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Experimental Investigations of a Hydrodynamic Deep Drawing of a Low Carbon Steel 1008 AISI

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ABSTRACT

This study aims to investigate the hydromechanical deep drawing process using a blank of low carbon steel (1008-AISI) with 80 mm of diameter and using different thickness (0.5, 0.7, 0.9) mm, respectively. Variable fluid pressure was applied by hydraulic oil (code number 3803) to get the finished product. A die was designed and manufactured. The conducted work of this study was achieved in three states as following: In the first state, the experimental work was done without fluid pressure, so the product suffers from wrinkles defect. In the second case, the wrinkles defects were minimized using 8 N/mm^2. The third case testing was achieved under the pressure of 1.5 N/mm^2. The results indicate that the free defect product can be achieved by choosing a blank holder force (BHF) not too high, not too low. If BHF is low, wrinkling defects appear in the cylinder cup, and I BHF is high, a rupture is found in the cylindrical cup. Therefore, the BHF value should be variable according to the material, thickness and product nature.

KEYWORDS

Hydroforming, Deep drawing, Sheet, Blank

INTRODUCTION

The hydromechanical deep drawing technology is a new technology for the forming purposes of sheet metals using a pressurized fluid as a medium. In this process, the pressurized fluid is used as a medium. The liquid is used as the medium of energy to form component shapes. This manufacturing process can manufacture different complex shapes with high strength and low cost instead of using traditional techniques such as welding, stamping, forging and casting. The hydromechanical deep drawing (HDD) widely used application industries such as application in automobile, reflectors of lighting equipment and aircraft manufacture [1]. The hydromechanics deep drawing has various names, e.g., hydroforming, Aqua-draw [2]. In such applications, fluid is formed, and a counter hydraulic pressure is developed. Many researchers have studied the (HDD) process to obtain analytical and numerical solutions. Yongchao Xu and Shijian Yuan [3] studied the influences of loading paths on the thickness of aluminium alloy (5A06) cup with a hemispherical bottom by using hydromechanical deep drawing process and the finite element method. With the optimal loading path, the thinning reduced, forming limit is raised, and thickness is more uniform.

Hakan Gürün and İbrahim Karaağaç investigated the effect of the sheet thickness, die radius and die chamber pressure which affects the formability of sheet metal (DC01) using the hydromechanical deep drawing and standard deep drawing [4]. The results found that the most significant drawing ratio obtained in the conventional deep drawing is 2.16, while the most effective drawing ratio obtained in the hydromechanical deep drawing is 2.33. The hydromechanical deep drawing process is sufficiently lubricated. The friction between the sheet material on the die and the die is low compared to the friction developed in conventional deep drawing. Tushar Khandeparkar and Klaus Siegert to be placed between the draw ring and the blank. (HDD) of the cylindrical cup, the sealing ensures minimal leakage of fluid; the result found (TiC-TiN) coated steel ring with two properties, good pressure and low friction [5]. Lingyun Zhang and Wenyuan Wang presented the (HDD) process to produce a half-three way tube part of aluminium alloy (6061-0) [6]. The product shape is considered one of the hard part manufactural, used different parameter punch structure, liquid pressure, thickness, and radius of the die. The result found the punch design has an impact on the (HDD) process to produce this shape. In contrast, the liquid pressure plays a crucial role in the (HDD) process, and the radius of the die corner is critical. The sheet was too large and easy pulled in the die, and the thinning sheet rate is increased.

The experimental work of Kotchakorn Wiratchakul and Thanasan Intarakumthornchai demonstrated the effect of friction coefficient punch/blank and friction coefficient blank/binder on thinning and wrinkling defects for parabolic shape part in hydromechanical deep drawing process [7]. The material used was [AL SI 1008(JIS G 3141 SPCC)], the result found the thinning can be improved by an increment of friction coefficient punch/blank for batter thickness of the parabolic part. Complex shape parts with variable cross-section size in hydromechanical process were studied by Qinglei Guo and Li Zhang, using aluminium alloy(2A16) [8]. The part shape of aluminium alloy ship-shape, the result found in this shape the main wrinkling area is the sharp corner area, increasing the liquid chamber pressure and initial inverse bulging pressure. The sharp corners are the regions of Wrinkling. This Wrinkling is reduced with the fluid chamber pressure and the initial reverse, but the maximum thinning rate steadily increases. Finally, by applying the maximum liquid chamber pressure and the initial inverse bulging pressure, the wrinkling defects of this shape can be reduced efficiently. The deep drawing process involved many aspects, such as producing conical shapes products using the AISI 1008 steel [9-11]. In this work, the hydroforming will be used, and a test rig will be designed and constructed for forming the cups made of a low carbon steel 1008 AISI using sheet metals of thicknesses 0.5, 0.7, and 0.9 mm and variable pressures.

THE CONSTRUCTED RIG

The design and manufacturing of different parts of the used rig in the hydromechanical deep drawing (HDD) operation were accomplished as presented in the following steps: Manufacture the fluid compressor from Iron and used it to push the fluid into a pipe. The die manufacture from stainless steel and consists of the cylinder, base, female die, punch and blank holder. To control the pressure in a system, using a relief valve [12-14]. Figure (1) hydromechanical deep drawing rig used in this study; figure (2) shown the schematic of the drawing.

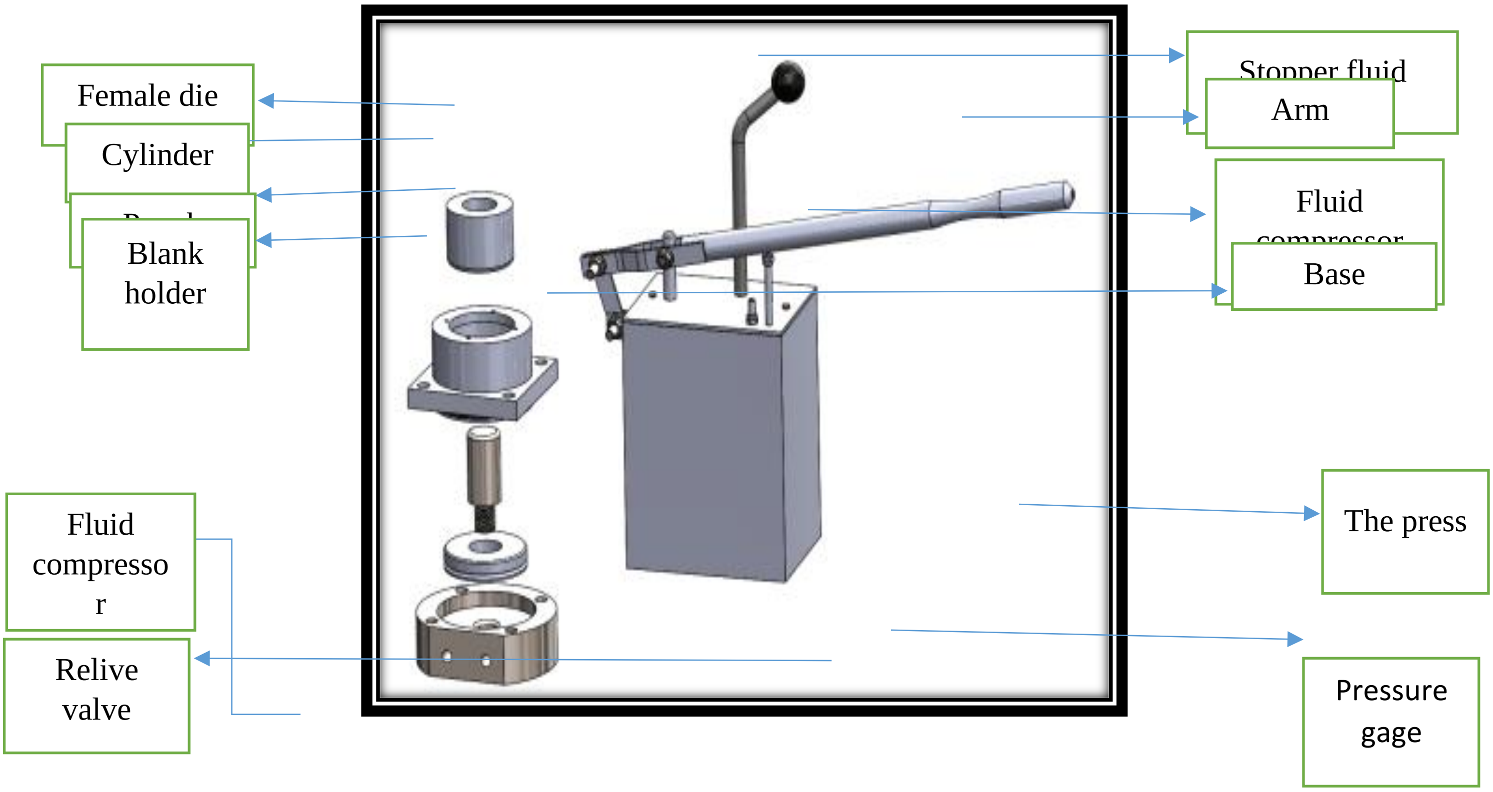

Figure 1. Hydromechanical deep drawing rig

Figure 2. The hydraulic pressure device and the system (HDD) tool

EXPERIMENTAL WORK

The sheet metal forming by hydromechanical deep drawing (HDD) is usually used to get a cylindrical cup. The blank used from low carbon steel (1008-AISI), with different thickness (0.5, 0.7 and 0.9) and different fluid pressure, the blank diameter used is (80) mm and the chemical compositions is as listed to this material shown in table (3).

Table 3. The Chemical composition of low carbon steel(1008-AISI)

C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	Cu %	Al %	Fe
0.07	0.016	0.192	0.012	0.009	0.014	<0.002	0.012	0.0106	0.026	Bal

The entire procedure can be abstracted in the following:

1. The compressor is filled with hydraulic oil (Code No. 3803). The hydraulic oil is pumped to the cylinder, which a pressure gauge can measure. The cylindrical blank is placed inside the cylinder between the blank holder (from down) and the female (from the top). The liquid will be under the blank.
2. The blank is placed inside the cylinder between the blank holder and the female die from the top. The liquid will be under the blank.
3. Apply the hydraulic press force on the female die. The blank will be under a force from the top and the liquid pressure from down. The forming process starts in this stage.
4. Releasing the force of the hydraulic press device and pump the fluid from the fluid compressor to ease product exit.

RESULTS AND DISCUSSION

Case I: Drawing without fluid pressure

In this state used the blank diameter (80) mm of the low carbon steel (1008-AISI) with different thickness (0.5, 0.7, and 0.9) mm and without fluid pressure, also the speed of press 5mm/mine (slow speed), can see table (4).

Table 4. State number one data

Thickness	Fluid Pressure	Pressure Press
0.5 mm	-------	1.2 N/mm^2
0.7 mm	-------	1.5 N/mm^2
0.9 mm	-------	1.8 N/mm^2

To calculate the area of blank:

$A= \pi D_b^2/4$ (1)

A = (3.14*80^2)/4
A =5024 mm^2
To calculate the force of press on the blank:

$P_p = F/A$ (2)

When P_p = the pressure of press, F = load of press, A =area of blank

<u>When thickness = 0.5 mm</u>
P_p = 1.2 N/mm^2
F = 6028.8 N
<u>When thickness = 0.7 mm</u>
P_p = 1.5N/mm^2
F = 7536 N
<u>When thickness =0.9 mm</u>
P_p = 1.8 N/mm^2
F= 9043.2 N

In this state, the product is obtained with the wrinkling defect, as shown in figure (3)

Figure 3. The wrinkling defect in the product

The Wrinkling appears in the product in case of forming without fluid pressure. The fluid pressure presses on the blank holder. This means that insufficient blank holder force increases the blank thickness, as shown in figure 4.

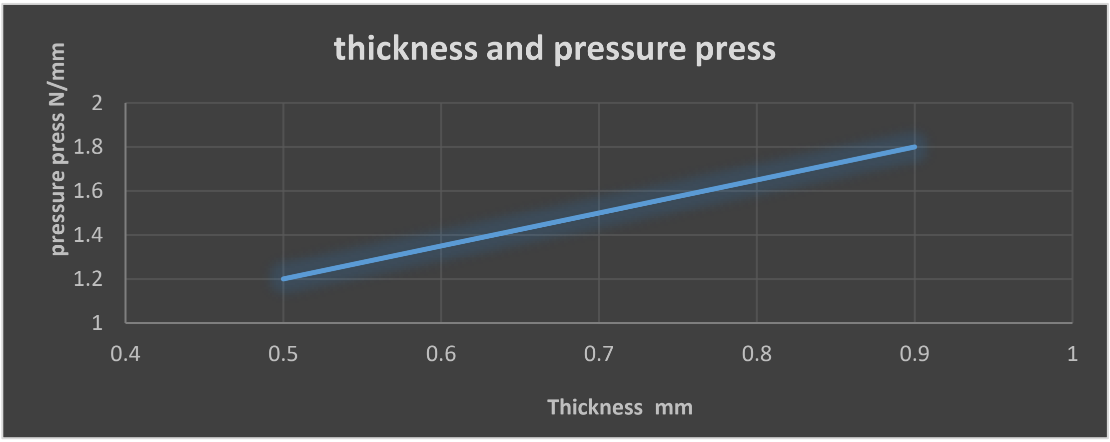

Figure 4. Effect thickness on pressure press

Case II: Low fluid pressure

In this state also used the blank holder diameter (80) mm of the low carbon steel (1008-AISI) with different thickness (0.5, 0.7, and 0.9) mm and fluid pressure (0.8) N/mm^2, also press speed 5 mm/min is low as shown table 5.

Table 5. State number two data

Thickness	Fluid Pressure N/mm^2	Pressure Press N/mm^2
0.5 mm	0.8	1
0.7 mm	0.8	1.8
0.9 mm	0.8	2

The second case:

The area of blank (A) = 5024 mm^2

To calculate the force, press on the blank

P_p =F/A

When thickness = 0.5

F = 5024 N

When thickness

F =9043.2 N

When thickness =0.9

F =10048 N

In this case, a wrinkling is developed due to insufficient pressure of the fluid to press on the blank to produce a good product and free o defects. The BHF, in this case, is low, which leads to a pure drawing that allows freely metal flow in the die cavity with radial tensile stresses and hoop stresses in the flange, which reduce the diameter and develop wrinkling defects, as shown in Fig. 5.

Figure 5. The wrinkling defect in state two.

Also, we see the thickness of blank increase, which leads to an increase in the loads press shown the figure (6).

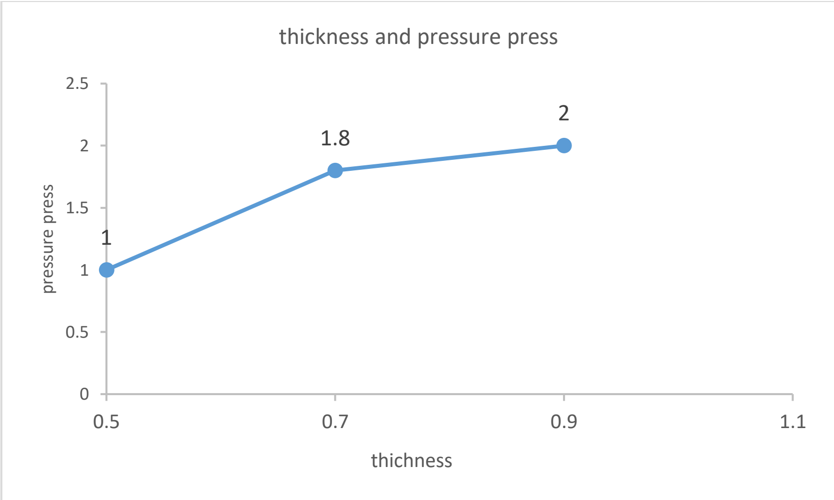

Figure 6. Effect thickness on pressure press with fluid pressure

Case III: Appropriate Fluid Pressure

In this state used blank diameter (80) mm of low carbon steel (1008-AISI) with different thickness (0.5, 0.7, and 0.9) mm and with fluid pressure (1.5) N/mm^2, also speed press (5) mm/min (speed very slow) shown table (6). Using the concept of accuracy and error in choosing the pressure fluid (state 1, 2 and 3), the value pressure appropriate is 1.5 N/mm^2. In this state, see the pressure fluid suitable and get a product without defect (cup cylinder) shown in figure (7).

Table 6. State number three data

Thickness	Fluid Pressure	Pressure Press
0.5 mm	1.5 N/mm^2	1.3 N/mm^2
0.7 mm	1.5 N/mm^2	1.9 N/mm^2
0.9 mm	1.5 N/mm^2	2.1N/mm^2

The area of blank (A) = 5024 mm^2

To calculate the force press on the blank

P_p =F/A

When thickness = 0.5

F = 6531.2 N

When thickness = 0.7

F = 9545.6 N

When thickness = 0.9

F = 10550.4 N

Thickness 0.5 Thickness 0.7 Thickness 0.9 Side View

Figure 7. The Product cup cylinder in state three

The cup cylinder dimensions shown figure (8).

when
d_1 = cup inner diameter (mm) =40 mm
d_2 = cup flange diameter (mm) = 63.2 mm
h = cup height (mm) =15 mm

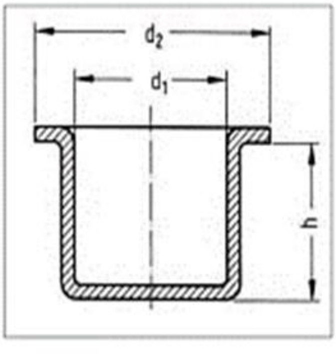

Figure 8. Cup dimension

The relation between the diameter and the blank and the cup

Cylinder is:

$$D = \sqrt{d_2^2 + 4d_1 \cdot h} \quad (3)$$

D = the diameter of the blank = 80 mm value pressure

pressure makes the blank value holder force appropriate (not low and not high) so that the blank holder force does not have to keep constant throughout the deformation (because of fluid pressure). The counter pressure develops compressive stress on the blank to reduce the thinning and then improves the formability for that good product (without defect). Through the states (1, 2 and 3), the value of fluid pressure changes with the change pressure press, whereas we can see figure (9).

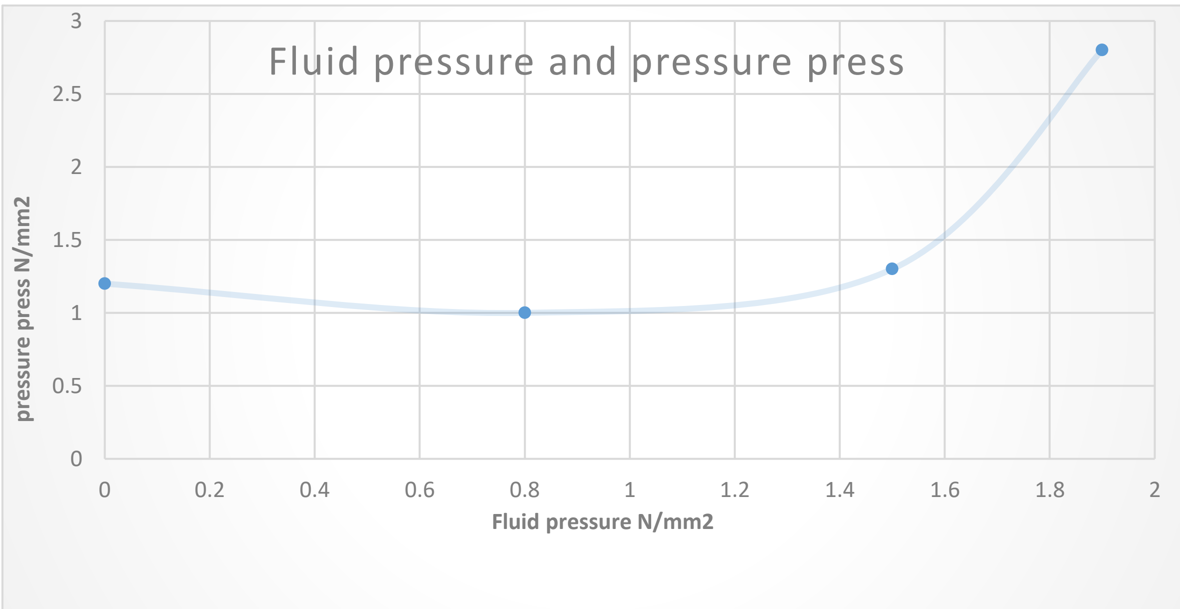

Figure 6. The fluid pressure and pressure press

The relation between the blank holder force and fluid pressure (BHF = $P*A_{BH}$)

So that each increase the fluid pressure wall increase the blank holder force, shown figure (4-27), to calculate the blank holder force:

BHF = $P*A_{BH}$
The area of blank holder (A_{BH}) calculates:
A_{BH} =(D^2-de^2).π/4
de= d+2.C+2Rd (when de = effective diameter of blank holder (mm))
when C= clearance
C= 0.77
de= 51.4 mm
A_{BH} = 2950.06 mm^2
BHF = 4425.09 N
DR=2

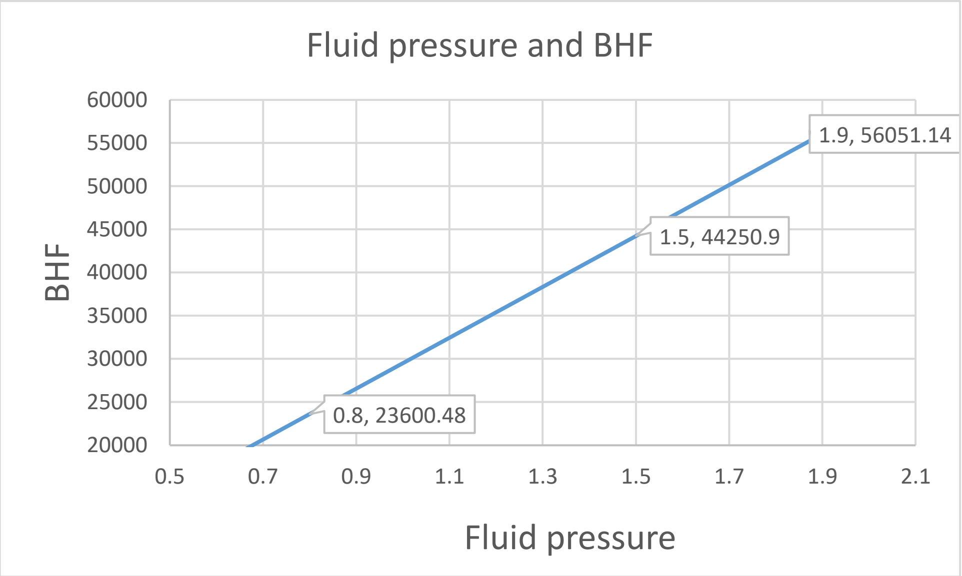

Figure 7. The BHF and fluid pressure (all unit's N and N/mm)

The cup product thickness will remain constant under punch face (cup bottom) because the flat face of a punch which is in contact with blank, drawing force and friction, all of which play a role in preventing any metal deformity at the site under the punch. The exerted stretching by tensile stress at the punch corner cause a definite thinning that increases with blank holder force increment. Afterwards, the cup wall thickness tends to increase due to the compressive stress that is applied to this region.

CONCLUSIONS

1- The sheet metal hydrodynamic forming becomes challenging to be achieved in case of thickness increase. The pressure required to avoid Wrinkling becomes high and cannot be achieved with the lab system,
2- The blank holder force (BHF) must be chosen carefully. If the blank holder force of a low value, wrinkling defects will be developed in the cylindrical cup, and if it is high, the products will have a rupture.
3- The fluid pressure should be compatible with the blank holder force to have a product free of defects.

It could be extended for investigating the impact of other parameters on blanking processes such as coefficient friction, clearance between die and punch, pressure pre-bulging, die radius, punch radius and punch speed.

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