Influence of Process Parameters and Viscosity on Radial Stresses of Magnesium Lithium Alloys in Fluid Assisted Deep Drawing Process

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Abstract

Hydro-forming process has become an emerging technology in recent years to reduce the weight of automotive body structure and to minimize the number of process steps. In fluid assisted deep drawing process, hydraulic pressure in radial direction on the periphery of the blank is obtained through the punch movement within the fluid chamber. Viscosity phenomena is applied for analyzing the radial stresses which are produced due to the punch force applied on the blank and the shear stresses acted by viscous fluid on both sides of the blank. In the present work, Magnesium Lithium alloys LA 141, LA91, LAZ933 and fluids such as castor oil, olive oil and heavy machine oil are used to investigate the radial stresses analytically, in terms of process parameters such as punch radius, punch corner radius, clearance, punch force etc. The influence of viscosity, process parameters and fluid pressure on radial stresses is thoroughly investigated. Radial stresses are determined for Magnesium Lithium alloys at different punch radii and constant thickness at different blank radial distances with three fluid media. The authors observed that for the alloys considered, the radial stresses increase, with a decrease in the radial distance of job axis and also with a decrease in viscosity of oils. The research also shows that, among the Magnesium Lithium alloys high radial stresses are obtained for LAZ933 alloy in olive oil and least radial stresses are obtained for LA91 alloy in castor oil medium. These radial stresses are used to get good results of formability for Magnesium Lithium alloys which can be seen as a new revolution in automotive sector and also play a vital role in environmental conservation.

Keywords: Hydro-forming deep drawing, Finite element Method, Radial stresses, Magnesium -Lithium alloys

1. INTRODUCTION

One of the metal forming process is “deep drawing” which is introduced in a wide range of industrial applications .Out of many innovative techniques Hydro forming deep drawing process plays a key role in producing light-weight materials with complex shapes. Numerous enhancements such as improving the material formability with uniform cup wall thickness, reduction of friction force and improvement in limiting drawing ratio [1,2] can be seen in this process. Finally, sheet metal parts can be formed with higher dimensional accuracy and better surface quality.

1.1 Sheet Metal Forming

Sheet-metal forming processes are technically the most important metal working processes. Among the various sheet-metal forming processes, hydro forming is one of the non-traditional ones. This process is also called hydro mechanical forming, hydraulic forming or hydro punch forming. In hydro forming process, liquid is used as the medium of energy transfer to form the work piece. Hydro forming as shown in Fig. 1 can be segregated as sheet hydro forming and tubular hydro forming according to blanks used.

Products made by these processes include a large variety of shapes and sizes which are used in automobile bodies, aircraft panels, appliance bodies, kitchen utensils and beverage cans [3].Sheet hydroforming (SHF) is classified into sheet hydroforming with a punch (SHF-P) and sheet hydroforming with a die (SHF-D) depending on whether a punch or a die is used to form the blank. Fig (2) is an illustrative of Sheet hydro forming process. It is an alternative to drawing process where either punch or die is replaced by hydraulic medium, which generates the pressure and forms the part. Hosseinzade M [4] explains the reduction in tooling cost due to replacement of punch or die with fluid pressure.

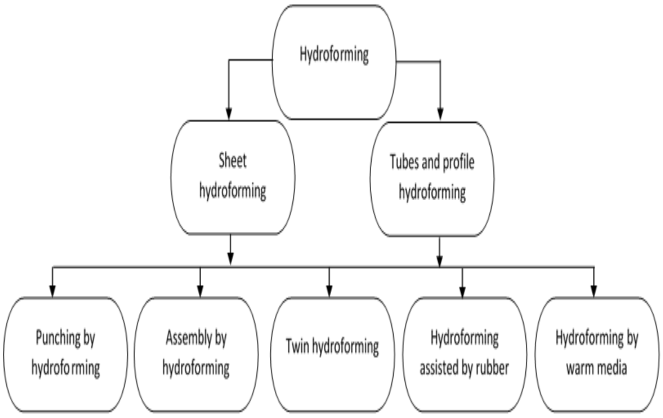

Fig .1 Classification of hydroforming

The process starts by positioning the blank over the rubber diaphragm. The blank holder is then positioned on top of the blank to prevent it from moving upward. A liquid is pumped into the cavity and at the last stage, the punch moves down to form the blank. The hydraulic pressure inside the container plays an important role throughout the drawing. A pressure valve is generally used to control and regulate the liquid pressure inside the container. After the component is formed, the punch moves upward and the liquid in the container is withdrawn. The blank holder can now be removed and the deep drawn cup can be collected from the press machine.

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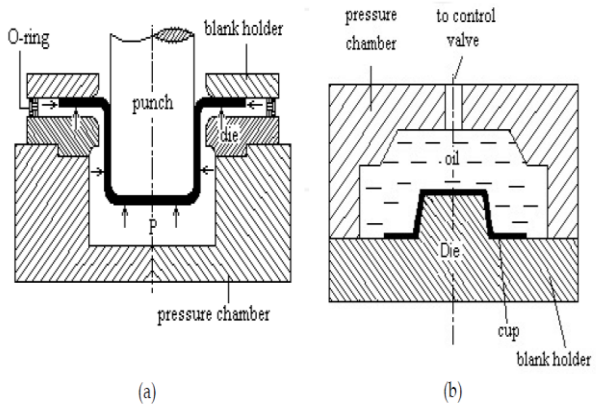

Fig.2 .a) SHF-with Punch b) SHF-with Die

1.2 Materials

The lightest of all the engineering metals is Magnesium, with density of 1.74 g/cm3 [5]. It is 35% lighter than aluminium (2.7 g/cm3) and over four times lighter than steel (7.86 g/cm3). Increase of magnesium alloys in transport application is due to mass reduction which leads to low fuel consumption. Alloying Mg with the lightest metal element, lithium, whose density is 0.534 gcm^{-3} yields a magnesium–lithium (Mg–Li) alloy which has only half the density of Aluminium alloys. Technology emergent areas such as aerospace and aircraft structures which are searching for ultra-light weight components are benefited from Mg-Li alloy. The mechanical properties of Mg-Li alloys are given in Table 1.

Table.1 Material Properties of Magnesium Lithium Alloys

Alloy	Nominal composition weight percent (balance Mg)	Density g/cm^3	Yield strength (MPa)
LA141	14Li-1Al	1.35	117
LA91	9Li-1Al	1.45	114
LAZ933	9Li-3Al-3Zn	1.56	144

2. METHODOLOGY

The pressure of fluid acting on the outer edge of the work-piece creates a radial stress which draws higher drawing ratio cups before the cup wall reaches its ultimate tensile strength. The maximum draw stress obtained at punch nose radius is transferred to die radius due to fluid pressure which effects the frictional stress distribution. Thus, the combination of the radial stress in the periphery of the flange area and frictional stress in the cup wall, together with the absence of contact in the die radius region cause the higher drawing ratio achievable in hydro forming deep drawing. The radius at the intersection between the flange and the cup wall can be controlled by changing the pressure inside the container. This is because of the hydraulic pressure pushing the rubber to the blank when it forms around the punch and the radial stress acting on the periphery of the flange. The combination of these two stresses decreases the tension on the cup wall and postpones failure of the cup. However, if the hydraulic pressure is too high, it increases the frictional resistance between the blank and the blank-holder which will increase the drawing force necessary to form the cup causing the cup to fracture. On the other hand, if the pressure is too low, wrinkling will occur in the flange area. Because of the absence of a rigid die in this process, puckering may also occur at the connecting region between the flange and cup wall due to the lack of sufficient pressure. So, the pressure in the container should be regulated in such a way to keep a balance between these opposing effects [6]. For all the reasons mentioned above, deep drawing using hydro forming technique is considered to be the simplest.

In the current work, the radial stresses are evaluated in terms of process parameters and viscosity of fluid for magnesium lithium alloys and compared with simulation results.

3. THEORETICAL ANALYSIS

Successful deformation of cup is possible by the combination of tensile radial stress and compressive circumferential and thickness wise stresses. Fig. 3 shows the flange part of the component where radial and hoop stresses are acting.

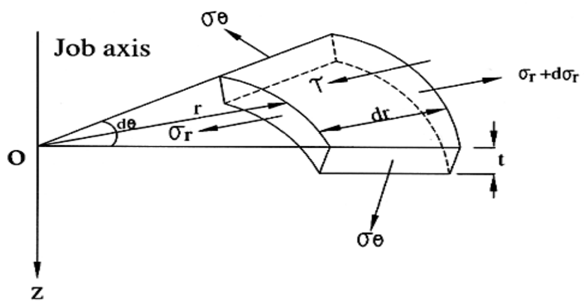

Fig.3 Acting of Stresses on the element during drawing process

The forces acting on the Element in radial direction

$(\sigma_r-\sigma_\theta)dr + rd\sigma_{r=}2\ \tau/t\ r\ dr$ . ... (1)

σ_r ,σ_θ are the two principle stresses, the equation is obtain by using Tresco's yield criteria

$\sigma_r-\sigma_\theta = \sigma_o$ .... (2)

Combining equations (1) and (2)

$\sigma_r = \sigma_o\ ln\ (rj/r)-2\tau/t\ (r_j-r)$ .... (3)

This equation (3) represents distribution of radial stresses in the blank during the fluid assisted deep drawing process. Evaluation of radial stresses in terms of viscosity by replacing $2\ \tau = 4\ \mu u/(h-t)$ in equation (3) we get

$\sigma_r = \sigma_o\ ln\ (r_j/r)$ - 4 µu/(h-t) $[(r_j- r)/t]$ . ... (4)

Equation (4) represents the effect of process parameters and viscosity of fluid on the distribution of radial stresses in the blank during fluid assisted deep drawing process.

4. RESULTS AND DISCUSSIONS

The failure modes such as wrinkling and local thinning of the work pieces during sheet metal forming processes is analysed by using FEM. Gelin and Delassus [7], Yang et al.[8] ,Qin and

Balendra [9] and An and Soni [10] have made some progress in analysis of HDD processes. As shown in figure 4, the finite element code in static analysis is used to simulate the HDD processes of the tapered cylindrical work pieces in the current work.

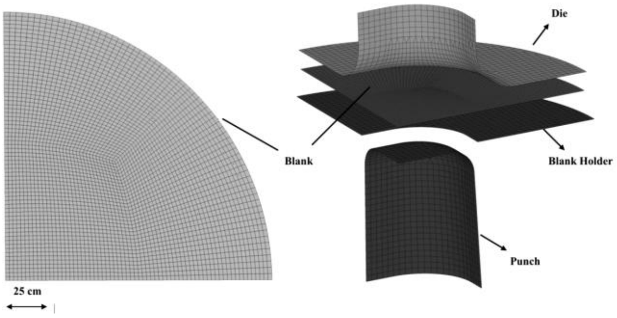

Fig.4 Finite Element Model

Using symmetric condition about one of the axis the component is generated in FEM static structural analysis. One of the blank diameters is simulated by applying the tooling constrains where tool components were treated as rigid bodies. The simulations are carried for different blank radius as 60mm, 70mm, 80mm, under various lubrications.

The distribution of radial stresses of LA91 magnesium lithium alloys at 60mm blank diameter is given in fig (4). In almost all alloys the stresses at punch corner is maximum which indicate more forces are required to deform the material at this location. Figure (5) shows the von-misses stresses for the same alloy at same blank diameter.

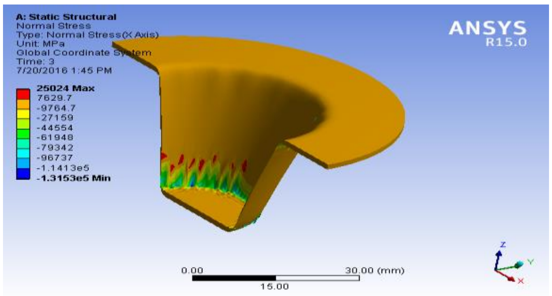

Fig.5 Distribution of Radial Stresses

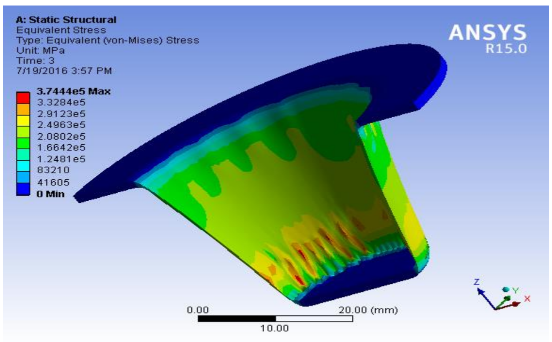

Fig.6.Distribution of Von-Mises Stresses

Figure (6) shows that the stresses decrease with increase in radial distance from the job axis. The percentage of increase in radial stresses of each magnesium lithium alloy within the range of given blank radius and at given thickness is 15%.Figure (7) shows the radial strain effect plays the key role in analysis which indicate strain rate also effected due to punch corner. The same analysis is carried for different alloys at different lubrication which resulted low stresses at lower blank radius in castor oil lubrication.

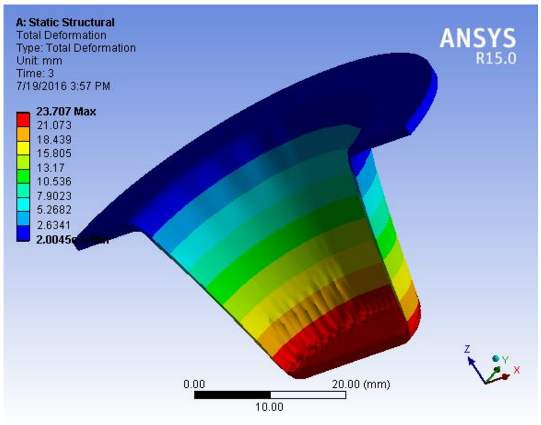

Fig.7. Total Deformation of cup

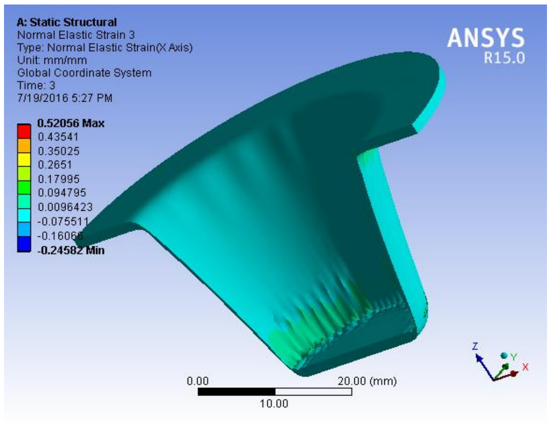

Fig.8. Distribution of radial strain of cup

Table 2 indicates the radial stresses in different magnesium lithium alloys and Fig 8 indicates radial stress distribution along the radial distances. It is observed that the stresses in LA91 are low compared to LA141 and more in LAZ933.

Table.2 Radial Stresses of Magnesium Lithium Alloys

Radial Distance from job axis	LA91 (MPa)	LA141 (MPa)	LAZ933 (MPa)
40	25024	40941	56970
45	7629.7	12405	20889
50	-9764	-9904	-7843
55	-27159	-25165	-20657
60	-44554	-34567	-27493

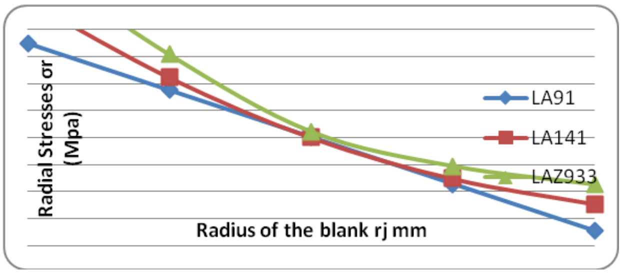

Fig.9 Comparison of magnesium lithium alloys

5. CONCLUSIONS

The radial stresses have been increased with increase in the radius of blank and decreased with increase in the radial distance of the blank from the job axis. This is due to shear stresses and shear forces acting on blank surface during the drawing process. The highest radial stresses have been obtained in LAZ933 and least in LA91. Among the magnesium lithium alloys the order of increase in radial stresses at different radii is found as $\sigma r_{60} < \sigma r_{70} < \sigma r_{80}$. The higher values of radial stresses will give higher forming limits and minimise the drawing time.

NOTATIONS USED

σ_r	Radial stress
σ_θ	Hoop stress
σ_o	Yield stress
r	Blank radius
rj	Radius from job axis
τ	Shear stress
t	Thickness of blank
μ	Co-efficient of viscosity

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