DETERMINATION OF STRESSES AT DIE CORNER IN HYDROFORMING

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ABSTRACT

Hydro forming technology provides an attractive alternative to conventional matched die forming, especially for cost-sensitive, lower volume production and for parts with irregular contours. The hydro forming process performance can be enhanced by using various kinds of liquids. Hydro forming deep drawing process is under consideration into one of the hydro forming process. In this process the methodology for applying the hydraulic pressure on blank periphery in radial direction. It is obtained through the punch movement within the fluid chamber, which is provided in punch and die chambers. These two chambers are connected with the bypass path and it is provided in the die. During the process punch movement within the fluid chamber the pressure is generated in fluid and it is directed through the bypass path to blank periphery, the thick fluid film is created on the upper and lower surfaces of the blank and subsequently reduces frictional resistance and is to reduce tensile stresses acting on the wall of the semi drawn blank. The blank is taking at centre place in between blank holder and die surface with supporting of high pressurized viscous fluid. The radial stresses are produced in the blank in radial direction due to the punch force applied on it. The shear stresses acted by viscous fluid on the both sides of blank, so apply viscosity phenomenon to this analysis. The radial stresses are determined at die corner in radial direction with consideration of castor oil medium, process parameters and study on these stresses.

Keywords : Hydro forming, deep drawing process, radial stress, shear stress

1. INTRODUCTION

The deep drawing process allows manufacturing lighter complex shapes more with increased strength at lower cost compared to more traditional techniques such as stamping, forging, casting or welding. The hydro forming deep drawing process is a one of the sheet metal forming process. In this process the medium is pressurized fluid. This pressurized fluid is used to form different component shapes. In the hydro forming deep drawing process the pressurized fluid serves several purposes are supports the sheet metal from the start to the end of the forming process, thus yielding a better formed part, delays the onset of material failure and reduces the wrinkles formation. The performance of deep drawing process can be enhanced for producing components through using the liquids in the process. The process performance like draw ratio, thickness ratio, ratio of volume to surface area of product, volume to thickness of product, good surface finish, high quality surface, high accuracy in dimensional, no scratches developed on outer side of cup, limiting drawing ratio, deep drawability and formability index are improved and these are obtained in higher levels. The fluid pressure effects on radial, hoop and drawing stresses of blanks in during the process. The various types of fluid forming are Hydroforming process [1-5], hydromechanical deep drawing process[6-8], Aquadraw process [9], hydraulic counter pressure process [10-12].These processes have some differences and some features are common. These principles are utilized for improvement in production of drawing cups with help of hydraulic pressure through conventional methods. In this process the blank is subjected to fluid pressure on its periphery to get high forming limits and also preventing the failure. So there is improvement of deep drawing process for making the cups with utilization of fluid pressure. The contribution of hydraulic pressure to the deep drawing process is positively in several ways. The frictional resistance reduces in the flange due to lubrication of flange and dies radius. Deep drawing is an important process used for producing cups from sheet metal in large quantities. In deep drawing a sheet metal blank is drawn over a die by a radiuses punch [13]. Amongst the advantages of hydraulic pressure assisted deep drawing techniques, increased depth to diameter ratio's and reduces thickness variations of the cups formed are notable. In addition, the hydraulic pressure is applied on the periphery of the flange of the cup, the drawing being performed in a simultaneous push-pull manner making it possible to achieve higher drawing ratio's then those possible in the conventional deep drawing process. The pressure on the flange is more uniform which makes it easiest to choose the parameters in simulation. The pressure in the die cavity can be controlled very freely and accurately, with the approximate liquid pressure as a function of punch position. In the hydro forming deep drawing process the pressurized fluid also serves to delays the onset of material failure and reduces the wrinkles formation. In this process, the pressurized fluid is utilized for many purposes as the sheet metal blank is supported in entire forming process, elimination of fracture in deformation of cup and formation of wrinkles on the wall and edges of the cup are minimized. The process is an automatic co-ordination of the punch force and blank holding force, low friction between the blank and tooling as the high pressure liquid lubricates these interfaces and elimination of the need for a complicated control system. Hydraulic pressure can enhance the capabilities of the basic deep drawing process for making cups and the parts can drawn without any scratches on the outside of the part and also obtained in good surface finish, surface quality, high dimensional accuracy and complicated parts.

2. NOTATION

r_p = radius of punch r_{cp} = corner radius on punch

r_d = radius of die opening r_{cd} = corner radius on die

t = thickness of blank r_j = radius of blank

σ_r = radial stress σ_θ = hoop stress

$d\theta$ = angle made by element at job axis P_h = blank holder pressure

P = radial pressure of fluid

τ = Shear stress acting by the fluid on each side of element

2τ = Total Shear stress acted by the fluid on the Element

dr = width of element r = radial distance of blank element from job axis

σ_0 = yield stress σ_{rd} = Radial stress at die corner.

$(dy)_1$ = distance between upper surface of the blank element and blank holder

$(dy)_2$ = distance between lower surface of the blank element and die surface

dy = distance maintained by blank element from both blank holder and die surface

τ_1 = shear stress acted by fluid on upper surface of the blank element

τ_2 = shear stress acted by fluid on lower surface of the blank element

du = velocity of the blank element relative to blank holder and die surface

μ = dynamic viscosity or absolute viscosity or Viscosity of fluid

τ_A = 2τ, the total shear stress acting by the fluid on the blank element

h = height of the gap = thickness of fluid

3. METHODOLOGY

3.1 Determination of Radial Stress

Hydro forming Process as shown in fig.1. In the hydro forming deep drawing Process, a high pressure is produced in the fluid by the punch penetration into the fluid chamber. This pressurized fluid is directed to the peripheral surface of the blank through the bypass holes and also this high pressure fluid leak out between the blank and both the blank holder and die. This creates a thick fluid film on upper and lower surface of the flange and subsequently reduces frictional resistance. During the process the shear stresses are acting by fluid on the both sides of semi drawn blank at a gap, which is provided between the blank holder and die surface and the semi drawn blank is taking place at middle of the gap. The height of the gap is more than the thickness of the blank. The radial stresses are generated in the blank in radial direction due to punch force applied on it So these stresses are generated in circular blank material during in the hydro forming deep drawing process. The various stresses acting on the blank element during the process is shown in fig.2.Evaluation of radial stresses , let us consider a small element of blank '*dr*' in between blank holder and die surface in radial direction at a distance '*r*' from the job axis of the circular blank with in the fluid region (fig. 2.).

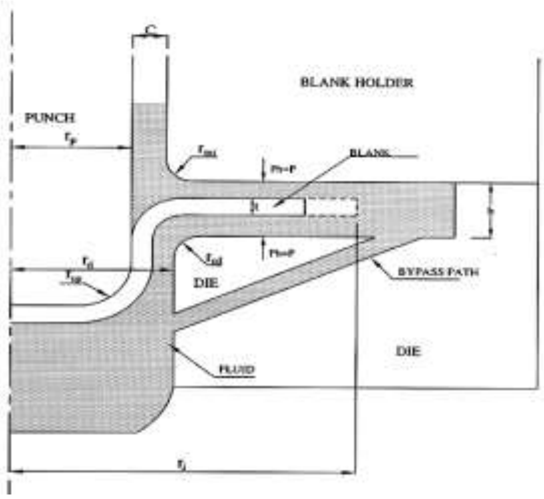

Fig.1 Hydroforming Deep Drawing process

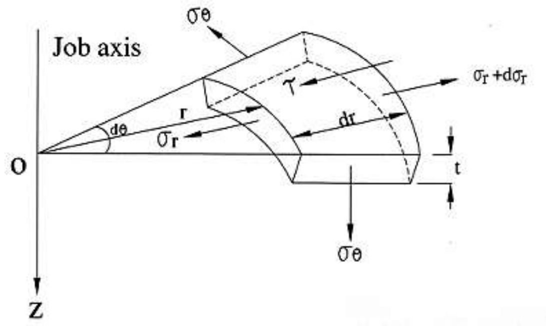

Fig.2. Stresses acting on the element during drawing process

The viscous fluid contact on the both sides of blank element, due to this, the viscous force is acted by fluid on the both sides of the blank element. The total shear stress acting by the fluid on the element = 2τ (i.e. shear stress τ is acting by the fluid on the each sides of element and it is same).Then shear force F_1 is given by, $F_1 = 2\tau \times A_c$

Where A_c = fluid contact area of element But $A_c = r dr d\theta + \frac{dr}{2} dr d\theta$. Apply the equilibrium condition in radial direction, i.e. Net forces acting on the element in the radial direction equal to zero.

$$\Rightarrow \sum_{\xrightarrow{+}} F_r = 0, \quad \Rightarrow (\sigma_r - \sigma_\theta) dr + r\, d\sigma_r = \frac{2\tau}{t} r\, dr \qquad (1)$$

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

$$\sigma_r - \sigma_\theta = \sigma_0 \qquad (2)$$

Combined eq. (2) and eq. (1)

$$d\sigma_r = \frac{2\tau}{t} dr - \sigma_0 \frac{dr}{r}$$

Integrating $\Rightarrow$ $\int d\sigma_r = \int \frac{2\tau}{t} dr - \int \sigma_0 \frac{dr}{r}$

$$\Rightarrow \quad \sigma_r = \frac{2\tau}{t} r - \sigma_0 \ln r + C \qquad (3)$$

Where C is constant, it is obtained from boundary condition.

That boundary condition : at $r = r_j$, $\sigma_r = 0$ $(\because \mu = 0)$

Where μ is the coefficient of friction between blank and both the blank holder and die surface

The boundary condition is Sub. in eq. (3) we get

$$C = -\frac{2\tau}{t} r_j + \sigma_0 \ln r_j$$

Component C is sub. in eq.(3)

$$\Rightarrow \sigma_r = \sigma_0 \ln\left(\frac{r_j}{r}\right) - \frac{2\tau}{t}(r_j - r) \quad (4)$$

This equation (4) represents distribution of radial stresses in the blank during the hydro forming process.

3.2. Radial stress at die corner (σ_{rd})

Radius of die opening $= r_d$ at $r = r_d \Rightarrow \sigma_r = \sigma_{rd}$

we know that from eq. (4) ,

$$\sigma_r = \sigma_0 \ln\left(\frac{r_j}{r}\right) - \frac{2\tau}{t}(r_j - r)$$

$$\Rightarrow \sigma_r\big)_{r=r_d} = \sigma_{rd}$$

$$\therefore \sigma_{rd} = \sigma_0 \ln\left(\frac{r_j}{r_d}\right) - \frac{2\tau}{t}(r_j - r_d) \quad (5)$$

The equation (5) represents radial stress distribution in the blank at die corner and it is acting in radial direction during the drawing process.

4. VISCOSITY PHENOMENA

In this hydro forming deep drawing process, the blank is interaction with the fluid, then the viscosity is comes into the picture. During the process the shear stresses and shear forces are acting by the fluid on the blank in the gap, which is the region between blank holder and die surface. During the hydro forming deep drawing process, the blank is taking place at middle of the gap. The effect of viscosity phenomenon in this process as shown in below fig.3.

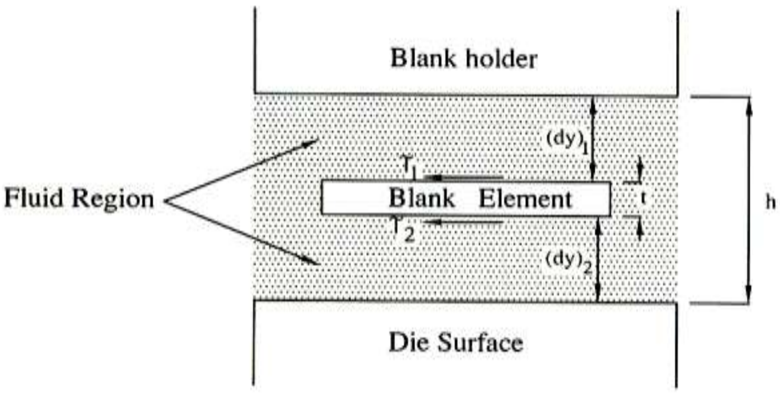

Fig.3.Blank element between blank holder and die surface within fluid region

Newton's law of viscosity is applied to this process for evaluation of radial stresses. Let us consider a small element of blank in between blank holder and die surface with in the fluid region i.e gap. as shown in fig.3.

But $(dy)_1 = (dy)_2$, because the blank element is taking place at middle of the gap

$$\therefore \ (dy)_1 = (dy)_2 = (dy) \Rightarrow dy = \frac{h-t}{2}$$

but $\tau_1 = \tau_2$, Because of $\left(\frac{du}{dy}\right)_1 = \left(\frac{du}{dy}\right)_2$,

According to Newton's law of viscosity $\tau_1 = \mu\left(\frac{du}{dy}\right)_1$, $\tau_2 = \mu\left(\frac{du}{dy}\right)_2$

Let us $\tau_1 = \tau_2 = \tau$

The total shear stress acting by the fluid on the blank element

$$\tau_A = \tau_1 + \tau_2 = 2\tau_1 = 2\tau$$

$$\therefore \ \tau_A = 2\tau$$

But $\tau = \mu\left(\frac{du}{dy}\right)$, Where $du = u - 0 = u$

$$\therefore \ \tau_A = 2\tau = 2\mu\left(\frac{du}{dy}\right) = \frac{4\mu u}{h-t}$$

$$\tau_A = 2\tau = \frac{4\mu u}{h-t} \qquad (6)$$

4.1 Radial stress at die corner in terms of viscosity

We know that radial stress $\sigma_{rd} = \sigma_0 \ln\left(\frac{r_j}{r_d}\right) - \frac{2\tau}{t}(r_j - r_d)$ (From eq.5) ,

Substitute $2\tau = \frac{4\mu u}{h-t}$, we get Radial stress at die corner in terms of viscosity

$$\Rightarrow \sigma_{rd} = \sigma_0 \ln\left(\frac{r_j}{r_d}\right) - \frac{4\mu u}{h-t}\left(\frac{r_j - r_d}{t}\right) \qquad (7)$$

The equation (7) represents radial stress distribution in the blank at die corner and it is acting in radial direction during the drawing process.

5. MAGNESIUM ALLOYS

Magnesium is the highest of the commercially important metals, having a density of 1.74 gm/cm^3 and specific gravity 1.74.Applications for magnesium alloys include use in aircraft, missiles, machinery, tools, and material handling equipment, automobiles and high speed computer parts. Like aluminum, magnesium is relatively weak in the pure state and for engineering purposes is almost always used as an alloy. Even in alloy form, however, the metal is characterized by poor wear, creep and fatigue properties. Strength drops rapidly when the temperature exceeds 100^{0}C, so magnesium should not be considered for elevated – temperature service. Its modulus of elasticity is even less than that of aluminum, being between one fourth and one fifth that of steel. For engineering applications magnesium is alloyed mainly with aluminum, zinc, manganese, rare earth metals, and zirconium to produce alloys with high strength–to-weight ratios. On the other positive side, magnesium alloys have a relatively high strength-to-weight ratio with some commercial alloys attaining strengths as high as 300 MPa. High energy absorption means good damping of noise and vibration. For this analysis type of Magnesium alloys considered namely AZ31B-O, Magnesium alloy AZ31B-0: composition (%): 3.5 Al, 0.6Mn, 1.0Zn and Tensile strength 240MPa, Yield strength 150MPa.

6. RESULTS & DISCUSSION

The radial stress distribution at die corner in the blank during the hydro forming process is given by eq .7

$$\Rightarrow \sigma_{rd} = \sigma_0 \ln\left(\frac{r_j}{r_d}\right) - \frac{4\mu u}{h-t}\left(\frac{r_j - r_d}{t}\right)$$

The following parameters are considered for evaluation of radial stresses at die corner for successful formation of cup in hydro forming deep drawing process.

r_p = 25 mm, r_d = 30mm , c = 5 mm, Radial pressure of fluid = P, Punch speed u =10mm/sec, h =12 mm, Type of materials used : Magnesium alloy, Yield Stress values (σ_0) of Magnesium alloys: AZ31B-O σ_0 = 150MPa , Type of fluid used: castor oil, viscosity μ =0.985N–sec/m^2, radius of blank r_j = 85mm, 90mm,95mm,thickness of blanks t = 1.5 mm. The evaluation of values of radial stresses at die corner (σ_{rd}) in the blanks of magnesium alloy with a given fluid and given thickness of blanks for different radius of blanks as follows. Substitute the above values in above equation we get generalized equations for evaluation of radial stresses at die corner during the process with respect to thickness of blanks of magnesium alloy with castor oil medium.

$$\Rightarrow \sigma_{rd} = \sigma_0 \ln\left(\frac{r_j}{30}\right) - 2.5\left(r_j - 30\right)$$

The results of radial stresses at die corner in hydro forming process for magnesium alloy with respect to radius of blanks as r_j =85mm,90mm,95mm , at t =1.5mm with castor oil medium are presented in fig.4.

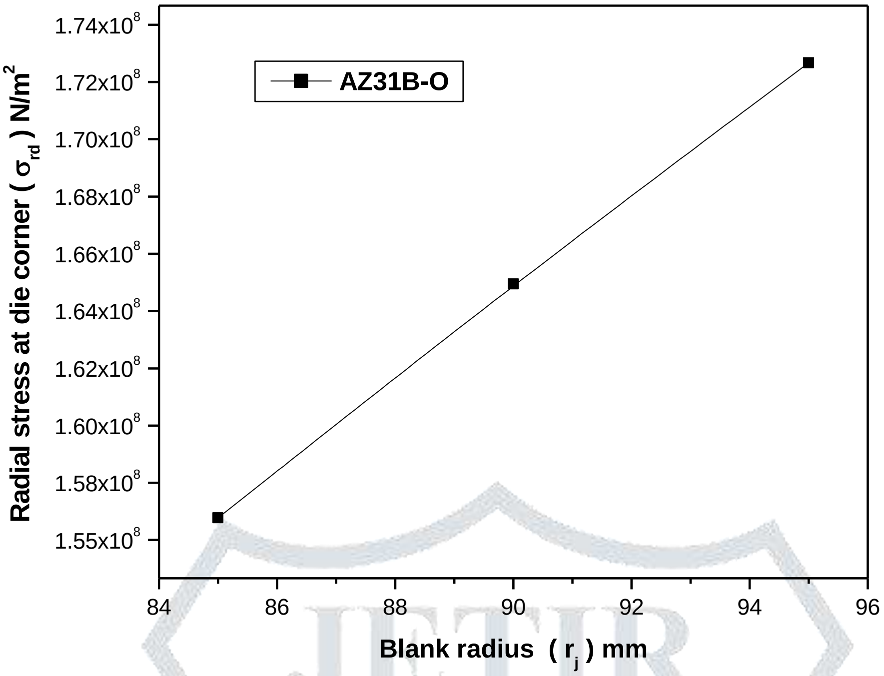

Fig.4 Radial Stresses at die corner in hydro forming

From this figure the radial stresses at die corner are increasing with increasing the radius of blank. This is due to viscosity of oil and shear stresses acted by this fluid during the process. It is also the function of process parameters, yield stress and fluid pressure. From fig.4 the magnesium alloy at t = 1.5mm with castor oil, range of radial stresses at die corner for AZ31B-O is 156217943.7N/m^2 –172901764 N/m^2 . The radial stress at die corner is higher when radius of blank is higher value.

7. CONCLUSIONS

In this present analysis the radial stresses at die corner are evaluated with in the range of radius is 85mm - 95mm, at constant thickness of magnesium alloy blanks. The radial stresses at die corner has been are increased with increasing in the radius of blanks. These effects are due to viscosity and pressure of castor oil acted on the blanks of magnesium alloy during the hydro forming process. The highest value of radial stresses at die corner occurred in AZ31B-O as 172901764N/m^2 at r_j = 95mm and lowest value occurred in AZ31B-O as 156217943.7N/m^2 at r_j =85mm.The percentage of increase in these stresses of magnesium alloy with in the range of given blank radius and at given thickness is 10.67 %. Higher values of radial stresses at die corner are obtained in high radius of blanks. These stresses are used to get good results of deep drawability, surface finish and accuracy in products of magnesium alloy. The wrinkling is reduced due to the blank supported by high pressurized viscous fluid.

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