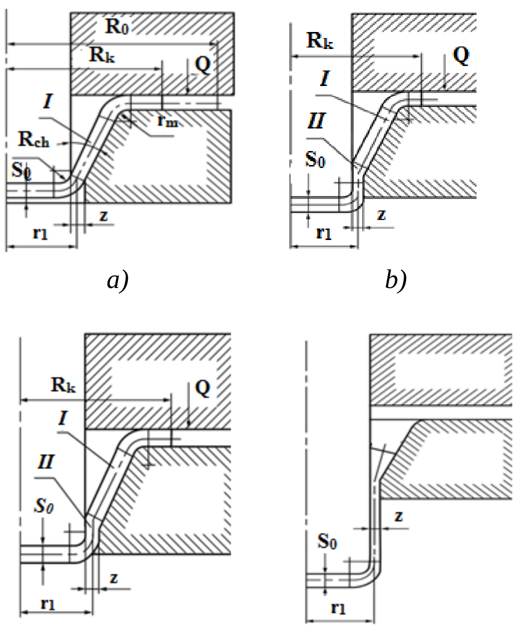
$$\Pi=\pi.dch.s1.z+2.\pi.dch.\theta TB.s0-s1sin\alpha \quad (4)$$

Where:
1.P – the combine drawing force;

2. d_{ch} –the punch diameter;
3. σ_z - the axial tensile stress;
4. s_1, s_0 – the wall thickness before and after thinning;
5. α - the tilt angle of die;
6. μ_2 - the coefficient of friction;
7. $\sigma_{\theta TB}$- the average deformation stress;
8. σ_s – the yield stress of the material.

The axial tensile stress(σ_z) is calculated by the formula as follows [5,6]:

z=slns0s1+21-12lns0s11-s0s112.sin2+tg2 (5)



a) b) c) d)

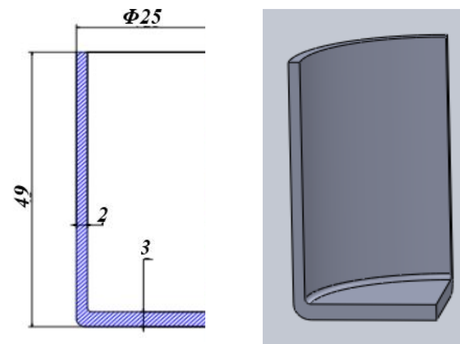
Fig 2:- The combine drawing process of the first step. a) phase 1; b) phase 2; c) phase 3; d) phase 4.

Based on the theoretical study of the combine drawing process, the article proceeds with the application of the 2D Deform simulation software, which simulated the first combine drawing technology in the fabrication of cylindrical details from sheet metal. Survey results include: wall thickness after combine drawing process, product height, stress effective, strain effective, combine drawing force. Based on the results confirmed the rationality of the technological process, confirming the role of digital simulation, contributing to shorten the design process and minimize the test, reduction in production costs.

II. SIMULATION OF COMBINE DRAWING PROCESS

A. The geometric model and tool geometry parameters and simulation conditions.

Respondents, the step 1 of the axisymmetric detail which has thick bottom (3mm) and thin wall (2 mm) with the 2D and 3D model are shown in Figure3.



a) *b)*

Fig 3:- The Axisymmetric detail. a) 2D model; b) 3D model.

Figure 4 shows the tools geometry model and the geometry parameters are presented in Table 1 [7].

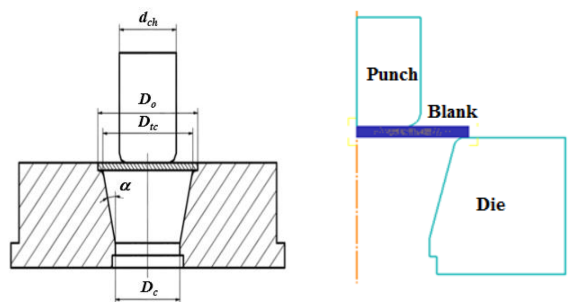


Fig 4:- The tool geometry model.

Geometrical parameters	Symbol (Unit)	Value
Step		1
Blank size diameter	D_p (mm)	62
Blank thickness	S_0 (mm)	3
Wall thickness of step 1	S_1 (mm)	2.40
Die radius	r_m (mm)	10
Punch radius	R_{ch} (mm)	4
Tilt angle of die	α (^{0})	15
Drawing ratio	m_d	0.55
Ironing ratio	m_s	0.80
The friction coefficient	f	0.16
Speed of the punch	v (mm/s)	15

Table 1. The Tool Geometry Parameters and Simulation Conditions

B. The material model

The detailed fabricated of 20 steel, which has mechanical properties depending on the degree of deformation shown in Figure 5. Building a steel material model by GOST 1050-88 standard. The material model used in simulations that hardening plastic material [6, 8] as shown in Equation 6, the coefficients of the model according to Table 2 [8].

$$i = k.in \quad (6)$$

Table 2. The Coefficient of Material Model of 20 Steel

S teel	*k*, MPa	*n*
2 0	75 0	0. 160

The model (6) corresponding to the material model in Deform 2D [8] is shown in Figure 6.

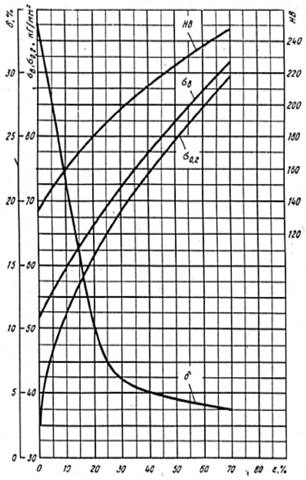


Fig 5:- The mechanical properties of 20 steel.

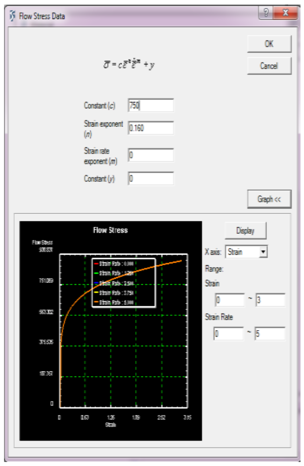


Fig 6:- The material model in Deform 2D.

C. Step controls and object meshing

The number of simulation steps to be run defines the number of steps to run from the starting step number. The simulation will stop after this number of simulation steps will have run, or if another stopping control is triggered to stop the simulation. The primary die is the object for which the stroke is measured for any values which refer to the die stroke.

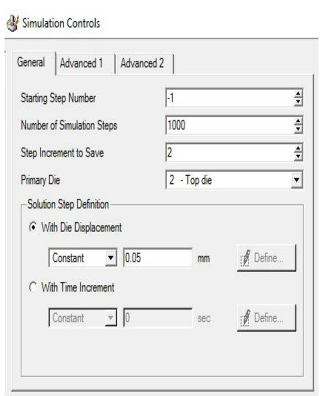


Fig 7:- Simulation Step Controls Window.

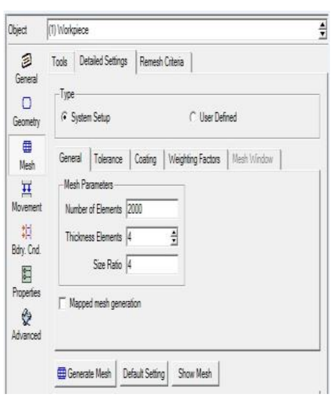


Fig 8:- Detailed mesh settings (general properties).

The step increment to save in the database controls the number of steps that the system will save in the database. Solution step size can be controlled by time step or by displacement of the primary die. The total movement of the primary die will be the displacement per step times the total number of steps. The parameters in step controls are shown in the Figure 7. Setting meshing parameters and generating the meshare shown in the Figure 8 [8].

A. *Simulation results*

The DEFORM post-processor is used to view and extract data from the simulation results in the database file. All results steps that are saved by the simulation engine are available in the post-processor. Survey simulation results include: wall thickness after stamping, product height, stress efftective, strain efftective, drawing force. Simulation results is shown in Figure 9 and Figure 10 and are presented in Table 3.

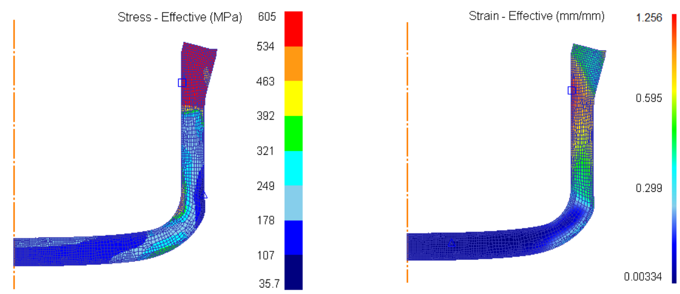


Fig 9:- The values of stress and strain when combined drawing.

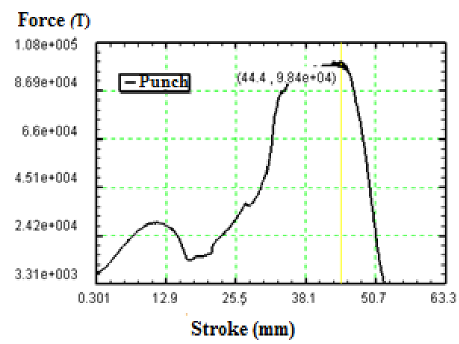


Fig 10:- The values of combine drawing force.

Figure 9 is shows the simulation results of stress effective (MPa) and strain effective (mm/mm), Figure 10 is shows the simulation results of combine drawing force. Values are defined as the maximum values, which characterize the deformability of the material.

Table 3. Simulation Results

Parameters	Unit	Value
Stress effective (max)	MPa	605
Strain effective (max)	mm/mm	1.256
Combine drawing force	Ton	9.84
Cup height of the first step	mm	28.5
Wall thickness of the product	mm	2.4

The stress and strain results allow the assessment of material deformability. Examination of the combine drawing forces recommended selection of stamping equipment.

Surveying geometric dimensions of detail allows for the assessment of the degree of similarity between theory, simulation and experimental, confirming the rationality of the design process.

III. EXPERIMENTAL PROCEDURE

To verify the simulation results, it was conducted of experimental combined drawing process of the first step (with plat bank – Fig. 11c) details which have wall thickness thinner than bottom with the conical die ($\alpha = 15^0$) on hydraulic presses YH32-100T at the lab of Department of Metal Forming - Faculty of Mechanical Engineering –Le Quy Don Technical University.

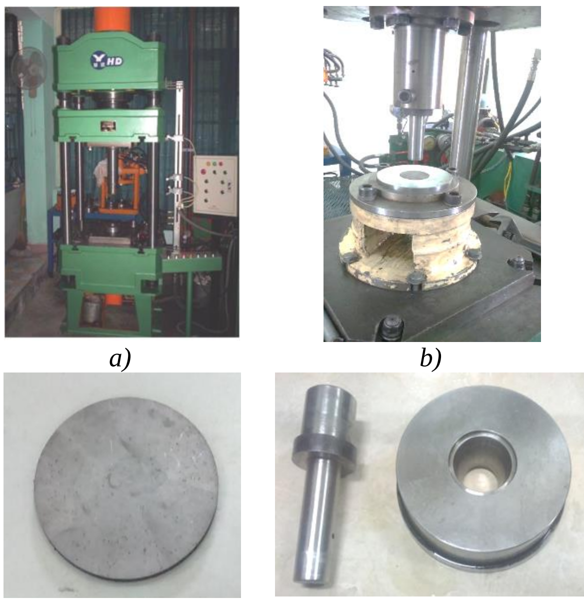


Fig 11:- Equipment and experimental instruments. a) Hydraulic presses YH32-100T; b) Tools;c) Blank; d) Punch and die

Experimental results showed that ability to deformation in combined drawing method, part of the first step obtained is satisfactory in terms of shape, drawing force, dimensions and wall thickness (Fig.12). The experimental results are presented in Table 4.

Table 4. Experimental Results

Force (T)	Height (mm)		Diameter (mm)		Wall thickness (mm)	
	H_{min}	H_{max}	D_{min}	D_{max}	S_t	S_r
P=10(T)	28.2	29	36.5	36.6	2.4	2.3

Where, P – the drawing force; H_{min}, H_{max} - the smallest and largest heights of product; $D_{min,}$ D_{max} - the smallest and largest outside diameter of the product; S_t - the wall thickness of the product; S_r – the wall thickness product in dangerous section.

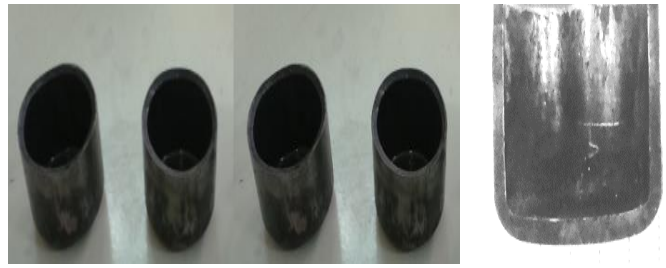


Fig 12:- The procedure of the first step. a) before slicing; b) after slicing

Realizing the experimental results and the calculated results (Table 1) and simulation results (Table 3) are similar to each other; from there, it is possible to create a combined drawing method when drawing of a cylindrical cup of sheet metal. The obtained products meet the requirements of calculated size according to the technology, the drawing force to ensure the conditions of equipment at the laboratory and production facilities.

IV. CONCLUSION

By using Deform 2D simulation software, the article has simulated the first combine drawing technology process in fabrication of cylindrical details from sheet metal with wall thickness thinner than bottom. Survey results include: wall thickness after combine drawing, product height, stress effective, strain effective, drawing force. The results show a similarity with the calculation and experimentation process. From this, it confirms the rationality of the technological process and the usefulness of simulation tools in the calculation and design of technological processes in order to minimize the testing process, increase productivity and reduction in production costs.

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