Numerical and Experimental Study of the hydroforming process for forming the spherical parts

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Abstract - ***One of the processes ofsheet metal formingdefined as Hydromechanical deep drawing. In this paper, changing the minimum thickness of the sheetin the hydro-mechanical deep drawing process is reviewedexperimentally and numerically.For this purpose, the hemispherical parts in the laboratory process are used.Numerical ABAQUS softwareis used in order to solve the numerical of the hydro mechanical deep drawing process of hemispherical parts.Coefficients of friction between the punch, sheet and clamp and fluid pressure on the curve of elasticity and thickness change is analysed completely. The sheet shrinkage in the flange area is also examined. In order to confirm the results of finite element simulation a studyconducted with laboratory equipmentand the results were compared.It was noted that no wrinkling and thinning parts were made in the flange.***

Key Words: *Hydroforming forming, deep drawing, parts hemispherical, numerical ABAQUS*

1. INTRODUCTION

Sheet metal formingand causing plastic deformation of the sheet is to produce adesired piece of geometry. The technology in the production of components used in various industries is including the automotive and aerospace industries. Various processes occurs such as deep drawing, expansion, bending, machining for forming plates, which they were used to produce pieces, depending on factors such as work piece geometry, material of the sheetand volume of the deformation and so on. There are limitations on conversion processes andsheet production that necessitatea suitableproduction of the piece. Because the processes havedrawing nature, instability in stretching and tearing is animportant limiting factor in conversion processes.

Folding sheets caused by compressive tensions in parts of the piece, spring back and thickness non-uniformity distribution are among the other defects that are caused in these processes.

Basically, fewer restrictions on the sheetwork process, costs reduction and increaseof theflexibility are among the things that have always been favoured in designing and carrying out these processes. This problem is enhanced by increasing use of lightweight high-strength alloys that make the conversion process facedwith problems and further restrictions and the need to produce various parts with complex shapes is enhanced.

Baratamarkvs [1] has studied the experimental and theoretical analysis of asymmetric forms with ABAQUS software and the effect of friction coefficient. Meryra and FEROON [2] investigated tearing in the formation of spherical parts using numerical and experimental analysis. Abdullah Shaaban [3] has been examined numerically strain rate effect on hydroforming parts of the spherical shape. Yoshida and Katayama [4] studied formation of spherical parts with high strength sheet numerically. Chrome and Etheridge [5] investigatedspherical copper parts by using the finite element method with changing the shape in several stages, with thedistribution of loading pressure.

Dailami and colleagues [6], by numerical simulation of hydromechanical deep drawing process and experiments, studied the effect of factors such as pre-bulge pressure,the bulge height and thickness distribution over the chamber pressure in the cylindrical parts.

The most important parameters in the process of thinning and thickening in hydromechanical deep drawing for aconstant draw ratio including chamber pressure, pre-bulge pressure, pre-bulge height and the distance between the plate and the clamp. The purpose of this paper is to analyze hydromechanical deep drawing process numerically and experimentally, which in particular, the spherical parts have been examined. The impact of changes in chamber pressure, pre-bulge pressureand height of the tablet and punch on thedistribution of the thickness was studied.Abaqus software is usedfor the numerical solution.The study was also performed to designing laboratory equipment process in order to verify finite element simulation. Comparing experimental and numerical results show good agreement.

2. Hydromechanical deep drawing process modeling

For hydro-mechanical deep drawing process modellingnumerical Abaqus software is used. Explicit solutions are used for this type of solution. In the simulation in order to apply the effect of fluidpressure, shaping of the pressure is used with the surface uniform distribution .Because of the time consuming process of solving the problem without sacrificing a whole, and to save computation time, total time taken to form was 11/0 seconds. As can be seen in Figure 1, the pressure changes in the process for forming and pre-bulge are linear.

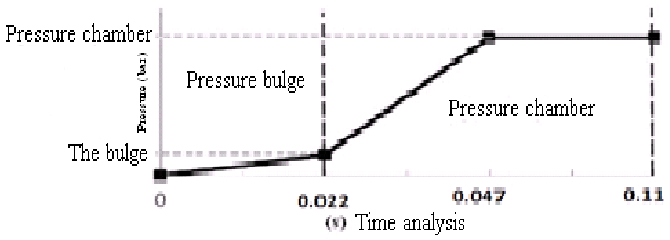

Figure - 1: The chamber pressure changes during the process

The material used is ST12 with the properties in Table 1.

Table-1: material properties and process parameters

size	characteristics (unit)
Low-carbon steel St-12	Material
1	Thickness (mm)
294	Yield strength (MPa)
401	The ultimate stress (MPa)
7.8	Density (g / cm3)
515	Coefficient of strength(MPa)
0.22	The strain hardening
0.3	Poisson's ratio
210	Modulus of elasticity (GPa)
60	Mandrel height (mm)
25	Radius mandrel (mm)
30×30	Matrix hole dimensions (mm × mm)

Mould, punch and plumb are modelled as rigid. The definition of the friction surfaces in the process of deep drawing is one of the most critical steps in the simulation process. The thickness of the pieces has to be modelled perfectly. Changing the Thickness has the most important effect inhaving contact between the surface of the sheet with the plumb andmatrix. Based on the experiments the most ideal coefficient of friction was considered. Coefficient of friction between the sheet and the plumb is 05 / 0 andbetween the punch and matrixis 1/0 and Columbus friction model is considered. The dimension of the punch and simulated model and the frictional conditions were shown in Figure 2. For spherical sections circular discs is preferred. Discs with original thickness of 1mmwere modelledby shell elementsof S4R.

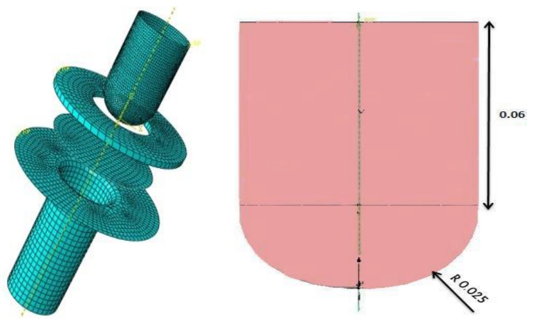

Figure - 2: a) the size of the punch b) simulation model

Table-2: Coefficients of friction between the tablet and tools

0/05	The coefficient of friction at the contact surface between the sheet and plumb	
0/1	The coefficient of friction at the contact surface between the sheet and punch	
0/05	The coefficient of friction at the contact surface between the plate and mold	

3. Drawing ratio

In The circular pieces,the ratio of sheet diameter to punch diameterof draw ratio is defined as the ratio of elasticity.

$$B = \frac{D_O}{D_m}$$

4. The impact of the pressure chamber

The force of forming includes the primary pressure of chamber and the ultimate pressure. The first step is sheetbuilding;total degrees of freedom for punch, matrix and plumbwere taken. In the first phase, the fluid pressure gradually applied to the sheet to prevent the dynamic effects. Fluid pressure increases linearly in bulging stage in order toapply the primary pressure chamber. By applying the pressure at the end of this stage, the top of the sheet will be tangent to the punch.

In the second phase,degrees of freedom of punch were moved to the matrix hole .punch moves to the matrix with a maximum speed mm / s5. At this stage, with the moves of punch into the chamber pressure gradually increased to reach the pressure of relief valve setting. Various scenarios have been considered for the fluid pressure changes to determine the impact on the chamber pressure on the maximum thinning and different simulations for final chamber pressure Bar 500 and 450..... 100 and 50 were performed. In all phasespre-bulge pressure was constant and wasBar20. As shown in figure4,for the ratio draw of 2.2, with the increase chamber pressure, thinning at the thinnest point, at the bottom,increasedand also in flangearea thickness increased with increasing pressure chamber. But considering the increaseof the pressure chamber,producedpiecehas less shrinkage in the flange area... Figure 5 shows shrinkage in the flange with the chamber pressure of Bar350 .in figure 3 for the draw ratio of 2.2 at a pressure of 3 Bar 400, the piecewas torn, but in the other pressuresthe piece has normal production.

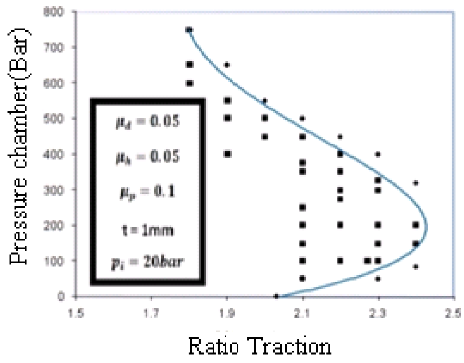

Figure-3: successful Stretch work area for the process

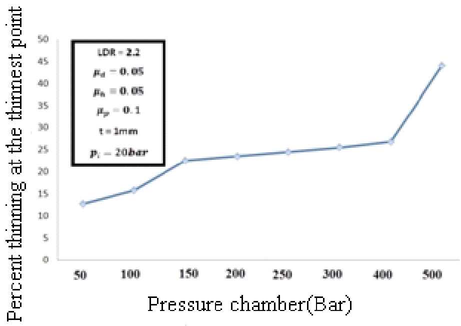

Figure-4: thinning in thechamber pressure for drawing ratio 2/2

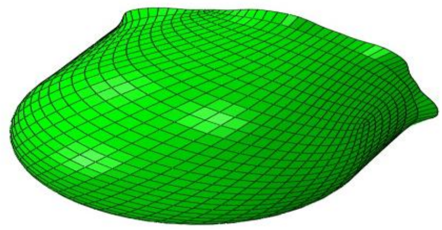

Figure-5: wrinkles in the chamber pressure Bar350

5. Thickness distribution in three differentareas of discs in different pressures

As seen in Figure 6 changes in thickness in the area of the discs after deformation can be seen. In the area there is anobvious thinning and we have theflange area which we have increase of thickness. Thinnest position is at the bottom that this is a distinction betweenTraditional deep drawing and hydromechanical deep drawingthat thinning of the walls is moved to the radius of the punch.

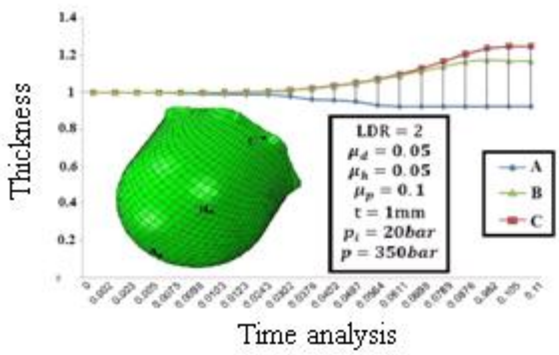

Figure-6: Change the thickness of the three regions of the flanges at the pressure of Bar350

ChamberPressure influence on the distribution of thickness in three floors, walls and flanges in the final piece in three pressure Bar350,450,550 can be seen in figure 7. The horizontal axis shows Time analysis between points and the initialcentredisc. According to the figure in the low pressure thickness changes happen within radius of punch which are less than high pressureand the more we close to the flung we have increase of thickness.

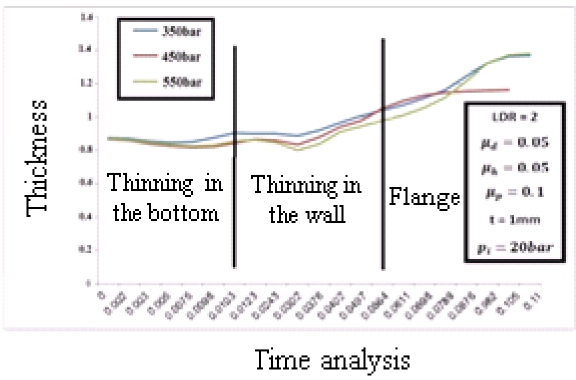

Figure-7: thinning at different pressures in the 3 areaof the discs for aratio ofdrawing of 2

6. The impact of pre-bulge pressure

Pre-bulgeheight, the distance between the disc and the punch is at the first of formation. With the increase of pre-bulge height, primary tension of sheet is increasing as well. The impact of different heights of pre-bulgecan be seen in Figure 8. For each pressure chamber and constant pre-bulge pressure there is an optimum amount for pre bulge height. According to Figure 9 pre bulge pressure of Bar 35, the height of less than mm 5 is not suitable due to less initialstretching and we have more thinning.

Heights more than 5 bars have more thinning due to great distance and pliable plate to the punch the initial non-formation. So the best heightis 5mm, and had the lowest reduction.

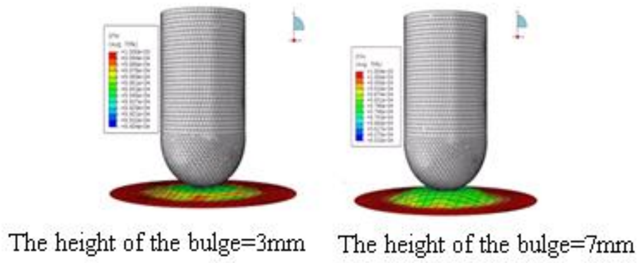

Figure-8: the effect of different pre-bulge heights

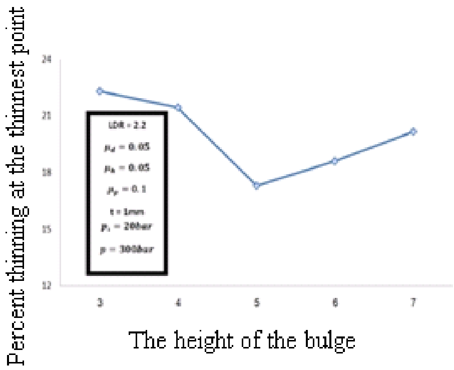

Figure-9: thinning changes in different pre-bulge heights

7. Experimental Study

In order to confirm a numerical simulation,the laboratory system of hydromechanical process was designed and built. This system is shown in Figure 10. The two relief valve 1 and 2, respectively, control the pre-bulge pressure and maximum pressure of the chamber. In pre bulge phase oilenters to the chamber with pump 3.The pressure in the chamber increases as well. In The formation processwith the moves of the punch into the chamber, oil pressureincreases greatly.

And one-way valve prevents the oil to be returned and let the oil discharges the oil pump track. After the pressure reaches to its standard, operation continues at a constant pressure. When the thickness is of the sheet is 1 mm, the distance between the sheet and the form is 1 mm. the condition of Friction and material properties is like the simulation.by controlling Thepressure chamber by two relief valve 1 and 2 the deep drawing process was conducted under different drawing ratios and the distribution of thickness and work area was designated.

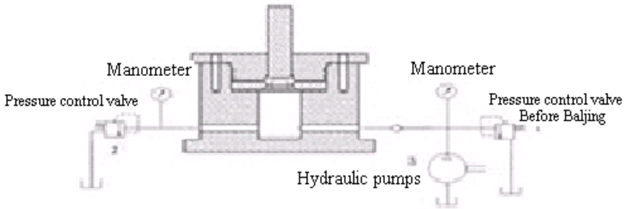

Figure-10: experimental test system of HDD process

8. Comparing thinning and empiricalsimulation results

The effect of thickness distribution in floors, walls and flung with the pressure of pre-bulge bar20can be seen in Figure 11 in order to achieve a thickness of the piece experimentally, at first the piece was created then this piece was cut with the Wire Cut device in half and one thin layer of 2 or 3 mm was separated bywire cutdevice and measured thickness in floor, wall and flung by a video profile .we will compare them with simulation process. The horizontal axis, time analysis and vertical axis of thinning was displayedin three areas.

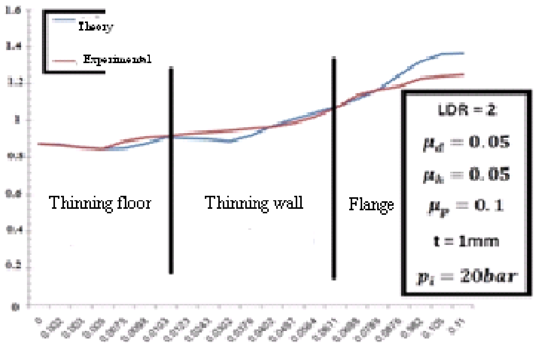

Figure-11:simulation and experimental thinning for the draw ratio

Figure-12: Examples cut by wire cut

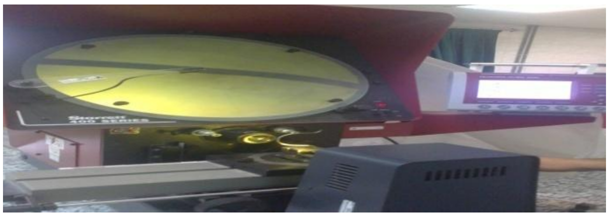

Figure-13: measuring the sample using video profile

According to the prediction of simulation results rupture in the traditional deep drawing occurs within punch radius whilein hydromechanical deep drawing there is the probability of rupturein the contact surface with the wall due to fluid pressure and friction in contact area of sheet and punch wall.

Figure 14 shows the tearing on the parts obtained from experimental work under two traditional and hydromechanical deep drawing processes that is confirming the simulation results.

Figure-14: tearing sample a) traditional deep draw b) hydromechanical deep draw

Figure-15: the appropriate produced piece using hydromechanical deep drawing process

9. Conclusion

In this paper, the numerical simulation of hydromechanical deep drawing process was done on square pieces. Here are the results:

1.With the increase of chamberpressure, thinning increases too, but with high pressure we have less shrinkage in the flange area of the produced piece.

2. In the pre-bulge low pressure, the disc will not be able to stick with the punch and cannot be like the shape of the punch and as a result the thinning increases.

3. By increasing the thickness of the sheet, there is a larger working area and the ratio of optimum drawing increases as well.The ratio of optimum drawing occurs in higher chamber pressures.

4. For each chamber pressure and constant pre-bulge pressure there is an optimal value for the height of the pre-bulge that by increasing or decreasing the height of thinning becomes more.

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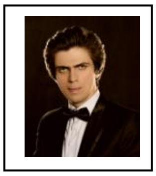

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