Research on Relationships Between Fluid Pressure and Technological Parameters, Shape of Cylindrical Part in Hydro Static Forming

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Received: September 13, 2017; Accepted: May 25, 2018

Abstract

In sheet hydrostatic forming, accuracy of products depends on many technological parameters and shape of die, especially working fluid pressure plays very important role. Determination of this pressure is usually difficult, because it depends on the other parameters, such as blank holder pressure, workpiece material, geometrical shape and tightness of die, so on. This article deals with determination of relationship between forming pressure, blank holder pressure and radius of bottom die using experiments. The results of this study are the basis for further validating the quality and accuracy of product, as well as optimizing hydrostatic forming technology.

Keywords: forming pressure, blank holder pressure, sheet hydro static forming.

1. Introduction

In hydrostatic forming, high pressure fluid works as punch (in conventional stamping hard die and punch) and has direct impact on surface of workpiece to deform it following to the die cavity [1]. Hence, the shape of die and working fluid pressures will play an important role for filling of material into small corner and complexity location of the die, while the traditional stamping technology is not able to do this. Therefore, it normally requires many steps for forming of complex parts by using conventional stamping technology, but those parts can be achieved with only one step by using hydrostatic forming.

The principle of sheet hydrostatic forming is shown in Fig. 1.

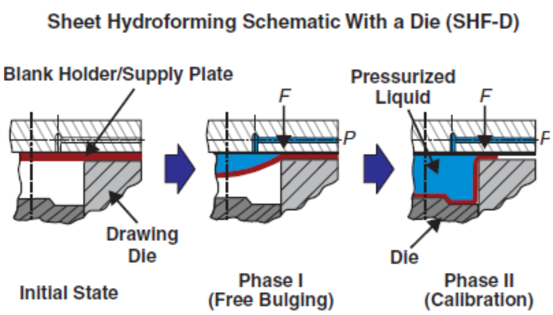

Fig 1. Process of sheet hyrostatic forming [2]

Sheet hydrostatic forming shows many advantages in comparison to conventional stamping, such as: enhance surface quality (avoid scratch on surface), decrease elastic deformation, especially suitable for forming complex profiled products[3] [4]. However, this technology has some disadvantages, for example local strong thinning, so that the product thickness it not equal [5]. Therefore, this technology is appropriately applied to manufacture body shells of car [6]. Many developed countries like USA, Germany, Japan, Korea, China are using this technology in the industrial fields such as defense, transportation, aerospace, home appliances ...

With development history of more than one hundred years, this technology is concerned both aspects research and application. Research objects are diversity (technological process parameters, effect of friction force, materials, product quality...)[7]

In Vietnam, this technology has been researching for more than 20 years, but actually, it has just drawn attention in the last 5 years. Lately, some research has been done on this technology for forming products of sphere, conical and asymmetric shape [8,9]. Meanwhile, cylindrical shape has not been studied thoroughly. Therefore, cylindrical part will be researched to investigate the effect of some technology parameters on product quality by experiment method. Specifically, effect of blank holder pressure on forming pressure and effect of forming pressure on the relative radius at the bottom of product.

Finding out the relationship among technological parameters in hydrostatic forming for sheet metal is essential, due to wide application of this techmology into manufacturing, especially thin sheet industry.

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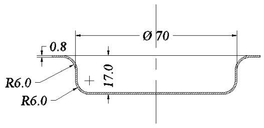
2. Experiments

Since hydrostatic forming is only suitable for products with small depth, a low cylindrical product is chosen for investigation as shown in Fig.2



a. b.

Fig 2. Investigated product: a- dimension; b- 3D product

Cylindrical product with the thickness of 0.8 mm, material of DC04 steel – a kind of material commonly applied in car production with chemical composition is shown in Table 1, specification in Table 2 is choosen for experimental investigation.

Table 1. Chemical composition hóa học of DC04 steel

C (%)	Mn(%)	P(%)	S(%)
max 0.08	max 0.4	max 0.03	max 0.03

Table 2. Specifications of DC04 steel

Mechanical behavior			**Equivalent quality**
R_m (Mpa)	R_e (Mpa)	δ (%)	Russia-GOST 08kp
314-412	210-220	38	Japan-JIS SPCE

With: R_m – Ultimate strength (Mpa)

R_e – Yield strength (Mpa)

Objectives: Experiments are implemented to investigate:

- Relationship between blank holder pressure and forming pressure.
- Relationship between forming pressure and relative radius at the bottom of product.

Experimental devices:

The following technological parameters will be determined:

- Working fluid pressure in the die P_{th} = 0÷550 bar.

- Blank holder pressure Q_{ch} = 0÷150 bar.

- Radius at the bottom of die R = 6 mm – expected radius for product.

Experiments are implemented in laboratory of Department of Metal Forming, School of Mechanical Engineering, Hanoi University of Science and Technology.

After computation and design, the experiment system consists of 4 main modules as shown Fig. 3:

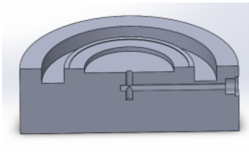
- Pump system for supplying high pressure liquid with P_{max} = 700 bar [8]

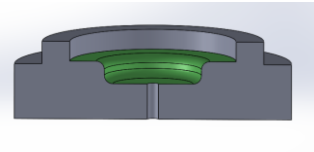
- Hydraulic press 125 ton [8]

- System for measuring pressure – displacement signals [8]

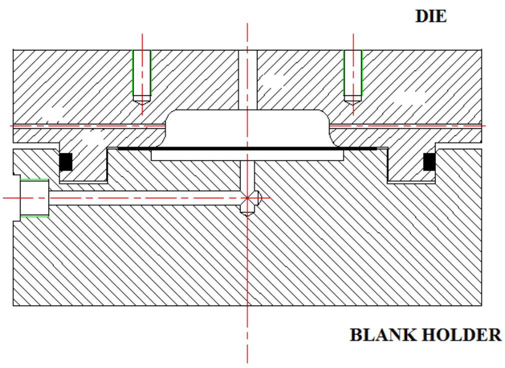
- Die system include die and blank holder as shown in Fig 4.

Fig 3. Experiment system for hydrostatic forming





a) b)



c)

Fig. 4 a. Blank holder b. Hydrostatic die
c. Die assembly

Method of investigation: Using experiment system established to match with the selected product.

Statistics are presented in Section 3: Results and discussion

3. Results and disscution

3.1 Establishing relationship between blank holder pressure and forming pressure

In usual forming, blank holder is used to keep blank stable when blank is drawn into die. Moreover, blank holder is also used to avoid loss of pressure during forming process.

Requirement for the product is that, thinning should be less than 20% ($\varepsilon \le 20\%$), radius of product bottom R_d = 6.00 mm with tolerance +10%.

Thinning is calculated by the following formula [10]:

$$\varepsilon = (s_0 - s)*100/s_0$$

Where:

s_0 – the initial thickness of blank (mm)

s – resulting thickness of product (mm)

The experimental system is connected to the measuring system through the Dasylab software. Outputs from sensors for blank holder pressure, forming pressure and stroke are demonstrated on the monitor.

Thereby, results are collected, and suitable values are then chosen.

Based on experiment results, range of suitable blank holder pressure is defined Q_{ch} = (75÷125) bar corresponding to range of forming pressure P_{th} = (350 ÷520) bar.

For measuring the radius at bottom: a number of points are measured by optical measuring method, and interpolation is made to obtain the product profile. Results of products meeting the requirement for R_d are shown in Table 3.

For thinning ε: Thinning is investigated at the position I-I as shown in Fig. 5. It is recognized by experiments that this is the position having the biggest thinning. Results of products meeting the requirement for thinning are shown in Table 3.

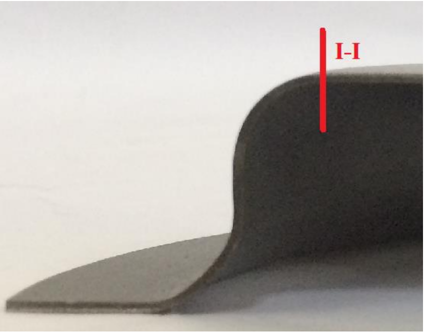


Fig. 5. Investigate the thinning at position I-I

Table 3. Suitable values of P_{th}, R_d, ε that are defined experimentally along with corresponding values of Q_{ch}.

Q_{ch} (bar)	75	85	95	115	125
P_{th} (bar)	350	400	460	500	520
R_d (mm)	6.50	6.31	6.14	6.00	6.08
ε (%)	17.5	15.34	10.12	8.75	5.78

From Table 3, the relationship between blank holder pressure and forming pressure is shown in Fig.6.

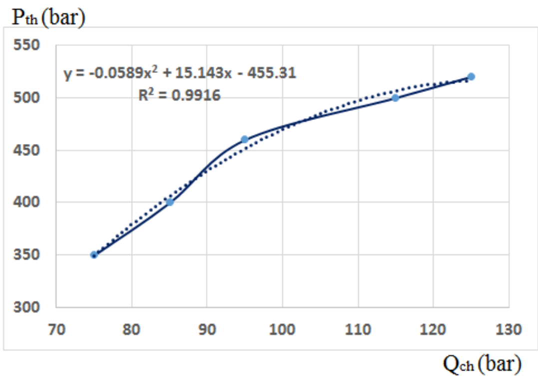


Fig. 6. Relationship between blank holder pressure and forming pressure to achieve expected product radius

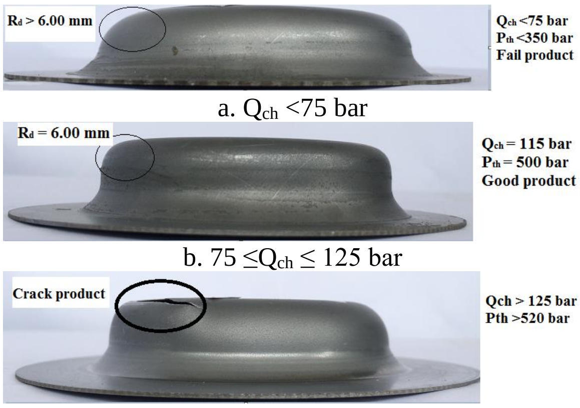
Relationship between blank holder pressure and forming pressure is established. From Fig. 6, there is a tendency that forming pressure increases when blank holder pressure increases. The relation function is interpolated:

$$y = -0.0589x^2 + 15.143x - 455.31 \quad (1)$$

with high reliability coefficient: $R^2 = 0.9916$

It is recognized by experimental investigation that, if the blank holder pressure Q_{ch} < 75 bar, it is impossible to find out the forming pressure P_{th} so that the product shape meets the requirement. Radii at bottom are all much greater than R_d = 6mm, as shown in Fig.7a

In case of Q_{ch} > 125 bar, the blank can hardly be drawn into the die capital because the blank holder pressure is too high, and the great value of blank holder pressure requires a coresponding great value of forming pressure P_{th}. Consequently, the blank can get too much thinning, even can be cracked as shown in Fig. 7c. Therefore, range of blank holer pressure Q_{ch} = (75÷125) bar and range of forming pressure P_{th} = (350 ÷520) are suitable as shown in Fig. 7b.



a. Q_{ch} <75 bar

b. 75 ≤Q_{ch} ≤ 125 bar

c. Q_{ch} >125 bar

Fig. 7. Three specific products after three value domains of Q_{ch} are applied

a. Q_{ch} <75 bar; b. 75 ≤Q_{ch} ≤ 125 bar;

c. Q_{ch} >125 bar

3.2 Establishing relationship between forming pressure P_{th} and radius at the bottom of product (R_d/s_o)

Relative curve radius is R/s_o

where s_o: material thickness (mm)

R_d: radius at bottom of product (mm)

With different kinds of material, different working conditions, the relationships shown by graph and function are different. Here, with this experiment conditions and boundary conditions, a specific relationship between forming pressure and radius at the bottom of product are defined.

Based on experiments as mentions in 3.1, different values of blank holder pressure are investigated to determine corresponding product radius:

Q_{ch} = 75, 85, 95, 115, 125 (bar)

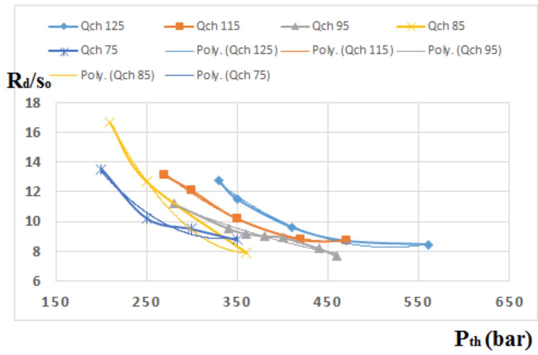


Fig. 8. Dependence of relative curve radius (R_d/s_o) on working pressure at different values of blank holder pressure (experimental and tend curves)

Fig. 8 illustrates dependence of relative radius (R_d/s_o) on forming pressure at different values blank holder pressure. Each value of blank holder pressure Q_{ch} is shown by 2 curves: experimental and trend curves. The trend of curves is similar, which means that the greater forming pressure, the smaller relative product radius.

However, the graph shows that the curves are not homothetic. That means at each value of blank holder pressure, the law of forming pressure acting to form relative curve radius is different.

Through experiment, it can be seen that blank holder pressure has important effect on forming of product radius. As the higher blank holder pressure, the better hermetical the die is kept, thus, forming pressure can be higher, forming smaller product radius. However, when blank holder pressure is too high, it is so difficult for material to fill into die, preventing the formation, causing thinning on the free part of material. Hence, although forming pressure can be obtained at high value (over 520 bar), it is almost impossible for the radius R_d to reach a small value as expected.

In case blank holder pressure Q_{ch} = 95 bar, effect of forming pressure P_{th} on relative radius is shown in Fig. 9.

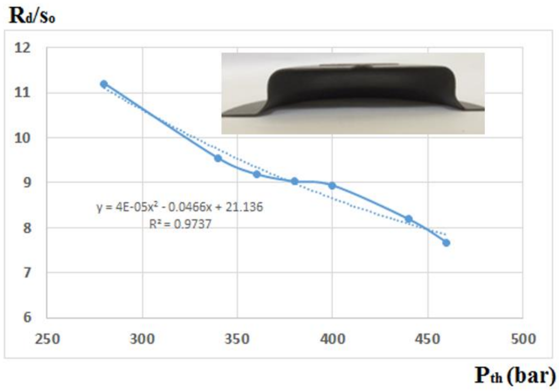


Fig. 9. Dependence of relative product radius on forming pressure at the value of blank holder pressure Q_{ch} = 95 bar

For the case Q_{ch} = 95 bar (Fig. 9), the relation function is interpolated:

$$y = 4.10^{-5}x^2 - 0.0466x + 21.136 \qquad (2)$$

with high reliability coefficient: $R^2 = 0.9737$

4. Conclusion

Based on experiments, it is able to determine blank holder pressure depending on forming pressure in hydrostatic forming for low cylindrical product through relation function (1). Compared to conventional stamping, blank holder pressure in hydrostatic forming has the mission to keep working pressure stable and prevents leakage. Therefore, in terms of value, blank holder pressure in hydrostatic forming is bigger than in conventional stamping.

The relationship between forming pressure P_{th} and relative radius at bottom of product R_d/s_o can be defined experimentally and demonstrated through relation function (2). At different values of blank holder pressure, the relationship is different, but the general trend is that the higher forming pressure, the smaller the relative radius. This trend is proved to be useful in product design and selection of forming equipments.

Furthermore, other relationships such as effect of forming pressure on thinning, effect of forming pressure on relative height of product, so on, also need to be investigated to develop the research orientation.

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