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THEORETICAL STUDY OF RADIAL STRESSES IN SHEET METAL FORMING

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Abstract*—Hydro forming manufacturing process, the fluid pressure contributes positively in several ways for producing of seamless shells, cups and boxes of different shapes. Hydro forming deep drawing process is the one of the hydro forming manufacturing. In this process, applying the hydraulic fluid pressure on blank surfaces in radial direction through punch movement within fluid in fluid chamber, which is provided in die and punch chambers. The fluid pressure is supported for the blank surfaces in entire process. In radial direction, radial stresses are generated in the blank due to punch force on the blank with supported by blank holder force. The radial stresses are evaluated in magnesium alloy with castor oil medium. The radial stresses are decreasing with increases in radial distance is obtained. The automatic co-ordination is developed in between the punch and blank holder.

Keywords : Hydro forming manufacturing, deep drawing process, radial stress, viscosity, shear stress.

1. INTRODUCTION

In the area of manufacturing , the various products can be developed by using hydro forming technology. Hydro forming manufacturing process, the radially pressurized fluid is main element for the process. It is an alternative to conventional forming. The fluid pressure effects on induced stresses in blanks during the process. The process of hydro-forming methodology, the fluid pressure is maintained major role for getting of outcome products. The ratio of increased depth to diameter is the one of the advantages of hydro forming. The drawing ratio's are obtained in higher level than general deep drawing. In sheet metal forming deep drawing methodology, the blank drawn on a die with help of punch with supporting of blank holder pressure. The radial stresses are produced in radial direction and hoop stresses are produced in circumferential direction in the blank due to punch force applied on it [1]. Wrinkles are produced in the flange due to insufficient blank holder pressure. For preventing wrinkling in the flange , apply sufficient blank holder pressure in the process[2].In the hydro forming technology of sheet metals, the various process such as hydro pressure forming [3], hydro-mechanical forming [4], hydraulic counter pressure forming [5], augmented hydraulic pressure forming [6].The automatic coordination is obtained in between punch force and blank holder force. High pressure fluid lubricate the interfaces and contact surfaces of tooling of entire process, so friction is reduces [7]-[12].The position of punch within the fluid chamber will effected on fluid pressure, hence fluid pressure is the function of punch position. This forming methodology to enhancement in drawability, formability index and also improve in surface characteristics of products.

2. RADIAL STRESSES

The hydro forming deep drawing process as shown in Fig.1. The punch moves through fluid in fluid chamber, pressure is generated in the fluid. This pressurized fluid passed through the bypass path which is provided in die , acted on the blank surface in radial direction. The circular blank is drawn into cup deformation using punch with supporting of blank holder pressure and semi drawn blank is moved to centre point between blank holder and die .The viscous fluid produced fluid film on both side surfaces of semi drawn blank in between gap, which is taking place between blank holder and die surface. The hoop stresses and radial stresses are produced in the blank due to punch force applied on circular blank. The shear force and shear stress are acted by fluid on the blank. It is taken into consideration for analysis of stresses. The Fig.2 shows complete picture of stresses acting on the element of blank in the process. Consider a blank element '*dr*' in radial direction at a distance *r* from the job axis of circular blank in fluid region in between blank holder and die (Fig.2).

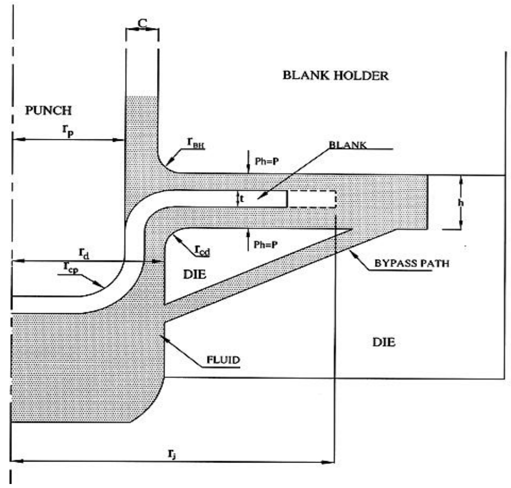

Fig.1. Hydro forming process

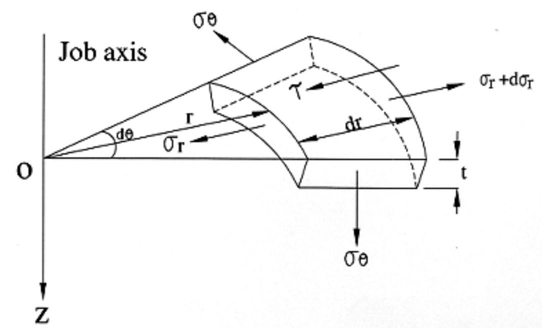

Fig.2. Complete picture of stresses acting on the blank element

The shear stress τ acted by fluid on the both sides of blank, so the total shear stress is equal to 2τ . Then shear force given by product of total shear stress and fluid contact area of element (A_c). Where $A_c = rdrd\theta + \frac{dr}{2}drd\theta$, Where $d\theta$= angle made by element at job axis.

Apply the equilibrium condition in radial direction,

$$\Rightarrow \sum_{\xrightarrow{+}} F_r = 0$$

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

Where σ_r = radial stress σ_θ = hoop stress t = thickness of blank dr = element width

τ = blank element affected by shear stress

r = radial distance of element of blank from job axis.

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

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

where σ_0 = yield stress

Combined eq. (2) and eq. (1) , Simplified and Integrating

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

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

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

Using boundary condition, the constant value C obtained

That boundary condition : at $r = r_j$, $\sigma_r = 0$ r_j = radius of blank

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)

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

The radial stress distribution in blank in the process is represented by equation (4).

3. VISCOSITY PHENOMENA

Hydro forming drawing process, the entire blank is interaction with fluid, the semi drawn blank is taking at centre place of the gap. The gap is the region between die and blank holder. Semi drawn blank is affected with shear stress of fluid. So viscosity phenomenon is considered for evaluation of radial stresses. The element of blank affected with shear stresses in gap as shown in Fig.3.

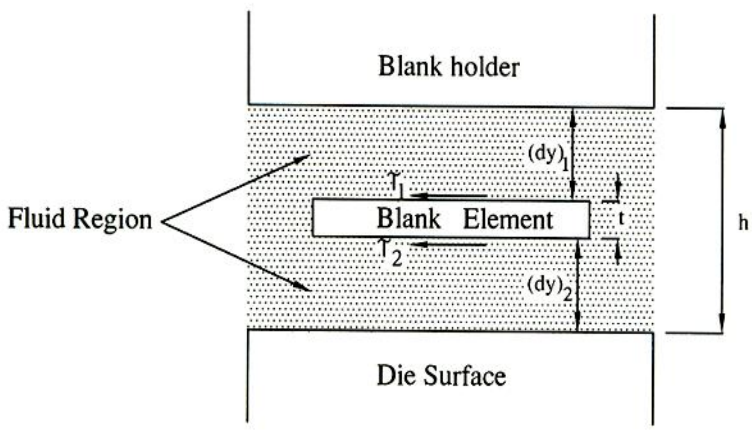

Fig.3.The element of blank in between die and blank holder within oil medium

Here $(dy)_1 = (dy)_2$, due to the element of blank at centre of the gap

$$\therefore (dy)_1 = (dy)_2 = (dy)$$

$$\Rightarrow dy = \frac{h - t}{2}$$

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

Using Viscosity principle $\tau_1 = \mu\left(\frac{du}{dy}\right)_1$, $\tau_2 = \mu\left(\frac{du}{dy}\right)_2$

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

Total shear stress acted on the blank element by the fluid τ_A

$$\tau_A = \tau_1 + \tau_2$$

$$= 2\tau_1 = 2\tau$$

$$\therefore \tau_A = 2\tau \quad , \quad \text{and} \quad \tau = \mu\left(\frac{du}{dy}\right) \quad , \quad du = u - 0 = u$$

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

$$\tau_A = 2\tau = \frac{4\mu u}{h-t} \tag{5}$$

Where

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

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

μ = dynamic viscosity

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

τ_1 = blank element affected with shear stress on its upper surface

h = gap height = fluid thickness

τ_2 = blank element affected with shear stress on its lower surface

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

τ = blank element affected with shear stress on its total surface

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

4. RADIAL STRESSES EXPRESSES IN VISCOSITY

The radial stresses are generated in the blank is given by eq.4

$$\sigma_r = \sigma_0 \ln\left(\frac{r_j}{r}\right) - \frac{2\tau}{t}(r_j - r) \quad \text{and substitute} \quad 2\tau = \frac{4\mu u}{h-t} \quad \text{, we get}$$

$$\sigma_r = \sigma_0 \ln\left(\frac{r_j}{r}\right) - \frac{4\mu u}{h-t} \cdot \frac{(r_j - r)}{t} \tag{6}$$

The equation (6) shows, determination of radial stresses in the blank in hydro forming process.

5. RESULTS & DISCUSSION

The radial stress distribution in hydro forming deep drawing in the blank is given by eq .6

$$\sigma_r = \sigma_0 \ln\left(\frac{r_j}{r}\right) - \frac{4\mu u}{h-t} \cdot \frac{(r_j - r)}{t}$$

The following are considered for determination of hoop stresses.

r_p = 25 mm, r_d = 30mm , c = 5 mm , pressure of fluid = P, speed of punch u = 10mm/sec,
h = 12 mm, blank thickness t = 1.5 mm, blank radius r_j = 80mm
Material : alloy of magnesium AZ31B-O and yield stress σ_0 = 150 x 10^6 N/m^2
Medium of fluid : castor oil, viscosity , μ = 0.985N–sec/ m^2

Using the above parameters values in above equation, we get generalized for radial stresses equation during process with respect to different radial distance of blank from job axis for blank of magnesium alloy with castor oil medium at blank thickness t=1.5mm

At r_j = 80 mm $\Rightarrow \sigma_r = \sigma_0 \ln\left(\frac{80}{r}\right) - 2.5\left[80 - r\right]$

Fig.4 presents radial stresses of magnesium alloy, at r_j = 80 mm , t=1.5mm with in radial distance r =40mm - 60mm through castor oil medium. The radial stresses are decreases with increasing of radial distance of blank. This is occurred due to viscosity and pressure of oil and also process parameters.

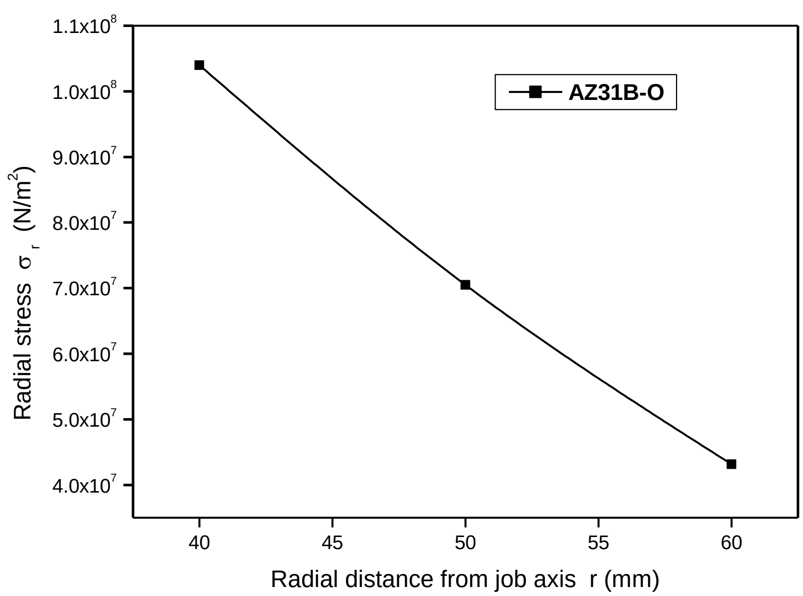

Fig.4. Radial stress distribution in the blank in hydro forming

The radial stresses range of AZ31B-O is 43152260.87 N/m^2 – 103971977.1 N/m^2 .

6. CONCLUSIONS

Evaluated magnesium alloy radial stresses within the range of r is 40mm – 60mm through castor oil. For r_j = 80mm, r = 40mm, the radial stresses values are occurred in high in AZ31B-O is 103971977.1 N/m^2, at r = 60mm lowest value occurred is 43152260.87 N/m^2. The percentage of amount decreased in radial stresses of alloy of magnesium is 58.49. The radial stresses are high at radial distance 40mm and low at radial distance 60mm. Radial stresses are at radial distance 40mm is equal to 2.4 times of radial stress at radial distance 60mm is obtained. The radial stresses are inversely proportional to the radial distance were obtained within the castor oil medium. These radial stresses are used for study of forming characteristics of process.

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REFERENCES

[1] D.F. Eary, and E.A. Reed, "Techniques of Press-working Sheet Metal", prentice-Hall, New Jersey, pp. 100–172, 1974,

[2] J.M. Alexander, "An appraisal of the theory of deep drawing", Met. Rev.Vol 5 (19) pp.349–409, 1960.

[3] X. Chateau and A Simplified approach for sheet hydro forming processes design, International Journal of Mechanical Sciences,Vol. 36, No. 6, pp.579-597, 1994.

[4] B. Larsen, "Hydro mechanical forming of sheet metal", Sheet Met.Ind. pp.162–166, Feb. 1997.

[5] K. Nakamura, "Sheet metal forming with hydraulic counter pressure" in Japan, Ann. CIRP Vol 36 (1), pp.191–194, 2006.

[6] S. Thiruvarudchelvan, "A novel pressure augmented hydraulic-deep-drawing process for high draw ratios," Journal of material processing Technology,Vol 54,pp.355–36, 2005

[7] S. Yossifon,and J. Tirosh, "on the permissible fluid-pressure path in hydroforming deep drawing processes—analysis of failures and experiments," Trans. ASME J. Eng. Ind. Vol 110 , pp.146–152,1988.

[8] K. Lange, "Handbook of Metal forming," McGraw-Hill, New York, pp. 20.21–20.24,1995.

[9] S.H. Zhang, J. Danckert, "Numerical analysis of hydro-mechanical deep drawing", Journal of material processing Technology ,Vol 83,pp.

14–25,1998.

[10] S.H. Zhan and, J. Danckert, Development of hydro-mechanical deep drawing, Journal of Mechanical Engineering and Technology, Vol 83 pp.14–25,2008

[11] S. Thiruvarudchelvan, and W. Lewis, "A note on hydro forming with constant fluid pressure," Journal of material processing Technology ,Vol 88, pp. 51–56,1999.

[12] D.Y. Yang, J.B. Kim and D.W. Lee, "Investigations into the manufacturing of very long cups by hydromechnical deep drawing and ironing with controlled radial pressure," Ann. CIRP , Vol 44, pp. 255–258,1995