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NUMERICAL SIMULATION TO STUDY EFFECT OF DIE DESIGN PARAMETERS ON DEFORMATION POSSIBILITY OF METAL ON COMBINED DRAWING

Nguyen Manh Tien*, Tran Duc Hoan, Nguyen Truong An, Pham Manh Tuan

Military Technical Academy, 236 Hoang Quoc Viet, Bac Tu Liem, Ha Noi

*Email: manhtiennguyen84@gmail.com

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Abstract. This paper uses numerical simulation to study a method in combined drawing process with thinning the wall when drawing of a cylindrical cup of sheet metal. The software Deform 2D is used to examine effect of die design parameters (inclination of die) on deformation possibility of metal. Based on simulation results, it is possible to select appropriate die design parameters (cone die) and improve deformability and improve product quality.

Keywords: die design parameters, combined drawing, deformation, ironing.

Classification numbers: 5.1.1; 5.1.3, 5.9.2, 5.9.3.

1. INTRODUCTION

The ironing process used to make details which have wall thickness thinner than bottom. Currently, the details of this type often is formed with normal deep drawing process of the first step, then the wall thickness is reduced in the next steps (Figure 1) [1].

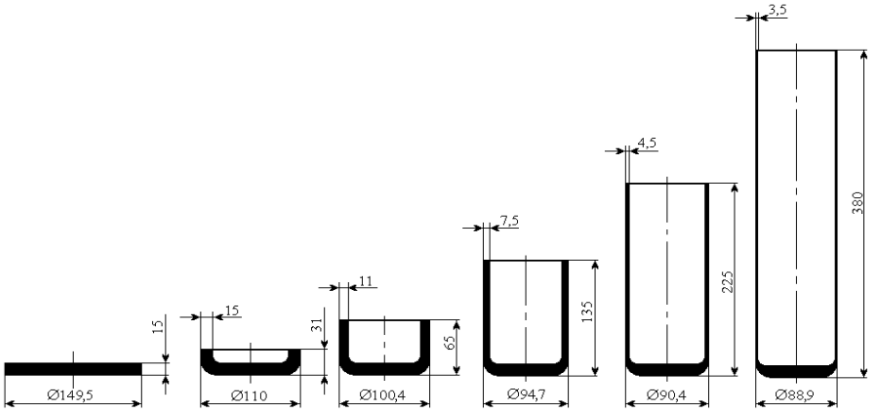


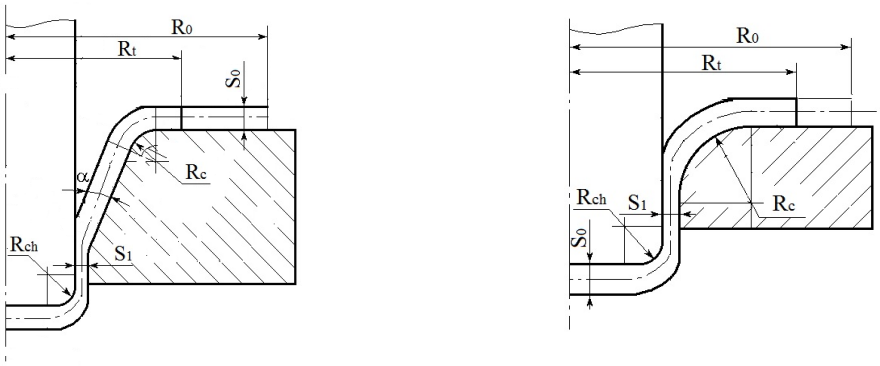
Figure 1. The ironing process.

To reduce number of step on ironing process (by improving the ability of the material deformation), the method of deep drawing applied is drawing combined. The drawing combined which reduce diameter and wall thickness of detail are shown in Figure 2 [2].

For drawing combined process of the first step, the parameter of die (geometry of die) influence on the process of deformation, stress, deformation ability, drawing force and product quality (height of details, uniformity of wall thickness etc.). Two types of die design parameters are presented in the study: conical die (Figure 3a) and none conical die (Figure 3b). When combined drawing with two types of die design parameters used angle bevel angle from 8 to 20 degrees depending on the ability to deformation (coefficient of thin and coefficient of deep drawing), the friction between the tools and the workpiece, the relative thickness of the material, mechanical properties of materials etc. When combined drawing with the none conical die depends on the thickness of material, ability to deformation, mechanical properties of materials, so we can choose radius of die from (2 to10) S_0 [3, 4].

Figure 2. The combined drawing process [2].

This paper uses numerical simulation to study a method in combined drawing process with thinning the wall when drawing of a cylindrical cup of sheet metal. The software Deform 2D is used to examine effect of die design parameters on deformation possibility of metal. Simulation results in order to select appropriate die design parameters, to enhance the ability to deform and contribute to improve product quality.



a) *b)*

Figure 3. Two types of die design parameters. a) conical die; b) none conical die.

2. SIMULATION OF COMBINED DRAWING PROCESS

2.1. Model of simulations

2.1.1. The detail geometry model

Respondents, the step 1 of the axisymmetric detail which has thick bottom (3 mm) and thin wall (2 mm) with the 2D drawing are shown in Figure 4.

a) *b)*

Figure 4. The axisymmetric detail: a) 2D drawing; b) 3D model.

The detail is made of 20 steel and Table 1 shows the chemical composition and mechanical properties of 20 steel (GOST 1050-88) [5].

Table 1. The chemical composition and mechanical properties of 20 steel.

Steel	Chemical composition					
	C (%)	Si (%)	Mn (%)	Cr (%)	Ni (%)	P, S(%)
20	0.17÷ 0.24	0.17÷ 0.37	0.35÷ 0.65	≤ 0.25	≤ 0.25	≤ 0.035
	Mechanical properties					
	σ_s (MPa)	σ_b (MPa)	ψ (%)	δ (%)		HB
	250	540	55	25		≤ 163

2.1.2. The tool geometry parameters

Figure 3 shows the tool geometry model, and the geometry parameters are presented in Table 2.

Table 2. Basic geometrical parameters.

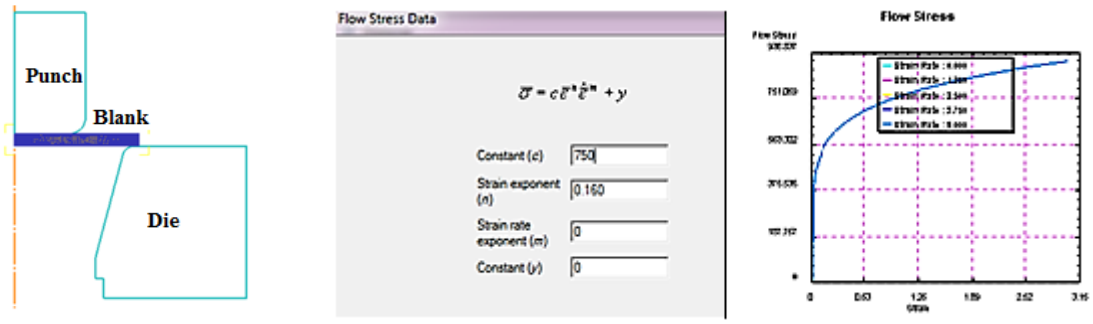
Geometrical parameters	Conical die on combine drawing	None conical die on combine drawing
Step	1	1
Blank size diameter (D_p)	62 mm	62 mm
Blank thickness (S_0)	3 mm	3 mm
Wall thickness of step 1	2.4 mm	2.4 mm
Die radius (R_c)	10 mm	10 mm
Punch radius (R_{ch})	4 mm	4 mm
Tilt angle of die (α)	15^0	0^0

2.1.3. Model of simulations

Based on calculations, the detail geometry model was built as in Figure 5a. The software Deform 2D is used to simulate on combine drawing process with plat bank (step 1 of 3). The material model used in simulations that hardening plastic material of 1008 steel (AISI-1008,COLD[70F(20C)]) are shown in Figure 5b and Formula 1. The coefficient of friction between the blank and tools get by 0.08. Speed of the punch is 15 mm/s [3, 4, 6].

$$\sigma_i = k\varepsilon_i^n \quad (1)$$

where, $k = 750\,Mpa, n = 0{,}16$ [5].



a) *b)*

Figure 5. The geometry model (a), the material model (b).

2.2. Simulation results

The simulation results are examined: stress effective, strain effective, damage, force etc. [6]. In which the value of stress effective and strain effective are evaluated the ability of the material deformation. The damage uses to evaluate product quality (by using Cockcroft-Latham ductile fracture criteria). The drawing force is examined to recommend for selection of combined drawing equipment.

- The values of maximum stress effective when combined drawing with two types of die design parameters are shown in Figure 6.

- The values of maximum strain effective when combined drawing with two types of die design parameters are shown in Figure 7.

- The damage (by using Cockcroft - Latham ductile fracture criteria, $D_{C\&L}$=0, 6 [7] with the following formula) when combined drawing with two types of die design parameters are shown in Figure 8.

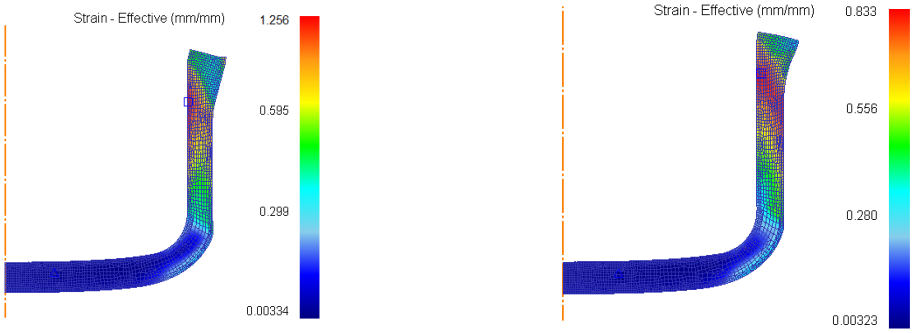
$$D = \int_0^{\bar{\varepsilon}_i} \frac{\sigma^*}{\bar{\sigma}} d\bar{\varepsilon}_i \quad (2)$$

where σ^* - the maximum principal stresses; $\bar{\sigma}$ - the equivalent stresses; $\bar{\varepsilon}_i$ - the equivalent strain.

- The drawing force is examined when combined drawing with two types of die design parameters are shown in Figure 9.

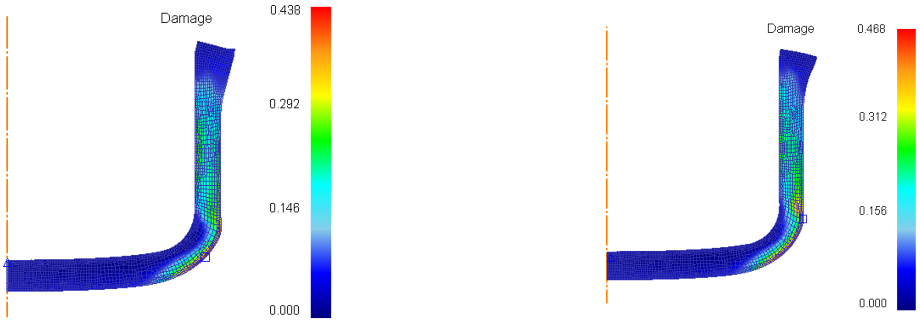
a) *b)*

Figure 6 . The values of maximum stress effective when combined drawing with two types of die design parameters:
a) conical die; b) none conical die.



a) *b)*

Figure 7 . The damage when combined drawing with two types of die design parameters:
a) conical die; b) none conical die.

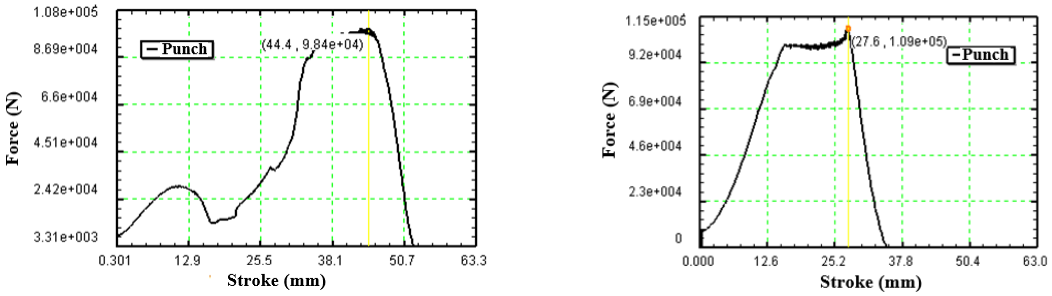


a) *b)*

Figure 8 . The values of maximum strain effective when combined drawing with two types of die design parameters:
a) conical die; b) none conical die.

2.3. Analysis of simulation results

The software Deform 2D is used to simulate on combined drawing process with two types of die design parameters, the simulation results are presented in section 2.2 and are summarized in Table 3.



a) *b)*

Figure 9. The drawing force is examine when combined drawing with two types of die design parameters: a) conical die; b) none conical die.

Table 3. Simulation results.

Parameters	Conical die	None conical die
Stress effective (max) (MPa)	605	620
Strain effective (max) (mm/mm)	1.256	0.833
Drawing force (T)	39.36	43.60
Damage	0.438	0.468

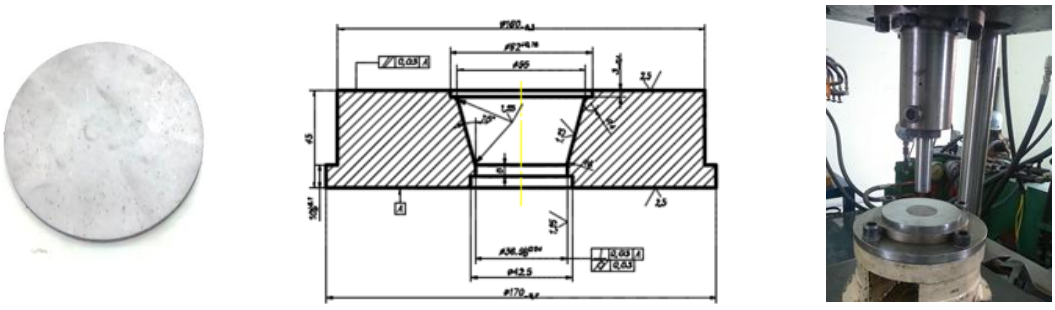
Based on the simulation results, the paper offers some reviews on:

+ The values of maximum stress effective when combined drawing with the none conical die (620 MPa) is greater than the conical die (605 MPa). So the resistance of deformation when combined drawing with the none conical die greater the conical die, so deformation possibility of metal is become more difficult.

+ The values of maximum strain effective when combined drawing with the conical die (1.256) greater than the none conical die (0.833). So the deformation possibility of metal when combined drawing with conical die is better than the none conical die.

+ The damage when combined drawing with the conical die (0.438) is smaller than the none conical die (0.468). So the part of 1 is contributed to improve product quality.

+ The drawing force is examined when combined drawing with the conical die (39.36T) is smaller than the none conical die (43.6T). This is the basis for choosing suitable drawing equipment.



a) *b)* *c)*

Figure 10. The blank (a), die (b), the tools when mounting on hydraulic presses YH32-100T (c).

To verify the simulation results, it was conducted of experimental combined drawing process of the first step (with plat bank - Figure 10c) details which have wall thickness thinner than bottom with the conical die ($\alpha = 15^0$) (Figure 10b) on hydraulic presses YH32-100T at the lab of Department of Metal Forming - Faculty of Mechanical Engineering - Military Technical Academy.

Experimental results showed that ability to deformation in combined drawing method with the conical die, part of the first step obtained is satisfactory in terms of shape, dimensions and wall thickness (Figure 11). After first step, the drawing force and the dimensions of the product was checked. The results are summarized in Table 4.

a) *b)*

Figure 11. Part of the first step (a) and part of the first step after slicing (b).

Table 4. Experimental results.

Force	Height		Diameter		Wall thickness	
P =39(T)	H_{min}, mm	H_{max}, mm	D_{min}, mm	D_{max}, mm	S_t, mm	S_r, mm
	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.

Realizing the experimental results and the calculated results (Table 2) 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.

3. CONCLUSION

By using software Deform 2D, the simulation of combined drawing process with two types of die design parameters (the conical die and the none conical die) has deduced the results, that are the basis for assessing the material of deformation ability. Based on the results of the study, when combined drawing with the conical die, the material of deformation ability is better (the stress effective is smaller, the strain effective is greater, the damage is smaller, the drawing force is smaller). So, the paper results provides a way to select appropriate die design parameters (conical die), to enhance the ability to deform and contribute to improve product quality.

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