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EXPERIMENTAL AND FINITE ELEMENT ANALYSIS OF HYDROFORMING PROCESS FOR STEPPED DIE

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ABSTRACT: *Hydroforming processes have become popular in recent years, due to the increasing demands for lightweight parts in various fields, such as bicycle, automotive, aircraft and aerospace industries. Hydroforming uses fluid pressure in place of the punch as comparing with a conventional tool set to form the component into the desired shape of the die. The hydroforming is very useful for producing whole components that would otherwise be made from multiple stampings joined together. Shape of hydro formed parts is more complicated but very smooth and harmonic. This research work details the comparison between high and low pressure AA5083 sheet hydroforming for the stepped rectangular geometry. It is determined that the applied pressure and clamping force required for optimum sheet hydroforming process. The bulging height and thickness distribution of the part after bulging tests were measured for analyzed. Finite element modeling of sheet hydroforming has been performed using finite element software ABAQUS.*

Keywords: *Hydroforming, FEA, Aluminium Alloy*

1. INTRODUCTION

Hydroforming is a material-forming process that uses a pressurized fluid (liquid or gas) in place of hard tooling (punch, die, mold, inserts, etc.) either to plastically deform or to aid in deforming a given blank material (sheet or tube) into a desired shape as depicted in Figure 1. With this technique, more complex shapes with increased strength and low cost can be manufactured as compared with stamping, forging or casting processes. The cost advantage usually stems from the fact that fabrication steps in hydroforming are significantly reduced, usually to a single step. In stamping, for example, multiple steps such as blanking, drawing, restriking, trimming, welding, etc. are needed to finalize a part whereas a sheet blank can be drawn into the final complex shape (as shown in Figure 2) in a single step.

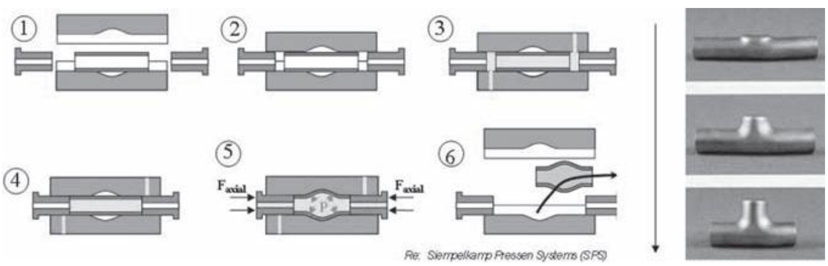

Figure 1 Steps in a typical hydroforming process shown on a small tubular part (courtesy of Siempelkamp Pressen Systems).

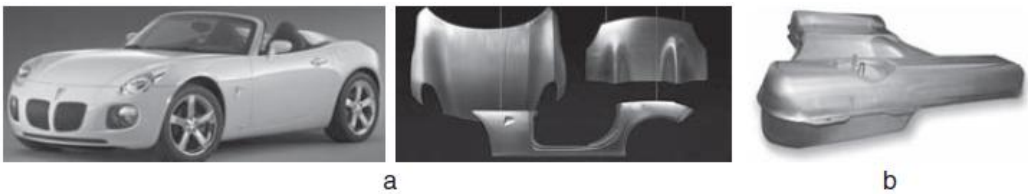

Figure 2 Example hydro formed (sheet) parts:
(a) 2007 GM Pontiac Solstice GXP has several hydro formed (warm) parts
(b) fuel tank comprising of two halves can be hydro formed in a single step.

In the sheet hydroforming (SHD) process, sheet blank is formed by hydraulic pressure inside the die cavity. This technique allows a much deeper draw, which is necessary for manufacturing panels with complex curves. Sheet hydroforming can be classified into two parts: Hydro Mechanical Deep drawing (HMD) and high-pressure sheet hydroforming with single and multiple blanks. Ahmad Assempour and Mohammad Reza Emami (2009) deal with the process of hydro forming of a pair of metal sheets. After obtaining the kinematically admissible velocity field, the pressure equation is obtained by the upper bound analysis. Gyliene and Ostasevicius (2005) considered the necking models, which were implemented in FEM code and numerical simulation results of simple sheet metal processing. Hatem Orban and Jack Hu (2007) has develops an analytical model for the expansion of a circular tube into a square die. Hatice Evlen et al (2012) have investigated the formability of steel sheet, uniaxial tensile tests and biaxial bulging tests were examined. This research work details the comparison between high and low pressure AA5083 sheet hydroforming for the stepped rectangular geometry.

2. EXPERIMENTAL WORK

There should be a clamping arrangement for holding the dies closely together and the clamping must not getting declamp during the forming operation. It means the clamping force should greater than the forming force. Placing the specimen blank material in between the dies and clamping will be carried out. After clamping the dies, the high pressure fluid for formability should send through the hole provided on the top die with proper hose and fittings arrangement. The high pressures enters and stretch the blank towards the cavity of the lower die, and getting form as per the desired shape provided on the lower die.
The channel frame type hydraulic press with 10 tons capacity is used for the hydro forming setup. The die is adapted in to the press and a clamping cylinder also provided separately. The upper die is attached to the clamping cylinder's piston rod end and the lower die is placed on the press bed. First of all the clamping cylinder will be operated and clamped the dies together with high clamping force by means of high pressure fluid to the clamping cylinder. Now the blank is held tightly without any shake or sliding movement inside. Now the hand pump will supply the high pressure oil for a little while with controlled flow manner and it will stretch the blank towards the cavity slowly. Step by step stretching will be carried out i.e. slowly 4 or 5 times this step will be followed.

The forming method will not be carried out with a single stroke, because shearing of blank may occur while stretching carried out with single stroke. For controlled flow we can apply with controlled stroking of hand pump or a cushioning valve can be provided on the bottom side of the lower die, and at the beginning oil should be fill in the die cavity of the lower die the process. A simple direct operated pressure relief valve can be used as cushioning valve. After finishing the forming the cylinder is to be declamp and remove the blank. Figure 3 shows the hydroforming experimental setup.

The steps in performing the sheet hydroforming experiment is as follows:

1. The 'O' rings is placed in the 'O' ring grooves.
2. The blank material AA5083 is placed over the bottom die which is guided by guide pins.
3. The top die is clamped to the hydraulic press. The top die lowered towards the bottom die which is guided by the guide pins and both the dies were clamped together with the hydraulic cylinder.
4. High fluid pressure fluid is created by the hand pump for hydroforming process. The process is repeated until the specimen is formed completely.

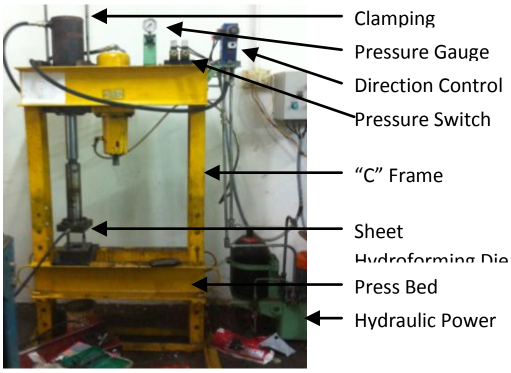

Figure 3 Sheet Hydroforming Experimental Setup

Finite Element Model and Geometry of hydroforming

The finite element models were created using the ABAQUS/CAE preprocessor, which is used to study the hydroforming process for the parent material at room temperature. The stress strain curve obtained from the blank material, which are the inputs for the material properties of the blank. Material properties like elastic property, that is, the Young's Modulus and Poisson's ratio are given as input. The blank as a dependent part and die assembled in the assembly section. In the step section, the static general type are created, and the actual time period, of the experimental data are provided with the initial, minimum and maximum time period, with a number of incrementation. Field outputs are created, such as stress, strain, displacement etc, for the entire blank. The parent material blank is meshed with the element CPS4R type, (Plane Stress family, Four noded bilinear element, reduced integration), with quadratic element shape and linear geometry.

Results and Discussion

The sheet hydroforming experiments have been conducted for various pressures and time to determine the optimum pressure for forming. The experiments have been conducted initially with trial and error method for a constant pressure of 6 MPa and 8 MPa for a time period of 100 and 120 seconds. The details of the experiments results have been given in Table 1.

Table 5.1 Sheet Hydroforming Experimental Results

Experiment	Clamping Pressure (MPa)	Forming Pressure (MPa)	Forming Time (s)	Forming Height (mm)	Rema88rk
Trial 1	5	6	120	10	"O" Ring got Misplaced. Component Failed at two edge.
Trial 2	9	8	100	11.5	
Exp. 1	15	10	40	8	The contact area of the blank was reduced in the top die. Component Failed at one edge.
Exp. 2	15	10	60	8.5	Component not Failed
Exp. 3	15	10	80	11.5	Component Failed at one edge.
Exp. 4	15	15	60	14	Component Failed at one edge.
Exp. 5	15	15	65	14.5	Component Failed at one edge.

The Figure 5 (a-g) shows the sheet hydroforming specimens obtained from trail and error experimentation.

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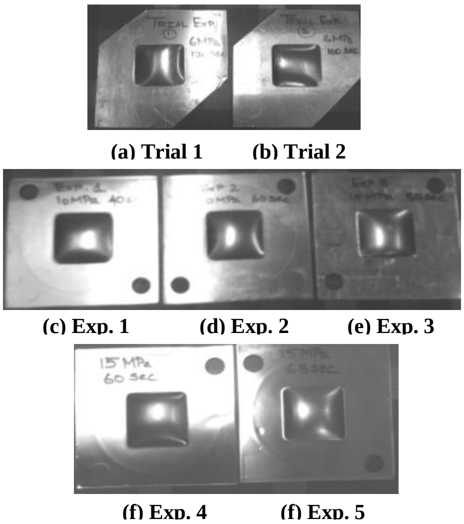

Figure 5 (a-f) Sheet Hydroforming Specimens

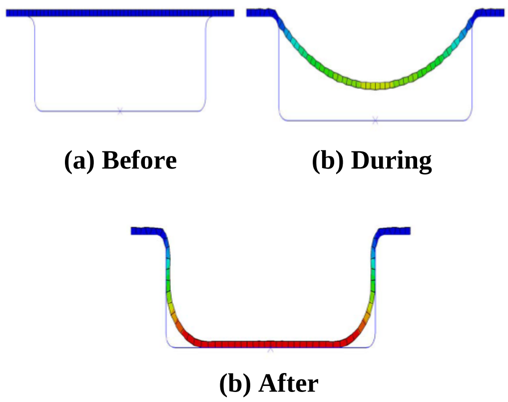

Figure 6 (a-c) Various Stages of Sheet Hydroforming in FEA

The finite element simulation at various stages of hydroforming is shown in Figure 6 (a-c). The thickness distribution obtained after sheet hydroforming form the finite element modeling has been shown in Figure 7.

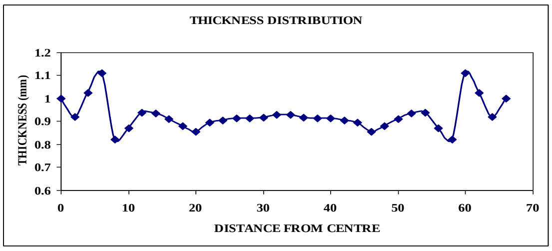

Figure 7 Thickness distribution after Sheet Hydroforming Process

The thickness distribution at the corner of the sheet is well reduced and it is in the range of 0.7 to 0.8 mm. Similarly the thickness at the centre of the sheet is in the range of 0.85 to 0.96 mm. The thickness at the clamped edge is in the range of 1 to 1.1 mm. The stress distribution and displacement obtained after sheet hydroforming form the finite element modeling has been shown in Figure (a-b) 8. The stress distribution obtained after sheet hydroforming form the finite element modeling has been shown in Figure 9.

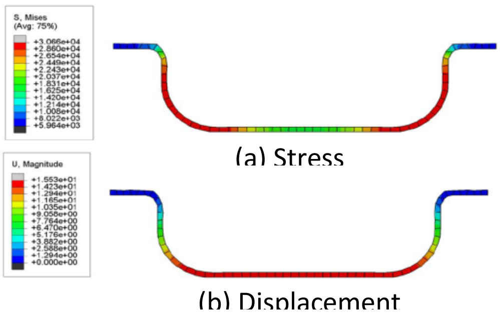

Figure 8 Stress Distribution and Displacement

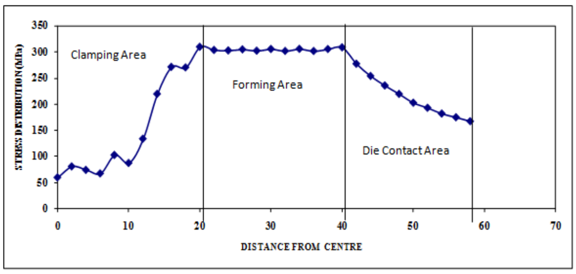

Figure 9 Stress Distribution after Sheet Hydroforming Process

3. CONCLUSION

The sheet hydroforming has been performed for the AA5083 alloy for a thickness of 1mm. The finite element modeling has been performed for the same and following conclusions has been drawn from the study.

1. The sheet hydroforming process has been thoroughly understood from literature survey
2. Aluminium Alloy 5083 has been selected as blank material for sheet hydroforming process
3. Stepped die experimental setup has been modeled and fabricated for sheet hydroforming process
4. From the sheet hydroforming experimental results, a maximum forming height of 14.5 mm was achieved for a clamping pressure of 15 MPa and forming pressure of 15 MPa with forming time of 65 seconds.
5. Thickness distribution and stress distribution has been determined from the finite element model
6. To perform the finite element model and compare with the experimental results.

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