Establish Experimental System of Sheet Metal Hydrostatic Forming for Stepped Cylinder

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Abstract

Hydrostatic forming is a deformation method which uses highly-pressed liquid to deform sheet metal following the shape of die. This method has been researched and applied in various industries of manufacturing cars, medicines, chemistry, military, and so on. However, in Vietnam, this method is still new and has not been researched specifically, leading to limited application into real manufacturing. In order to demonstrate specific influence of technological factors on sheet metal hydrostatic forming process, the study on influence of die structure and surface shape on forming ability in sheet metal hydrostatic forming base on the combination of simulation and experiments is needed. Therefore, it is essential that the initial experimental system must be established to research hydrostatic forming process. In this paper, all devices in an experimental system are describes as well as accuracy assurance in sheet metal hydrostatic experiment are presented.

Keywords: hydrostatic forming, sheet metal forming, die, high pressure

1. Introduction

Hydrostatic forming has been studied in a number of institutes and universities in recent years. This is a technology of forming sheet metal which owns many advantages: has ability to form complex-profiled parts such as car shell, car structure (Fig. 1), convex and convey parts, conical or spherical parts, so on with good surface quality and few operations.

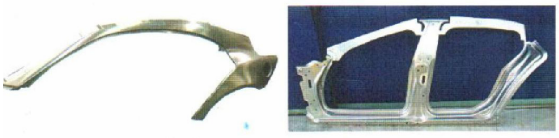

Fig. 1. Some hydrostatic-formed parts [1]

In Vietnam, there have been some significant research on high-pressed fluid forming have initially evaluates influential parameters in fluid forming. At present, research has been done to investigate the hydrostatic forming and applying capacity in manufacturing, but there has not been intensive research on this field. Parameters, processes, materals, systems, interactive relations among parameters, working range of forming parameters. Therefore, research on hydrostatic forming in Vietnam will make foundation to apply this technology into manufacturing for improving product quality and ability to forming complex-shaped parts.

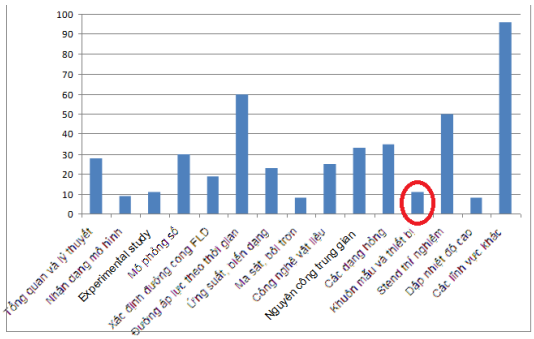

Fig. 2. Research orientations in hydrostatic forming [1]

As can be seen from Fig. 2, the research orientation on die and devices has not been paid much attention. Scientists have concentrated on optimizing die system, blank holders, and supporting devices in order to satisfy technology ability the best. There have been studies on geometrical parameters of die for optimizing parameters of surface roughness to improve forming ability and product quality [2] [3]. Furthermore, there have been application studies on supporting devices for creating synchronicity and flexibility in controlling technological system, blank holder force, fluid pressure in die, forming pressure, so on to improve forming ability and formed product quality [4].

Succeeding domestic studies, and for studying effect of geometrical and shape factors of die on product quality in sheet metal hydrostatic forming, the authors have established experimental system consisting of essential modules which are presented below.

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2. Experiment

2.1. Die Design Calculation

Based on results of the paper [5] from the 12th National Conference on Solid Mechanics at Duy Tan University, Da Nang of the same authors, the design and manufacturing die for experiment rely on main parameters as Fig. 3:

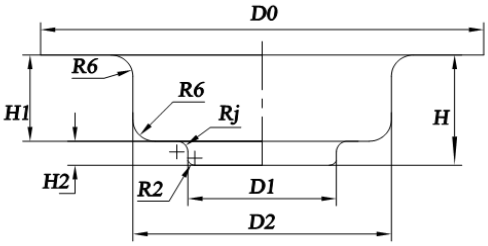

Fig. 3. Shape of the investigated product

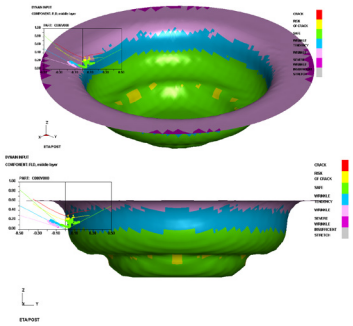

Fig. 4. Product shape in simulation

Fig. 4 shows result of hydro static forming simulation for the stepped cylinder by Dynaform software. After simulating, investigating some geometrical and shape factors, optimum database is chosen as below:

H1 = 16 mm, H2 = 7 mm, D_0 = 114 mm, D_1 = 70 mm, D_2 = 44 mm, R_6 = 6 mm

Moreover, for evaluating effect of fillet radius (convey and convex) R_j and R_2 as in the **Fig.** above, the experimented die is manufactured with R_j = 1÷6, R_2 = 1÷ 6 (based on results from evaluating through numerical simulation published in the paper [4]). With such database, the die is designed as follow:

2.2. Hydrostatic forming die

Due to the characteristic of sheet metal hydrostatic forming that operating fluid pressure uniformly exerts on blank surface, formed part will be uniformly deformed, which benefits forming complex-shaped parts.

From the requirement, the hydrostatic die is as follow:

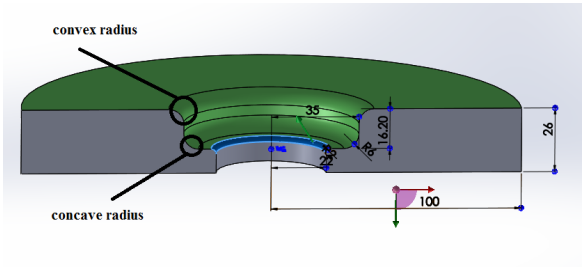

Fig. 5. Hydrostatic die

Hydrostatic die shown in Fig. 5 is where the part is formed according to the die profile and dimensions. Die is drilled with air holes so that product can be taken out after forming.

Hydrostatic die is an important factor in forming products, is one of the determinants of the accuracy of the shape of the product. The purpose of the experiment uses to investigate deformation at convex and concave radii as shown in Fig. 5, so that the die shape is consistent with the survey requirements.

Blank holder is as shown in Fig. 6. It creates blank holder force and guides the highly-pressed fluid to form.

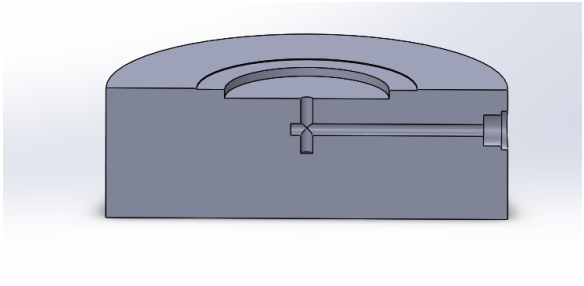

Fig. 6. Blank holder

In addition, there are other parts: die base, plate holder, guide pins and bushes showed in the overall drawing as shown in Fig. 7:

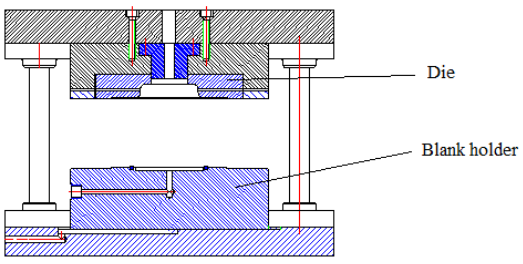

Fig. 7. Experimented die drawing

2.3. Seal

Function of seal is to tighten the contact surface between die and blank holder, for avoiding leaking fluid, ensuring forming fluid pressure. Fig. 8 shows the shape of seal.

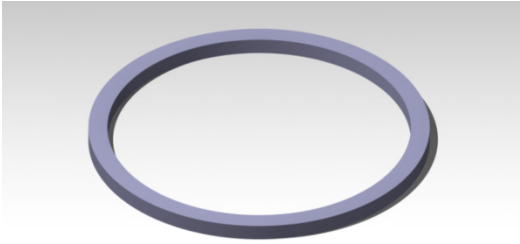

Fig. 8. Seal

Because of complex profile of the die, it is necessary to guarantee the tightness between the seal and the whole blank surface. Furthermore, the seal also makes sure that the blank slided into the die. For such characteristics, seal material is chosen to be bronze or load-bearing rubber.

2.4. Fluid

Hydraulic mineral oil is the most ideal fluid for almost hydraulic systems. Mineral oil with high viscosity index (VI) can be used in a wide range of viscosity. Products with high viscosity are normally used at low temperature. All kinds of oil contain additive, such as antioxidant, antirust and abrasion-proof. In case that additive is consumed or disappears in the operation, these oils can be still used for a long time. They are thoroughly treated to have high water disposal and antifoaming ability. Thanks to high antioxidant ability, these properties can maintain for a long time.

Based on experiment requirement, hydraulic diagram is established as shown in Fig. 9:

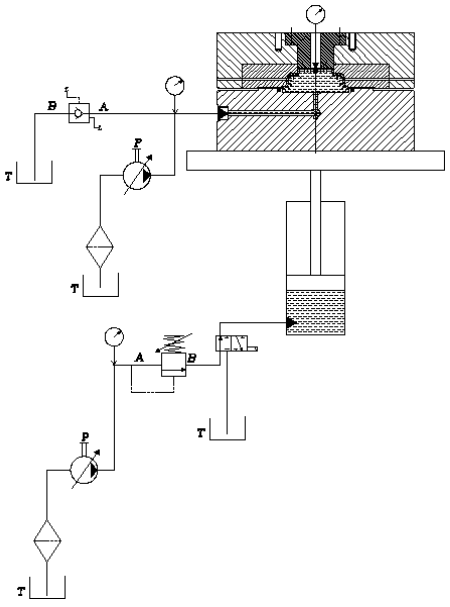

Fig. 9. Hydraulic control system diagram for experiment

Based on real conditions of experiment, 125-ton hydraulic press is used to create blank holder force, and highly-pressed fluid resource for forming is provided by injection pump CP 700.

3. Result

Based on calculation for hydrostatic forming die above, the authors established experiment system consisting of modules including: experimental die system, 125-ton hydraulic press, increased pressure device, measuring system.

Hydraulic press is used to clamp the die and generate blank holder force during forming process. The die consists of lower die and upper die. The lower die works as a blank holder and is holed to provide forming liquid. The upper die consists of die cavity and product that is supposed to be formed like the shape of the cavity. Hydraulic pump will propel high-pressure liquid into the die surface, draw the blank into the die cavity. Measuring system including sensors connected to PC measured the height of the product as well as forming and blank holder pressures.

Operating procedure of the system is as follows: the blank is put on the lower die, the press moves the lower die up until the blank is clamped between the die and blank holder. After that, liquid is pumped from increased pressure device into blank surface, draw the blank into the die cavity. Signals of the product height, forming and blank holder pressures is displayed on PC through measuring system. After the forming process finishes, liquid propel is stopped, the press moves the lower die down, and the product is taken out.

3.1. Experimental die system

After calculation and design, hydrostatic die is completed as shown in Fig. 10:

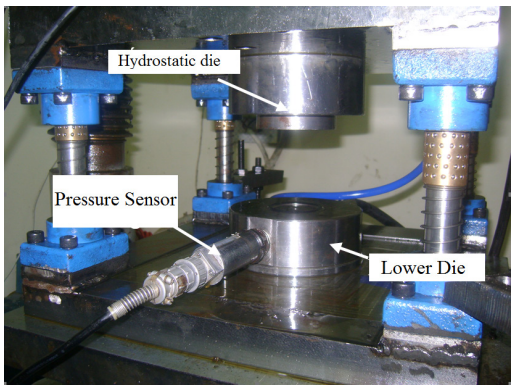

Fig. 10. Overall single sheet metal hydrostatic die

Fig. 11. Upper and lower die

The die is manufactured for evaluating effect of geometry and shape of die on forming ability as shown in Fig. 11. Therefore, the die is designed flexibly to lift or lower the bottom. Additionally, other dies are manufactures for investigating effect of fillet radius. Processing, manufacturing and calibrating, testing are implemented in the laboratory at Hanoi University of Science and Technology.

3.2. 125-ton hydraulic press

This device is available in the laboratory. The experiment system is established on hydraulic press with nominal press of 125 tons illustrated in Fig. 12. and table 1. The establishment is considered to be a creative application of design of die and supporting devices into implementing hydro-static forming experiment. The experiment system aims to define technological parameters such as holder pressure, in-die pressure and choke.

This device is chosen to be a module in the system thanks to ability to create blank holder force.

Fig. 12. 125-ton hydraulic press

Table 1. Parameters of 125-ton hydraulic press

TT	Specification	Unit	Value
1	Nominal press	kN	1250
2	Maximum displacement	mm	710
3	Stroke speed	mm/s	5/10
4	Platform dimension	mm	500 x 500
5	Drive mode		Dưới
6	Main cylinder diameter	mm	220
7	Hydraulic pressure	bar	320

3.3. Increased pressure device

The Hydraulic Pump CP 700 (Fig. 13) is used to provide highly-pressed fluid resource to form sheet metal.

Fig. 13. The Hydraulic Pump CP 700 [5]

This is a manual hydraulic pump, hence there is a disadvantage that pressure supply is discontinuous and fluid speed cannot get high. However, high forming speed is not required with drawing. Thus, this device is proved to meet the authors' demand and suitable for investigating necessary parameters. In case of mass production, this device can be replaced with an automatic pressure supply system.

Table 2. Main parameters of The Hydraulic Pump CP700

Maximum pressure	700 (bar)
High pressure capacity	2.3 cm^3
Low pressure capacity	13 cm^3
Oil volume	1270 cm^3
Weight	12 kg
Dimension (mm)	580*140*165

3.4. Measuring system

The measuring system shows in Fig. 14, collecting and processing signal (measures pressure – displacement, pressure of blank holder cylinder, directly connected to computer with a control software), is manufactured, calibrated and tested at Institute of Missile – Institute of Military Science and Technology.

Fig. 14. Measuring system for pressure and displacement

Sensors are attached to the die, transfer signals including forming pressure, blank holder pressure and displacement to a computer. The result is graphs demonstrating relations of parameters.

Fig. 15. Complete Experiment System

The system is connected to a PC as shown in Fig. 15

Product images:

a) b)

Fig. 16. (a) two-step product; (b) one-step product (after the height of the second step is reduced to zero)

Fig. 16 is the experiment result of one-step and two-step products. The experiment has made initial success in forming. Different experiments need to be carried out to evaluate influential elements in sheet metal hydrostatic forming. The evaluation of technological elements will be presented in upcoming papers.

4. Conclusion

The paper presents steps of establishing and manufacturing experiment system for single sheet metal hydrostatic die, including modules:

- Hydrostatic die
- 125-ton hydraulic press
- The Hydraulic pump CP 700
- Measuring system

Compared to previous systems, this experiment system gives out accurate and clear results thanks to integration of measuring system connected to PC; therefore, it can be widely used for research. Moreover, it is flexible to replace different kinds of die in this system. Moreover with the suitable arrangement of hydraulic elements in this system, it is easy and convenient to investigate the change of blank holder force – the problem that has never been paid attention to before.

The establishment of experiment system on the press available is considered to be a creative application of design of die and supporting devices into implementing hydro-static forming experiment. Hydrostatic die systems can be flexibly replaced to suit each survey requirement.

The experiment has initially obtained certain results. The systemization of experiment results and comparison between experiment and simulation will be presented in upcoming papers.

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