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SMALL DIAMETER HYDROSTATIC FORMING OF Al 5754 and Al 1050 SHEETS

Elmas AŞKAR*, İbrahim KADI*, Mustafa YAŞAR**
*Karabuk University, Technical Education Faculty, Karabuk

Abstract

Hydro forming is a forming method in which metal sheet material is formed in a closed pot via fluid atmosphere (water, viscous polymeric material). It is preferred because the forming process ends with better results, there are less wrinkles during forming and forming process can be done easily. In this study, it is aimed to form aluminum sheets on a small scale with hydrostatic pressure got from mold. The experiment setup has generated having designed a forming pot that will be enduring to necessary pressure and that will prevent leaking of compressed fluid. Female mold of 38 mm diameter is used in the study. Experiment samples have been chosen as Al 5754 with 68 mm in diameter 0,5 mm thickness and Al 1050 0,6 mm thickness sheet material. The theoretical model of the forming has been formed having used ANSYS/Ls-Dyna software and model has been analyzed. Comparison of experimental and theoretical results thickness change and forming amounts according to material models have been carried out.

Key words: Forming with fluid, Finite elements method, Al 5754, Al 1050

1. Introduction

Hydraulic forming appeared for the first time in 1890s but it is a manufacturing method that gained the main improvement after II. World War [1]. Hydraulic forming is a process in which high pressured fluid is sent into a pipe or sent onto a sheet and so pipe/sheet surfaces expand according to geometry of the mold and as a result it takes the desired form. Hydraulic forming is a kind of flexible forming technology. Working principle of hydraulic forming of sheet materials are the same with drafting molds. But; during hydraulic forming process, forming is done by putting fluid into mold space instead of mold [2].

In traditional methods, it is not possible to get desired bend in one level without deformation. Also, it is necessary to consider a lot of parameters such as elastic/plastic behavior of sheets, friction and abrasion generated between sheet and kit , heat generated during the forming, expansion of the heat, mechanical control and design of the pressure. Production with mold and punch in conventional methods is more difficult and more expensive and also takes much more time. Hydro forming becomes more attractive because it is hard even impossible to provide necessary pressure in order to form huge parts by conventional methods whereas it is possible to form complex parts and the production process takes shorter time than conventional methods. Although usage areas of this method is relatively limited, it is preferred since forming process ends with better results, there are less wrinkles during forming and the forming is done more easily [3].

Hydraulic forming has 3 different elements as hydraulic, tube and hydro mechanic forming [4]. When we examine the studies in literature, is seen that there are studies mostly about tube forming. Forming of complex sheet materials are generally done by hydro mechanic deep draft (HDD) technology. Zhang et al. realized deep draft process using explicit finite element method with various method parameters by hydro mechanic deep draft technology for parabolic aluminum sheet material [5-6]. Clift et al. [7], Hartley et al. [8], showed that they delayed start of micro fractures in sheet metals deep draft studies by means of hydro static pressure which they used and also even in case of generation of fractures they showed that they prevented their spread. The success in these studies lies beneath the delay of starting of fractures that arise on sheets by means of using hydro static pressure. Kim's et al., they compared

Corresponded Author; easkar@hotmail.com

hydro mechanic sheet forming and traditional draft process. They used explicit finite element code during this comparison. They found that hydro mechanic forming needed twice much more time than traditional drafting method and this was because of pre-forming and calibrations periods. Despite of this fact, they confirmed that the part could be manufactured smoother and without fault comparing to traditional method. They showed that friction coefficient between mold and sheet material in hydro forming was much lowers that traditional method because of the effect of fluid [9].

Forming Al and its alloys at small scale were examined theoretically and experimentally using punch less hydro mechanic method among hydraulic forming methods. Considering the studies in literature, it is seen that female molds or male punches in 100 mm and upper are used generally in hydraulic forming. In this study, it is also aimed to examine usability of hydro forming at small scales. Referring to past studies, desired draft deepness was achieved in forming big scale metallic sheets and they did not face any problems. Because of this reason, it is aimed to study drafting deepness with suitable fluid pressure and pot pres force in forming small scale aluminum.

2. Material and Method

2. 1. Material

International regulations introduced first and the most important precaution as the necessity of decreasing the weight of vehicles in automotive sector. Aluminum and its alloys are the most suitable material for this aim. Al 5754 that is 68 mm in diameter and 0.5 thick and Al 1050 that is 0.6 thick sheet materials were used in this study.

2. 2. Method

At the beginning of forming process, sheet is put into metal mold and then the mold is closed. In the mold, pressured oil that will realize forming is applied to sheet metal. Compressed oil is applied to sheet metal and it is formed as taking the shape of mold interior shape (Figure 1).

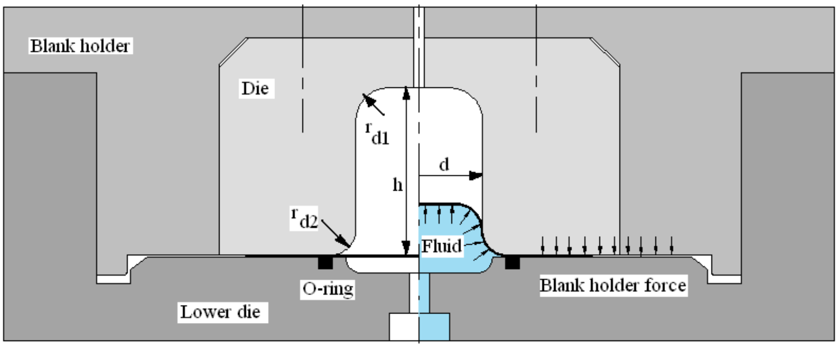


Figure 1. The hydro forming die.

Maximum draft height is given as h, first diameter of the sheet to be drafted is given as D, mold geometry diameter is given as d, mold curves are given r_{d1} and r_{d2} in the system in Table 1.

Table 1. Parameter sizes of designed mold.

Parameters	Max h (mm)	D (mm)	d (mm)	r_{d1} (mm)	r_{d2} (mm)
	50	68	38	10	7.5

In this system, press of Hidroliksan brand mark of 30 tones was used. Bottom mold, press plate, nucleus where the forming will take place, imperviousness elements, binding elements and hydraulic oil since female mold was not used in forming were used in the system. At the beginning of forming process, sheet was put into metal mold and then the mold was closed. In the mold, pressured oil that would realize forming was applied to sheet metal. Compressed oil was applied to sheet metal and it was formed as taking the shape of mold interior shape. Air discharge holes were put on the mold in order to discharge the air that arose by filling the fluid in the system. Hydro forming system is shown in figure 2.

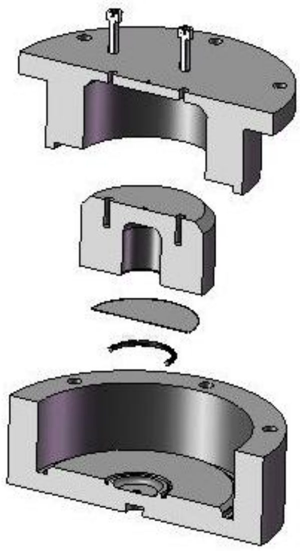


Figure 2. Hydraulic forming model.

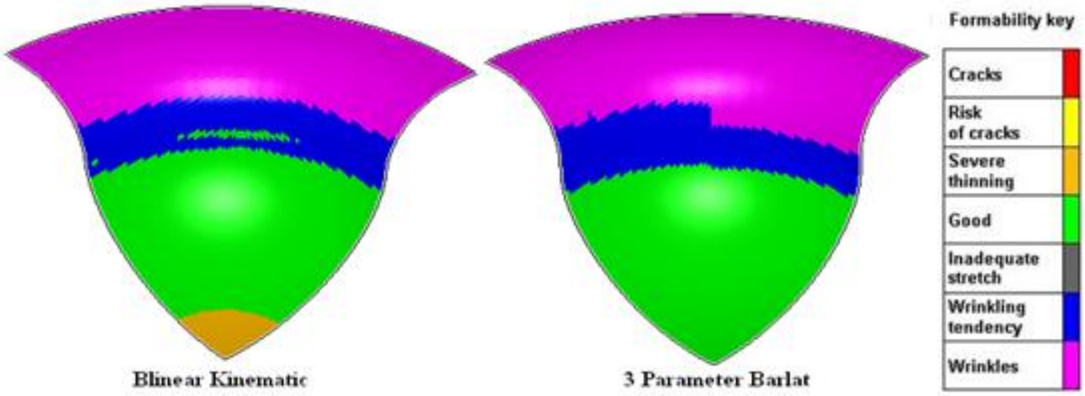
System was designed as closed system since it was hydraulic fluid forming. The system was formed of two molds as bottom and upper molds that were crowded since imperviousness was important problem in pressured fluid forming. The nucleus put into upper mold was designed as modular in order to make aluminum material take the shape of mold by pressing it with hydraulic fluid. 2 screws of M12 that was fixed onto press head in the system by binding upper mold in order to make press plate move up and down and press over aluminum sheet easily. O-ring of 3.5 mm in diameter was used in the system in order to prevent leaking of hydraulic oil during forming process. Hydraulic oil was given into the system by manual pump of 700 bar pressure.

3. Experimental Results

Pot press force and effect of fluid pressure forming for both materials were examined depending on forming depth and thickness change. Experimental studies were continued as increasing pot press force in MPa one each. Pot press force and fluid pressure force values were taken as a basis for execution of experimental studies.

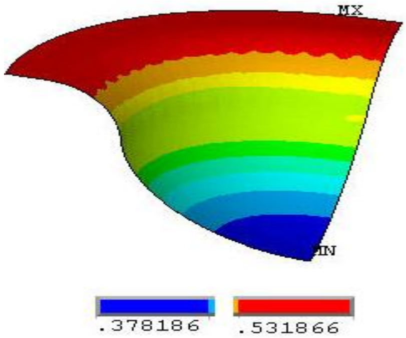
3.1. Al 5754

Aluminum material was provided to take the shape of nucleus mold under different pressures. Suitable fluid pressure was determined as constant 7.5 MPa for Al 5754. In experimental studies of Al 5754 sheet the most suitable pot press force was calculated as constant 8 MPa. Forming limits and thickness changes of material models belonging to Al 5754 are shown in figure 3.



(a)

(b)



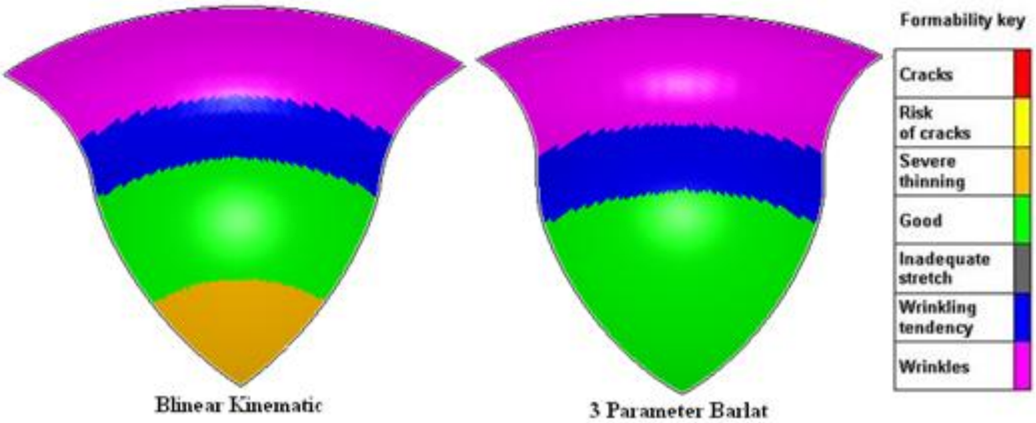
(c)

Figure 3. Al 5754 sheet achieved at the end of experimental results with 7.5 MPa fluid pressure (a) forming limits, (b) experiment photograph, (c) thickness change.

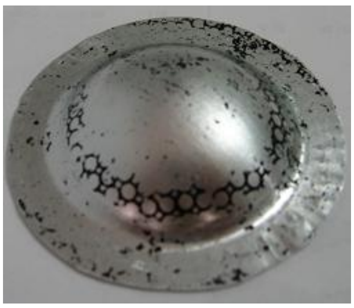
As a result of theoretical forming realized in Ansys programme, regular change occurred in material thickness. Thickness change of material occurred near center in experimental forming and fractures occurred in some experiments.

3.2. Al 1050

Most suitable pot press force of Al 1050 sheet in experimental studies was calculated as constant 4 MPa. Suitable fluid pressure for Al 1050 was determined as constant 4 MPa in experiments. Forming limits and thickness change of material models belonging to Al 1050 were shown in figure 4.



(a)



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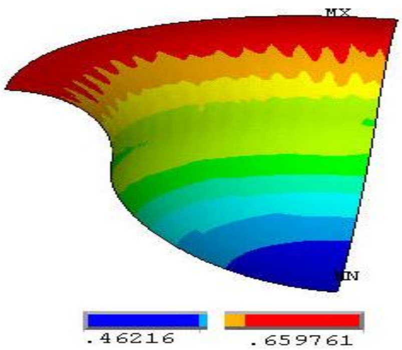

(c)

Figure 3. Al 1050 sheet achieved at the end of experimental results with 7.5 MPa fluid pressure (a) forming limits, (b) experiment photograph, (c) thickness change.

While there was a regular change in material thickness at the end of the theoretical forming, rises and falls were seen on some points in experimental forming and some fractures appeared in some experiments.

3. 3. Theoretical Model

Theoretical model was modeled on the basis of ¼ sections since theoretical model is a symmetric part. THİN SHELL 163 was defined as element type; Belytschko-Wong was selected as element formulation. In theoretical analysis Bilinear Kinematic and 3 Parameter Barlat Anisotropic material models defining was done for Al 1050 and Al 5754 sheet material. In order to examine deformations in Al 1050 and 5754 sheet materials; press plate and mold Rijid and all rotations were limited. Surface to surface contact model was defined between sheet-mold and sheet- press plate in the parts. Mesh (net) as shown in Picture 5 were built for mold elements according to used element type and material properties.

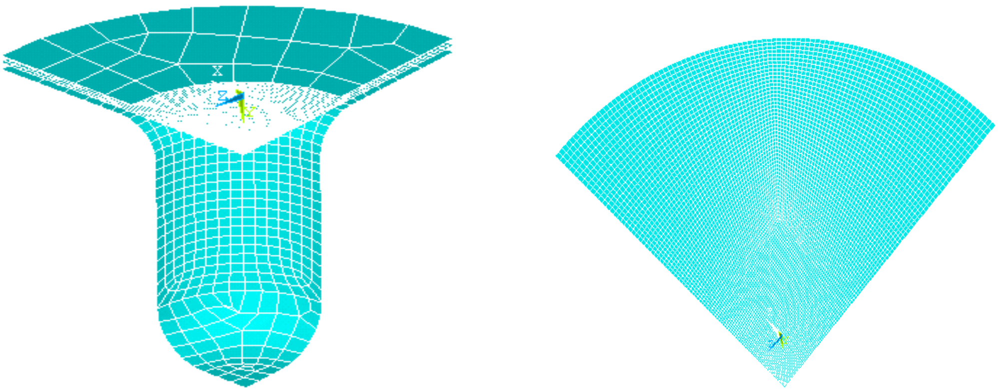

Figure 5. Theoretical model formed in ANSYS.

Mechanical properties of Al materials are given in Table 3-4.

Table 3. Mechanical properties of Al 5754 sheet material.

Mechanical properties	**Al 5754**
Density, kg/mm^3	2,643x10^{-3}
Yield Strength, MPa	100
Young Modulus, MPa	71000
Poisson Ratio	0,33
Tangent Modulus, MPa	416
$\mathbf{r_0}$ [10-11]	0,705
$\mathbf{r_{45}}$ [10-11]	0,765
$\mathbf{r_{90}}$ [10-11]	0,906

Tablo 4. Mechanical properties of Al 1050 sheet material.

Mechanical properties	**Al 1050**
Density, kg/mm^3	2,705x10^{-3}
Yield Strength, MPa	28
Young Modulus, MPa	69000
Poisson Ratio	0,33
Tangent Modulus, MPa	84
$\mathbf{r_0}$ [10-11]	0,67
$\mathbf{r_{45}}$ [10-11]	0,45
$\mathbf{r_{90}}$ [10-11]	0,73

4. Results

In this study, forming was enabled via using pressed fluid instead of using punch that is used in traditional deep drafting method. Forming of two different aluminum sheets was examined in this experimental study in which designed as closed system. Maximum draft height, thickness changes in material after forming was studied. Most suitable parameters were tried to be found using ANSYS-LS DYNA software, so execution of the experiments were facilitated. Forming of Al 5754 sheet material of 0.5 mm thickness was enabled as 8 MPa pot press force, 7.5 MPa fluid pressure and 16 mm draft depth taking previous values before detaching of material. There were no hanging and wrinkles in experiments. Forming of Al 1050 sheet material of 0.6 mm thickness was enabled as 4 MPa pot press force, 4 MPa fluid pressure and 19 mm draft depth. It was seen that 3 Parameter Barlat Anisotropic material model gave positive results for both sheet materials. Comparing compatibility of results of theoretic model and experimental results, it was observed that they had near results.

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