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An Experimental Study of the Sheet Hydroforming Process

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Abstract — **Hydroforming of aluminum sheets is a plastic deformation process largely used in automotive industry. Among the different hydroforming processes, the Flexform is the one in which the punch is replaced by a fluid cell. This cell consists of a rubber membrane that is filled with a controlled pressure fluid that will deform the sheet in the tool. A rigid die is used for obtaining the shape of the workpiece. For obtaining a sound product a balance between the pressure fluid and the blank material and geometry must be assured. The paper presents experiments carried out for analyzing the influence of the die geometry, the blank thickness and the fluid pressure toward the product accuracy, in terms of thickness and shape variations. The results will be useful in process modeling and in estimation of hydro-deformability of aluminum sheets.**

Keywords—*sheet hydroforming, unconventional sheet metal forming, flexforming, deep drawing*

I. Introduction

Sheet hydroforming (SHF) is widely used in automotive and aviation industries [1, 2] because its advantages such as complex component shapes, improvement of the formability, high surface quality, accurate dimensions, reduction of the springback, and uniformity of the product wall thickness.

Hydroforming, using fluids as a replacement of rigid tools [3] can be classified into groups according to: the working media role (punch or die); the blank-holder presence or absence; the form of contact between the work-piece and the working media (direct or indirect).

Different methods of (SHF) have been developed during the years: hydro-mechanical deep drawing [3, 4, 14], hydroforming with elastic membrane [5-7, 12], counter pressure drawing [8, 9], hydraulic pressure-augmented drawing [10, 11, 13].

Hydro-mechanical deep drawing is the process that metal sheets were formed by deep drawing punch with a hydraulic counter pressure. The counter pressure was controlled by a relief valve and an additional safety relief valve avoids bursting of the counter pressure (Fig. 1).

In hydraulic counter pressure drawing process, radial push is applied on the blank periphery by an amount of the fluid contained inside the pressure container, flowing through special passages. In addition, this fluid reaching to the gap between the upper die surface and the blank holder lubricates both sides of the cup flange that is being formed (Fig. 2)

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In hydraulic pressure-augmented drawing there is no hydraulic fluid pressure in the female tool cavity to counter the rigid punch. The hydraulic pressure here is exploited for providing drawing force and blank holding force simultaneously through getting the fluid in a direct contact with both of the punch and blank holder. Therefore, the punch force and the blank holding force proportional to the fluid pressure generated in the device (Fig. 3).

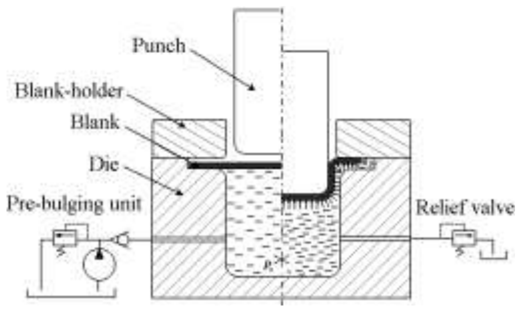

Figure 1. Hydro-mechanical deep drawing [4]

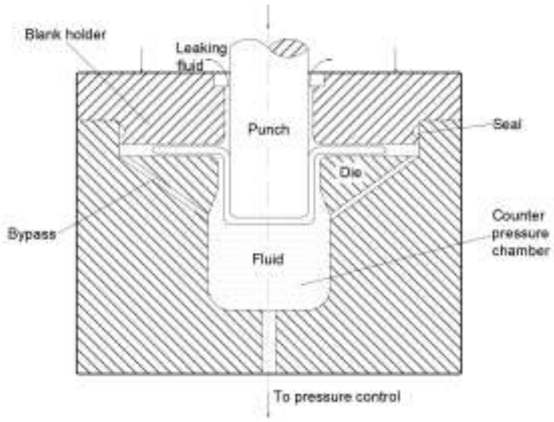

Figure 2. Hydraulic counter pressure drawing [9]

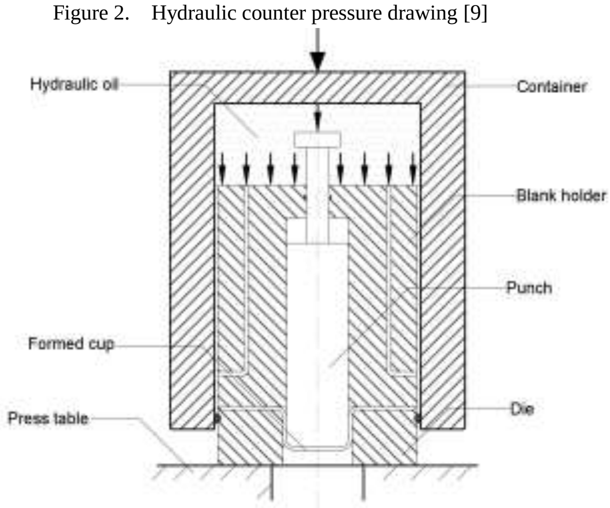

Figure 3. Hydraulic pressure-augmented drawing [11]

In hydroforming with an elastic membrane, the so called flexforming a flexible rubber and a chamber with oil replace the solid punch. The rubber membrane prevents direct contact between the hydraulic fluid and the sheet metal material and is used to transfer fluid pressure [7]. Due to the flexibility of the rubber pad, parts even with undercuts and sharp contours can be formed, even for sheets with different initial thickness (Fig. 4).

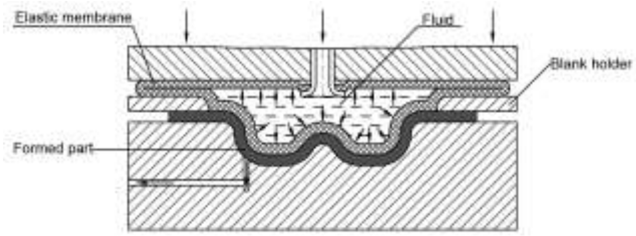

Figure 4. Hydroforming with an elastic membrane [5]

In this research work, the sheet hydroforming process with an elastic membrane is investigated as a means for shaping aluminum sheet metals with the objective of achieving higher draw-depths and forming wrinkle-free parts using fluid pressure.

II. Experimental Work

Fig. 5 presents an image of the part model. The forming part cavity consists of succession revolution surfaces; both stretching and compression are presented during the material deformation.

Figure 5. Picture of the designed part

The circular blanks have a diameter of 140 mm each and different thicknesses (0.4, 0.6 and 0.8 mm).

For this study, aluminum is chosen, because of its large applications in automotive and aero industry. For determining the material properties, a traction test has to be done. The traction tests have been realized with Instron 352 testing machine. The test samples used had the calibrated dimensions of 120 x 20 x material thickness, in accordance with ISO 6892-1:2009. Three thicknesses (0.4; 0.6; 0.8) were tested. The media values of maximum tensile stress Rm were 109, 99, 110 MPa for the considered thicknesses.

A hydraulic press, Fig. 6, is used for the experimental study of the sheet hydroforming process. The fluid pressure is applied to the sheet with the help of an elastic rubber, as a uniformly distributed load on the inner surface of the blank.

Fig. 7 shows the hydraulic scheme of the press to obtain the hydraulic pressure required for the material deformation. The pressure chamber is delimited by the body 1 and the elastic membrane 2.

The fluid in the chamber is characterized by low speeds and high-working loads, channeled by a variable flow pump 6. Parallel to that variable flow pump, two safety valves 4 are mounted to prevent any overpressure. The deformation takes place in the die 8.

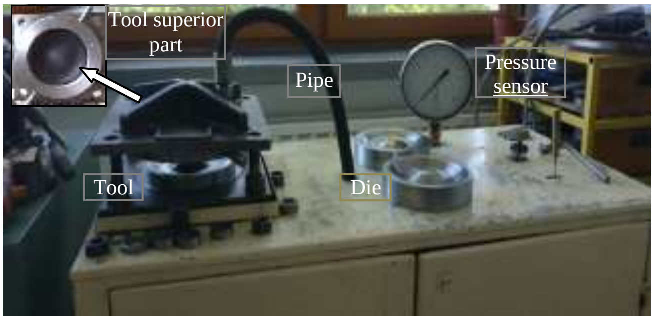

Figure 6. Press for Sheet Hydroforming

When the distributor is in neutral position with the drawer 3, the pressurized fluid is conveyed to the tank, passing through filter 5 mounted over the drain pipe.

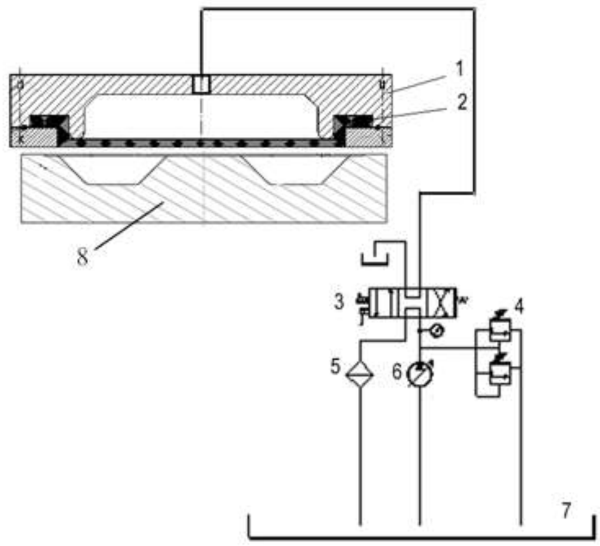

Figure 7. Hydraulic scheme

When the distributor is switched to the first position, the variable pump will dispense a flow corresponding to the needs of the upper plate.

As a result, as the pump reaches the end of the stroke or overloads, the nominal pressure is exceeded in the safety valves. The valves will open and the fluid will flow to the tank 7. If not, the safety valves are closed and do not discharge oil to the tank.

The hydraulic system ensures a maximum pressure of 25 MPa. Table 1 presents values of the applied pressures.

The first step in the flexforming process is to place the circular blank on the die. In the second step, the upper part provides a seal by closing on the die, and then, the sheet

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metal material is deformed by pressurizing the hydraulic fluid. The pressure increased from zero to the selected value. A holding time of 5 s was chosen. In the third step, the hydraulic fluid pressure is set to zero, and the process is completed by raising the upper part of the die [7].

The flexible membrane of the pressure chamber has a thickness of 5 mm. This membrane is a natural vulcanized rubber, and has the following properties: 55 Shore A's hardness; tensile strength of Rm=3500 MPa at 20°C; elongation at break of 650% at 20°C.

Dies are made from a stainless steel, to prevent any corrosion. The depth of each die is presented in table I.

TABLE I Parameters of the process deformation

Depth of the die (mm)	Thickness of the blank (mm)	Pressure (MPa)
9	0.4	6
10.5	0.6	8
12.5	0.8	10

III. Experimental Results

The parts obtained from blanks with 0.8 thicknesses are shown in the table 2. To the highest depth, of the profile, 12.5 mm, all parts have been cracked during the deformation process; however, the other parts didn't have wrinkles and seems to have a good shape.

TABLE II Deformed parts from Al material, 0.8 thickness

Depth of the die (mm)	Deformed part	Pressure (MPa)
9		10
10.5		10
12.5		10

The use of blanks from 0.4 mm thickness didn't give good results. The material and the die profile are not in accordance. The use of blanks 0.6 mm thickness gave similar results as in the case of 0.8 mm.

We measured the profile of each die and deformed part thanks to a CMM Tesa Micro Hite 3D. The data of the profiles has been generated on a notepad file, and then exported to excel.

An example of the part experimental profile, upper and lower surface, is presented in Fig. 8.

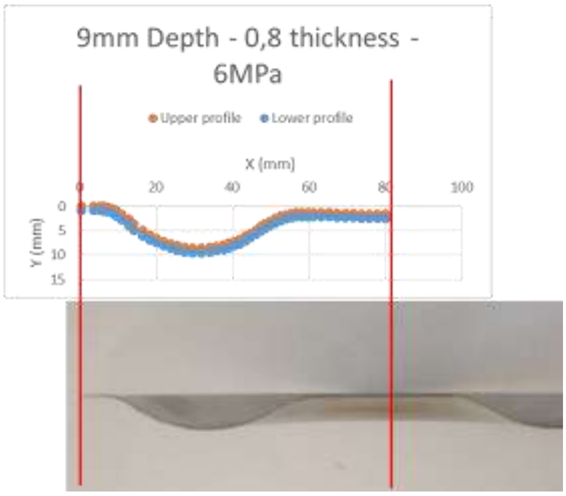

Figure 8. Upper and lower profile of the part

A comparison between the part and die profile, for the same pressure and different dies depths show that increasing the deformation depth the profile of part, at the bottom, differs from the die profile, mainly in the radius zone (Fig. 10).

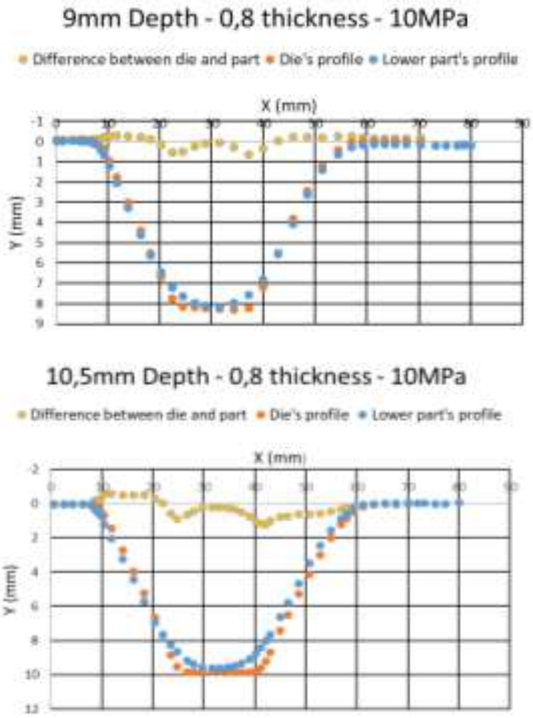

Figure 10. Comparison between the part and die profile, same pressure, different die depths

A comparison between the part and die profile, for the same depth and different die pressure show that by increasing the pressure the profile of part, at the bottom, is closely to the die profile, (Figs. 10 and 11).

Figure 11. Comparison between the part and die profile, 10.5 mm die depth

One reason for the differences between the die and the part is the formability of the rubber membrane. When the depth of the die is 9 or 10.5 mm, the parts which are closer to the die's shape are those which were deformed with the highest pressure. When the depth is 12.5, all of parts have cracked. Due to pressure increases and the uniform pressure applied on the sheet metal, a decrease in springback was observed based on frictional increases.

IV. Conclusions

The flexforming process was used to form sheet metal parts with complex geometries and in small quantities.

The process parameters that affect the sheet hydroforming have been studied. The variables affecting the forming pressure according to experiments are the forming pressure, the rubber hardness and the part profile.

Achieving deeper profiles will require constructive modifications of the part so that by increasing the working pressure the greater deformation depths will be obtain.

A springback is more important when the pressure is lower, which leads to a difference more important between the die and the part.

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References

[1] S. Thiruvarudchelvan, "The potential role of flexible tools in metal forming", Journal of Materials Processing Technology, vol. 122, pp. 293-300, 2002.

[2] A. Kocanda, H. Sadlowska, "Automotive Component Development by Means of Hydroforming", Archives of Civil and Mechanical Engineering, Warsaw University of Technology, Poland, vol. VIII, pp. 55-72, 2008

[3] S. M. Kulkarni, V. V. Ruiwale, M. S. Jadhao, A. A. Kadam, S. R. Kale, "A review on Hydroforming Processes", International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

[4] J. Danckert, K. B. Nielsen, "Hydromechanical Deep Drawing with Uniform Pressure on the Flange", CIRP Annals - Manufacturing Technology, vol. 49, pp. 217-220, 2000.

[5] F. Vollertsen, R. Breede, K. Lange, "Method for deep drawing with multiple elastomer membranes", CIRP Annals - Manufacturing Technology 48 (1), pp. 221-226, 1999.

[6] M. H. Parsa, P. Darbandi, "Experimental and numerical analyses of sheet hydroforming process for production of an automobile body part", Journal of Materials Processing Technology, vol. 198, pp. 381-390, 2008.

[7] I. Karaagac, , "The Experimental Investigation of Springback in V-Bending Using the Flexforming Process", Arab J Sci Eng (2017) 42:1853–1864.

[8] N. Abedrabbo, M. A. Zampaloni, F. Pourboghrat, "Wrinkling control in aluminum sheet hydroforming", Int. J. of Mechanical Sciences, vol. 47, pp. 333-358, 2005.

[9] L. Lang, J. Danckert, K.B. Nielsen, "Investigation into hydrodynamic deep drawing assisted by radial pressure: Part I. Experimental observations of the forming process of aluminum alloy", J. of Mater. Process. Technol., 148 (1), pp. 119-131, 2004.

[10] S. Thiruvarudchelvan, M. J. Tan, "A note on fluid-pressure-assisted deep drawing processes", J. of Mater. Process. Technol., vol. 172, pp. 174-181, 2006.

[11] S. Thiruvarudchelvan, H. Wang, "Investigations into the hydraulic-pressure augmented deep drawing process", J. of Mater. Process. Technol., vol. 105, pp. 161-175, 2000.

[12] V. Paunoiu, V. Teodor, F. Susac, "Researches regarding the hydroforming process of aluminum components", Modern Technologies in Industrial Engineering (ModTech2015), IOP Conference Series-Materials Science and Engineering 95, ISSN: 1757-898, 2015.

[13] G. Palumbo, S.H. Zhang, L. Tricarico L, C. Xu, L.X. Zhou, "Numerical/experimental investigations for enhancing the sheet hydroforming process", Int. J. of Machine Tools and Manuf., Vol. 46, pp. 1212-1221, 2006.

[14] M. Dariani, A. Fazli, "Parameter study of the axisymmetric hydromechanical deep drawing process", Proceedings of the Institute of Mechanical Engineers (IMechE), Vol. 220 Part B: J. Engineering Manufacture, pp. 1937 – 1944, 2006.

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