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Design Of Conventional Deep Drawing And Hydro Forming Deep Drawing By Finite Element Analysis

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Abstract : Deep drawing and hydro forming deep drawing (HDD) are the two conventional methods for production of cylindrical cups. In this paper, various cylindrical work pieces have been produced with various dies radius with different fluids and FEA values of radial & hoop- stresses for increased blank sizes are compared with experimental results**.** For increasing drawing ratio in the hydro forming deep drawing, pressure chamber must be calculated and exerted properly by varying various viscous fluids. Limited tearing pressure curve have been obtained with finite element simulation. There are several types of deep drawing process, in that hydro-assisted deep drawing process is used. In the hydro-assisted deep drawing process fluid with some velocity in injected between die and punch. Finally comparison of theoretical & FEA radial & axial stresses for various blanks sizes.

I. INTRODUCTION

1.1 Deep Drawing Process And Its Importance

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 radiused punch. As the blank is drawn radially inwards the flange undergoes radial tension and circumferential compression. The latter may cause wrinkling of the flange if the draw ratio is large, or if the cup diameter-to-thickness ratio is high. A blank-holder usually applies sufficient pressure on the blank to prevent wrinkling.

Radial tensile stress on the flange being drawn is produced by the tension on the cup wall induced by the punch force. Hence, when drawing cups at larger draw ratios, larger radial tension are created on the flange and higher tensile stress is needed on the cup wall. Bending and unbending over the die radius is also provided by this tensile stress on the cup wall. In addition, the tension on the cup wall has to help to overcome frictional resistance, at the flange and at the die radius. As the tensile stress that the wall of the cup can withstand is limited to the ultimate tensile strength of the material, in the field of deep drawing process the special drawing processes such as hydro-forming, hydro-mechanical forming, counter-pressure deep drawing , hydraulic-pressure- augmented deep drawing .

1.2 Hydro-Assisted Deep Drawing Process

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. 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, 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.

In the fluid assisted 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.

In fluid assisted deep drawing process the radial stresses and hoop stresses are generated in the blank due to punch force is applied on it. The radial stresses are evaluated in terms of viscosity of fluid, blank geometry, and process parameters for magnesium alloys and studied using above process theoretically. The viscosity phenomenon is considered for evaluation of the Radial Stresses theoretically and it is compared with Analytical results.

2. Hydro Mechanical Deep Drawing

Hydro-mechanical deep drawing is a new sheet metal forming technology originating from hydro-forming technology. It combines the features of both traditional deep drawing technology and hydro-forming technology. In hydro-mechanical deep drawing the limit drawing ratio (LDR) values can reach compared with the traditional deep drawing process where the LDR values are only about. Since its inception, the hydro-mechanical deep-drawing process has found increasing application in industry, such as application in automobile and aircraft manufacture.

After continuous improvement and innovation, much specialized equipment and many devices have also been devised and put into use. The hydro-mechanical deep-drawing process can replace some other metal forming processes, because this process can improve the quality of the product without losing productivity. Hydro-mechanical deep-drawing technology was first developed in 1890 .

2.1 Features Of Hydro-Mechanical Deep-Drawing Process

(a) It has a friction-holding effect (friction forces are produced between the blank and the punch and serve as part of the forming force)

(b) It has a resistance-reduction effect (the friction resistance between the flange and the die is reduced because of the flowing out of the fluid)

I it has an initial extension effect (extension in the vicinity of the die shoulder portion is caused by pre-bulging, the thickness thus becoming more uniform, by using pre-bulging the material over the die cavity is initially stretched, causing a more uniform thickness distribution).

Because of the above three fracture-prevention effects, this process can improve the fracture limit. The process also has a wrinkle-prevention effect; the unsupported portions are sub$_j$ected to bulging pressure, causing circumferential tensile stresses, which prevents wrinkles from occurring.

2.2 Advantages Of Hydro-Mechanical Deep Drawing Process

(a) Due to the fracture-prevention effects and the wrinkle-prevention effect, the product may have a higher drawing ratio (the LDR is increased), the forming steps are reduced, a sizing tool and a sizing operation are unnecessary, the limitations of the quality and size of the product are overcome and costs are reduced.

(b) Due to the forced contact between the blank sheet and the punch and the lubrication effect of the liquid between the flange and the die, less damage is suffered by the flange, the deep drawing products have a better surface quality, wrinkles can be suppressed, the dimensional accuracy is high and the wear of the dies is clearly reduced.

(c) It is Because of the friction-holding effect, local thinning is lighter and the thickness distribution is more uniform.

(d) As the female die is replaced by fluid pressure, only a punch is used and the drawing operations are reduced. Therefore, the process is cost effective and can be used in small batch production and even in sheet metal property tests.

(e) The process can be used for the manufacture of complex-shaped work-pieces and for the deep drawing of some materials that are not suitable for intermediate heat treatment. The process is flexible. When drawing automotive body panels higher deformation may easily be obtained to increase the stiffness of the product. However, the process has its drawbacks, the main drawback being that a higher drawing force and a higher blank-holding force are needed compared with those of conventional drawing technology.

2.3 Hydro-Mechanical Deep Drawing Applications & It's Classification

In fact, the hydro-mechanical deep-drawing process is a kind of soft-tool forming technology or flexible-forming method originating from hydro forming technology. Soft-tool forming technologies have been used widely in industries because of their simple equipment and convenient devices, their low energy consumption, their fine product quality and their cost effectiveness. Soft-tool forming technologies include rubber-die forming and fluid-hydraulic forming .

Hydraulic forming is used widely in sheet metal forming and tube forming and it includes soft punch forming (in which pressurized water or other fluid media such as oil is taken as the punch, whilst the female die is a rigid body) and soft-die forming (the pressurized water or other fluid media is taken as the female die, the punch being a rigid body). The former is usually referred to as hydro-bulging by most researchers and the latter is usually referred to as the hydro-mechanical deep-drawing process. However, some researchers call it the hydro forming process (especially when using a thin rubber diaphragm between the blank and the fluid). Hydro forming (hydro bulging) has been reported most recently in automobile industry, especially for tube forming and the forming of panel parts.

The hydro-mechanical deep-drawing process can be divided into the hydrostatic type and the hydrodynamic type on the basis of the feature of the fluid pressure. The hydro-bulging process can also have the two different situations according to the loading. In most cases, hydro-bulging is in the hydrostatic state, but there exist some cases, such as explosive forming with fluid as the medium, where the fluid is in the dynamic state. The hydro-mechanical deep-drawing process has different performances during operation. The main reason for the reduction in LDR is due to the friction between the blank flange and the die. The fluid pressure is used in the hydro-mechanical deep drawing process mainly so that friction can be significantly reduced and so that the clamping (or friction-holding effect) between the punch and the blank can prevent fracture of the blank at the punch corner, thus enabling the LDR value to be increased. However, the fluid can be used in different ways; therefore the LDR values can be increased to different levels. Usually LDR values can be increased to about 2.7 within one stroke by means of the hydro-mechanical drawing process, whilst the LDR can be increased to 3.2 for the radial hydro-mechanical deep-drawing process in one step. It is reported that the LDR values may be increased to about 6 for the radial-pressure deep-drawing method (two steps).

2.4 Hydraulic Counter-Pressure Deep Drawing & Its Principle

In hydraulic counter-pressure deep drawing , forming is performed by filling the die cavity with oil or water in the conventional sheet metal deep drawing, as shown in Fig. 2.1

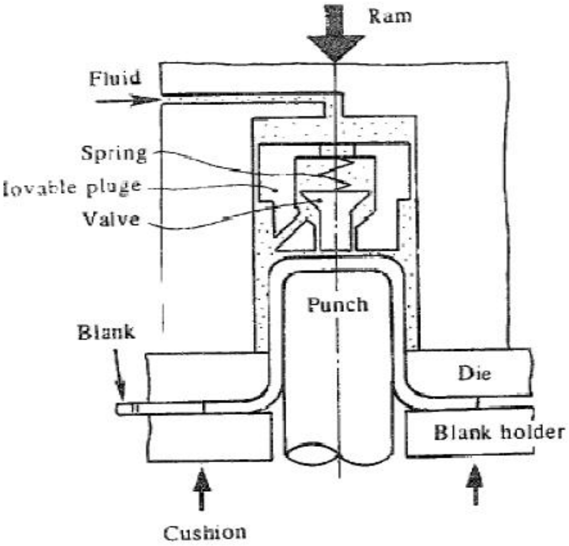

Fig.2.1 Hydraulic Counter Pressure Deep Drawing

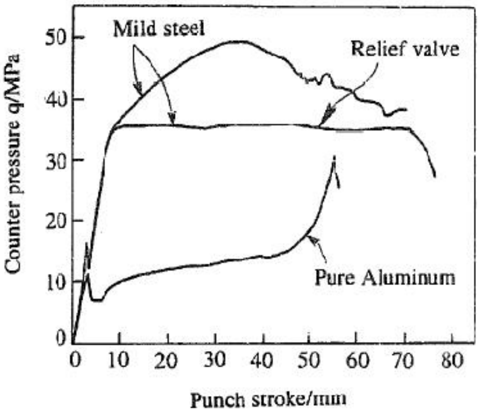

Fig.2.2. Punch Stroke Vs Counter Pressure.

As forming is carried out, the hydraulic pressure rises, the relief valve works so that the liquid flows out or the liquid flows out from the gap between the die and the flange of the sheet through the shoulder of the die. This method was studied by the Japanese Professor Kasuga and others at Nagoya University in the beginning and application to production was first carried out by SMG of Germany. This method has various names-pressure lubricating deep drawing, hydro mech, aqua draw and fluid former. In Japan, it is generally known as hydraulic counter-pressure deep drawing. Looking at the forming process, it is the same as the normal deep drawing process, except for the fact that the die cavity is filled with liquid so that hydraulic pressure is applied during the forming process, but this makes a huge difference. In the normal deep drawing process, blank holding pressure is applied to control the blank but essentially no other force except to the punch and die is applied. Thus the mere application of hydraulic pressure from the bottom creates a huge impact on the forming process. Fig. 2.2 shows the details of the change in hydraulic counter-pressure during deep drawing. First when the punch moves and enters the die and forming starts, the hydraulic pressure increases rapidly.

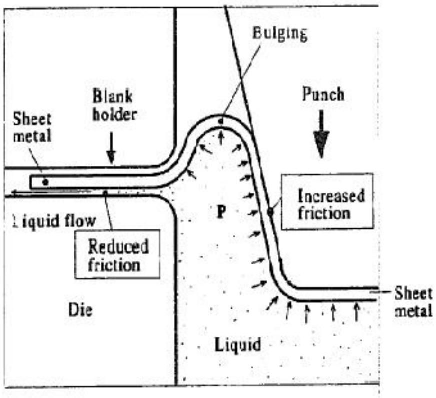

Fig. 2.3 Bulging Effect in Counter Pressure Deep Drawing

At the same time, the sheet metal is pressed firmly against the base of the punch by this hydraulic pressure. Hydraulic pressure reaches the relief valve p the liquid starts flowing out of the valve In addition by setting the valve pressure to strong level. The liquid will flow outside from the flange part via the die shoulder. The conditions for flow out from the flange depend on the blank holding force mainly. In whichever case, the liquid flows out as the punch moves, so that the hydraulic pressure during maintained at a constant level. Sometimes, from the flange is intermittent and the hydraulic pressure shows a slightly pulsating motion. As forming reaches its final stages, the liquid flows out more easily fro the flange and the hydraulic pressure drops. The punch force becomes great It.; hydraulic pressure is added in addition to the normal deep drawing force. A larger blank holding force is also necessary for the hydraulic pressure imposed on the flange to prevent the flow of liquid from the Range, or to attain a high hydraulic pressure at a low blank holding pressure.

2.5 Hydro Dynamic Deep Drawing Process

A sketch of the conventional hydrodynamic deep drawing (HDD) process. Initially, the flange of the blank is in contact with the draw die. When the punch is moved down, the liquid pressure in the die cavity increases and when the pressure reaches a certain magnitude, the flange is lifted from the draw die and the liquid starts to flow out through the gap between the draw die and the flange. In FEM simulation of the conventional HDD, it is very difficult to determine the pressure at which flow between the draw die and the flange is initiated and also very difficult to determine the correct pressure distribution on the flange after the flow has been initiated. The conventional HDD process is thus very difficult to be simulated correctly. A sketch of the proposed HDD process with radial pressure on the blank rim. In this process there is a small gap *g* between the blank holder and the out rim of the draw die. The height of the gap is controlled by 4 spacers placed on the draw die, and the blank holder force is kept so high that the height of the gap remains fixed throughout the drawing. Before the punch is moved down, the initial pressure is applied to the liquid in the die cavity (pre-bulging). This pre-bulging pressure lifts the blank from draw die and presses the flange of the blank on to the blank holder so that a seal is formed between the blank flange and the blank holder (the liquid can only escape through the gap *g* and through the relief valve). When the punch is moved down the liquid pressure in the die cavity presses the blank on to the punch as in the conventional HDD process. The gap between the blank holder and the die is so small that only a very small amount of liquid escapes through this gap and during the drawing the pressure in the die cavity is controlled by the pressure setting of the relief valve. The proposed HDD process has many advantages compared to the conventional deep drawing process. The pressure on the flange is more uniform, which makes it easier to choose the parameters in simulation. The pressure in the die cavity can be controlled very freely and accurately. With the appropriate liquid pressure as a function of punch position, parts can be drawn without the blank coming into contact with the draw die (parts can be drawn without any scratches on the outside of the part). There is a radial pressure on the blank rim equal to the liquid pressure in the die cavity.

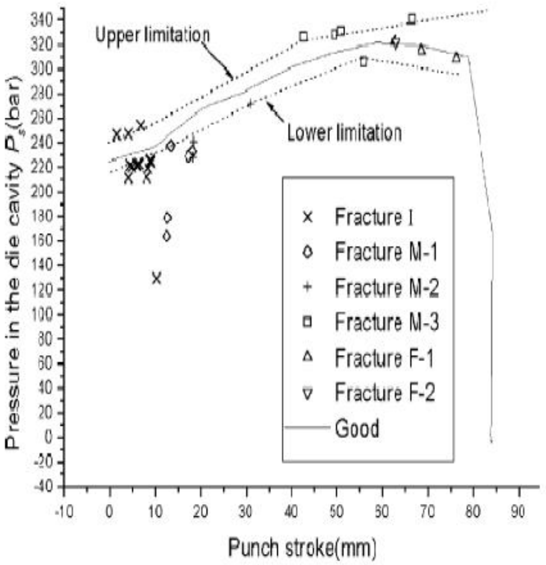

Fig.2.4. Pressure Variation in Die Cavity wrt to Punch Stroke

This radial pressure increases the maximum drawing ratio. The tools are simple and no special sealing devices are needed. The proposed HDD process has been analyzed using FEM simulations and experiments. In recent years, some low-density materials have gained much attention and many applications in the fields of automotive. Because the need for the weight reduction of vehicles, consequently the production of high-strength Al alloy is continuing to increase. When setting $P_r = P_s$, the maximum drawing ratio obtained in the experiments with AL6016-T4 was 2.54. With this drawing ratio severe earring occurred and wrinkles were also formed in the upper part of the cup. With pure Al the maximum drawing ratio was 3.11 and the cups could be made without any wrinkles and completely scratch free.

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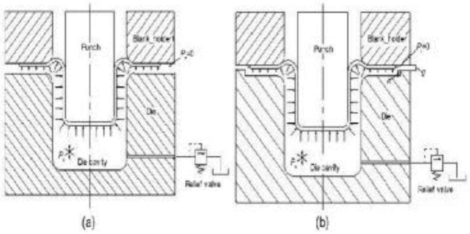

Fig 2.5.Hydro-Dynamic Deep Drawing

$$f_D = f_P - \frac{1}{4}\pi d_p^2 \; P_S \quad \text{--------} \; (2.1)$$

In the above equation (2.1) , where f_D is the sheet drawing force, f_P the total punch force collected through the force sensor in time by computer, d_p the punch diameter and Ps is the liquid pressure in the die cavity.

In recent years, the weight reduction of vehicles has been of great concern, consequently the production of high strength aluminum alloys continue to increase. Particularly, the Al–Mg–Si aluminum alloy sheets are widely used in the car and aerospace industries.

2.6 Re-Drawing Process

In deep drawing a sheet metal blank is drawn over a die by a radiused punch. As the blank is drawn radially inwards the flange undergoes radial tension and circumferential compression . The latter may cause wrinkling of the flange if the draw ratio is large, or if the cup diameter-to-thickness ratio is high. A blank-holder usually applies sufficient pressure on the blank to prevent wrinkling. Radial tensile stress on the flange being drawn is produced by the tension on the cup wall induced by the punch force. Hence, when drawing cups at larger draw ratios, larger radial tension are created on the flange and higher tensile stress is needed on the cup wall. Bending and unbending over the die radius is also provided by this tensile stress on the cup wall. In addition, the tension on the cup wall has to help to overcome frictional resistance, at the flange and at the die radius. As the tensile stress that the wall of the cup can withstand is limited to the ultimate tensile strength of the material, the draw ratio possible in deep drawing is usually limited to about 2.1 or 2.2, to draw deeper cups recourse being made to special drawing processes such as hydro-forming, hydro-mechanical forming, counter-pressure deep drawing, hydraulic-pressure-augmented deep drawing, etc. These processes are relatively slow (compared with the deep drawing or redrawing process) and the draw ratios are limited to 3.5 or 4 at most. However, a conventionally-drawn cup can be redrawn twice or more to obtain draw ratios of the order of 5, 6 or even larger values. Redrawing is carried out with a cup that has been deep drawn conventionally. Using a die, a blank-holder and a punch of smaller diameter, the cup is redrawn to a smaller diameter, and consequently becomes deeper. There are several techniques for redrawing a cup, these including direct and reverse redrawing, and also using different tool geometries. The redrawing ratio (the ratio of the original cup diameter to the redrawn cup diameter) is also limited by factors similar to those limiting the draw ratio in deep drawing. Furthermore, the cup drawn in the first stage becomes work hardened, and its ductility is limited.

The tensile stress induced on the wall of a redrawn cup taking into account bending and unbending and die-friction can be shown to be

$$\sigma = \mathrm{Y}_M \left[2^{\text{«®}/2} \frac{d_0 - d_P}{d_0 + d_P} \quad 1.1 \quad + \quad \frac{t}{2r_D} \right] - p$$

-------- (2.2)

Where, Y_m is the mean yield stress of the metal, *d*0 is the diameter of the first-stage cup, *d*p is the redrawn cup diameter, *p* is the hydraulic pressure applied on the first-stage cup wall during redrawing, s is the redraw stress, m is the coefficient of friction at the die and *t* is the nominal thickness of the cup.

From the Eq.(2.2), it is clear that the greater is hydraulic pressure, the less will be the draw stress on the cup wall, or alternatively if s is quite close to the UTS, then a larger ratio of d_0:*d*p is possible. The above Eq(2.2).does not take into account the frictional resistance at the cup holder caused by high values of the cup holding pressure in the present method of redrawing.

2.7 Hydro Forming Process

The essential parts of the tooling for hydro forming include a punch, a blank holder, a pressure chamber and a rubber diaphragm used to seal the liquid in the pressure chamber. The pressure chamber with the rubber diaphragm at the bottom is mounted on a press ram. When the punch is retracted down, and the pressure chamber moved up, a sheet metal blank is placed on top of the blank holder mounted on the press table. Then the pressure chamber with the rubber diaphragm descends and contacts the blank.

The fluid in the chamber is pressurized in coordination with the punch movement upwards. The flange of the cup is also kept pressed against the blank holder by the fluid pressure transmitted through the rubber diaphragm. As the punch moves into the pressure chamber, drawing the cup, a control valve regulates the liquid flow to maintain the pressure needed. The pressure increases with stroke, the pressure variation being predetermined for successful drawing, and repeated during the operating cycle by a servo-controlled valve.

Once the cup is fully drawn, the chamber is depressurized and the punch retracted. The pressure chamber is then moved upwards leaving the cup on the blank holder. The pressure used may be as high as 100Mpa. The draw ratio achievable in hydro forming is high, very little thinning of the cup wall occurs, and unsymmetrical shapes can be drawn. The hydraulic pressure acts on the surface of the cup being formed including the outer edge of the sheet metal.

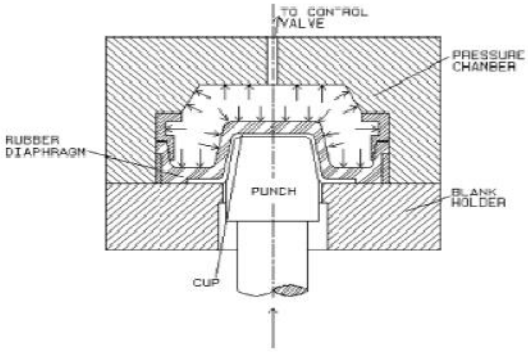

Fig.2.6: Hydro forming Process

2.8 Aqua draw Process

Aqua draw is similar to hydro mechanical forming, except that there is no fluid seal to prevent leakage of oil from the pressure chamber, As a consequence the leakage of fluid in this process can be substantial, unless a very large blank holding force (BHF) is applied. There is no pressure control as in hydro mechanical forming, but the pressure in the chamber is inherently controlled by the leakage of fluid during drawing.

When the punch enters the die cavity, deforming the sheet metal the fluid pressure rises and the fluid flows out creating a film between the blank and the die. Thus, the die radius friction and the friction on the lower side of the flange are small. However since the BHF is high, the friction on the upper surface of the flange can be significant.

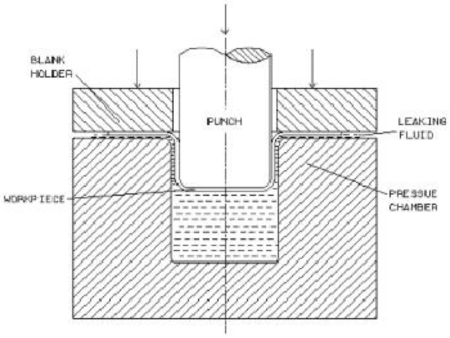

Fig.2.7Aquadraw process

2.9 Hydro-Assisted Deep Drawing Process

Although the processes has many advantages and good application prospects, due to the usage of liquid in the die cavity in this process, the optimal control parameters are difficult to determine. Much know-how and many black boxes also exist in this processes, especially the radial pressure makes this process more complicated, and limits the application and development greatly. It is necessary to explore the application problems connected with this new process. In recent years, some other materials such as aluminum alloys, titanium alloys and even composite blanks have been used in hydro forming . This process is a supplement to the family of hydro forming but it needs to be studied and developed systematically, which will be very helpful for spreading this technology in industry and for creating a knowledge base for the so-called “virtual design” or “virtual prototyping” which are both based on the FEM tool.

It is the combination of all hydro forming processes like, hydro-static, hydro-dynamic, hydro mechanical & hydro forming processes. In this process, both the die chamber (female chamber) and the punch chamber (male chamber) are filled with a hydraulic fluid and these two are connected with by pass as shown in 2d-figure below. Initially fluid will be at rest (static condition), also the blank will be in rest on the supports of the die chamber, when punch moves downwards with certain velocity (dynamic condition), the fluid in the punch chamber gets kinetic energy and it exerts some pressure on the blank and for further movement of the punch the liquid with more velocity hits the blank & then it moves into the die chamber through the by-pass provided.

Like this it moves continuously for the further punch displacement & in die chamber more pressure will be created because of the continuous fluid flowing through by-pass. Because of the pressure difference between the die chamber (high pressure) and punch chamber (low when compared with die chamber), the fluid present in the die chamber exerts pressure on the blank and it lifts the blank for the equilibrium condition (shown in fig). Then fluid rushes and escapes from the gap between the blank & die.

Thus avoiding the direct metal contact between the blank , blank holder & die. So less friction force, the cup produced will be of wrinkle less. Because of the continuous in contact of the liquid (in die chamber) with the blank the cup produced is of wrinkle less & of uniform thickness.

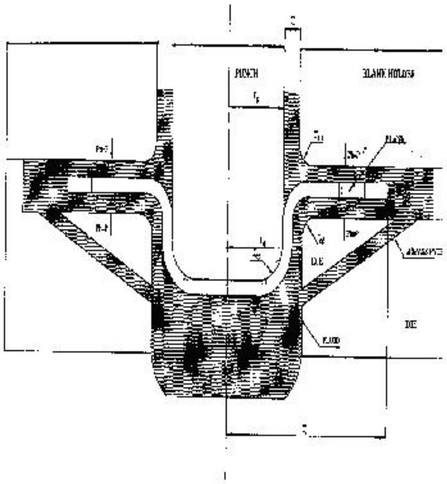

Fig.2.8 Hydro-Assisted Deep Drawing Process

In addition to these, in hydraulic pressure assisted deep drawing processes the hydraulic pressure performs several useful functions, namely:

(1) Contributing to the externally supplied work to deform the sheet metal to the shape of the cup;

(2) Helping to generate frictional support of the cup wall so that the strain-hardened metal at the die throat can be subjected to a large draw stress while not over-stressing the softer metal further down towards the bottom radius of the cup;

(3) Efficiently lubricating the flange of the cup being formed;

(4) Effectively lubricating the die radius in processes where the metal flows over a die radius;

(5) Lifting the sheet metal off the die radius and thereby eliminating die-friction as in hydro-mechanical forming;

(6)Pre-bulging the sheet metal and thereby increasing the contact area between the sheet metal and the crown of the punch before substantial drawing action takes place;

(7) Providing blank holding force in some of the processes, such as hydro-forming;

(8) Generating punch force and blank holding force in addition to a radial push on the blank periphery in the hydraulic pressure augmented deep drawing process and

(9) It enables the use of a high-pressure liquid of increased viscosity, thereby improving the lubrication of the drawing process.

Also, Hoop & Radial stresses will be developed in hydro assisted deep drawing process in drawing the cups. These stresses should not be more than the ultimate tensile stress of the material of the blank to avoid the wrinkles & failure.

Thus in this Analysis, an attempt is made to determine the Hoop (Compressive) & Radial (Tensile) stresses. First these stresses are calculated theoretically & then they are co-related with FEA results.

3. Dimensions Of The Hydro-Assisted Deep Drawing Model

Figure 3.1 shows the dimensions of the Hydro-Assisted Deep Drawing Model. In Ansys Flotran- CFD, Hydro assisted Deep drawing model is generated by these dimensions to obtain the pressure which is acting on the blank

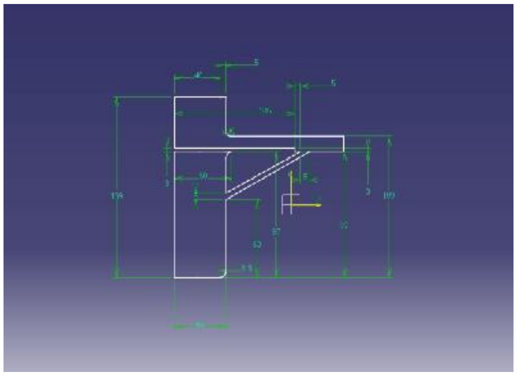

Fig.3.1 Hydro-Assisted Fluid forming model Dimensions

3.1 Modeling Of Hydro Assisted Deep Drawing Process In Ansys Flotran-Cfd

To know the pressure value which is acting on blank, Fluid analysis have to carried out. So Geometric Model of Hydro forming process has to be modeled. This is a simple geometric model, so this model is created in Ansys itself. It is Axi-symmetric model, so for the sake of ease I have modeled only half of the Original model. For this, initially key points are created as per the dimensions of the model and then, using the create areas through Arbitrary by key-points option, areas are modeled. Figure4.5 shows the Axi-symmetric Fluid model.

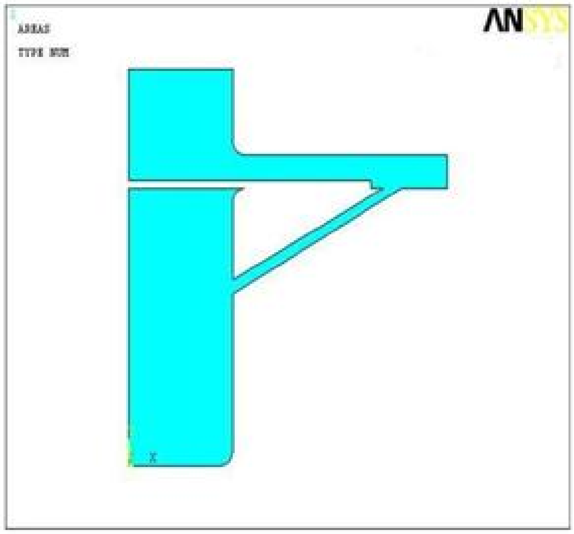

Fig.3.2 Axi-symmetric Hydro-assisted Fluid model

3.2 Meshing Of The Hydro-Assisted-Deep Drawing Process

For any FEA, every model has to divide into finite number of elements, that process is called Discretization or simply called as Meshing. Here, because of the 2-D model, the element type I have taken is 2D FLOTRAN. In meshing, the element size is given using manual-global size edge length option, in size controls of Meshing option. And then it is meshed, using free mesh option in mesh-areas. The elements generated for this model is 7972. The following figure shows the Mesh model of Hydro-Assisted Fluid Forming. Figure 3.3 shows the meshed model of Hydro-Assisted Deep drawing Process.

Fig3.3 Meshed Model of Hydro-Assisted Deep Drawing Process.

3.3 Geometric Modeling Of The Blank

After arriving the pressure from Flotran-CFD Analysis, that pressure is taken as input load in structural analysis. It is also Axi-symmetric, so only half of the blank is modeled. Here, the model is Rectangular blank for the structural Analysis, it is modeled using the options rectangle (by dimensions), in create areas option.

The mesh has been generated for the blank is, using mesh ¾ sided area in Mapped mesh option. The element type which we have used here is 'Solid Quad 4node 42'. the meshed blank. The number of elements generated is 72-80.

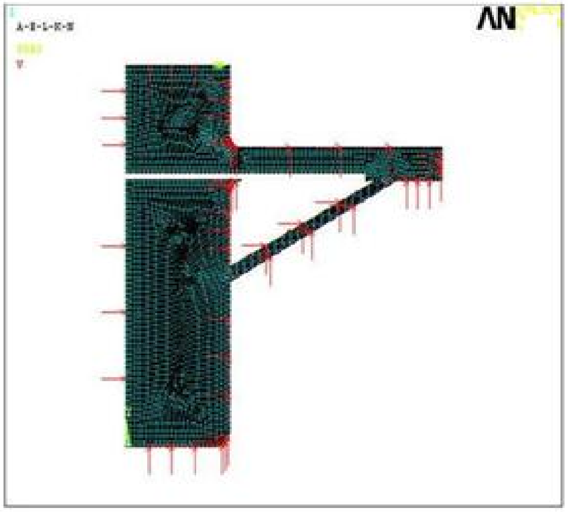

Fig.3.4 Boundary Conditions of HydroAssisted Deep Drawing Model

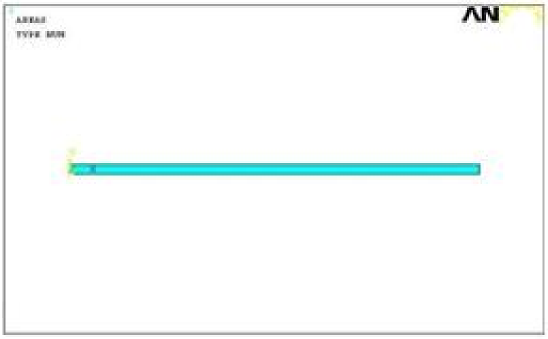

Fig.3.5 Geometric Model of Blank

4. RESULTS & DISCUSSIONS

4.1 Pressure Values Obtained For Different Fluids For Corresponding Blank Sizes & Punch Velocities

For the Ansys Flotran-CFD Analysis, initially two fluids are considered, named Caster oil & Olive oil. In this Analysis, for each oil the pressures are found for different blank sizes (R_j=90, 95 &100mm) by varying the punch velocity each time (i.e u=9 mm/sec, 12mm/sec &15 mm/sec). The table 5.1 shows the pressure values for corresponding blank sizes & punch velocities.

4.2 Pressure Acting On The R_j = 90 Mm Blank

After Flotran CFD, the pressure which is arrived for Caster oil for the r_j=90 mm blank size under u= 9 mm/sec are shown in Fig 4.1. The Maximum pressure arrived here is 150.594 $\frac{N}{m^2}$. But the pressure acting on the blank is 101.609 $\frac{N}{m^2}$. This pressure is the cause for the deformation of blank (cup formation). Thus this pressure is taken as the input pressure load for R_j=90mm blank in the Structural Analysis, to determine the Radial & Hoop Stresses at each radius r= 45, 55 ,65 & 75 mm from the axis of centre of the blank.

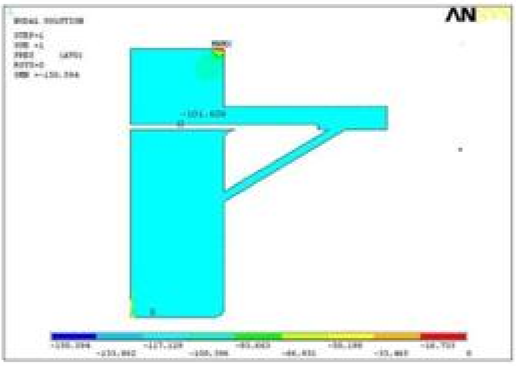

Fig.4.1 Pressure Distribution in Fluid Forming for R_j=90mm blank

4.3 Pressure Acting On The R_j = 95 Mm Blank

After Flotran CFD, the pressure which is arrived for Caster oil for the r_j=95 mm blank size under u= 9 mm/sec are shown in Fig 5.2. The Maximum pressure arrived here is 150.4 $\frac{N}{m^2}$. But the pressure acting on the blank is 101.523 $\frac{N}{m^2}$. This pressure is the cause for the deformation of blank (cup formation). Thus this pressure is taken as the input pressure load for R_j=95mm blank in the Structural Analysis, to determine the Radial & Hoop Stresses at each radius r= 45, 55 ,65 & 75 mm from the axis of centre of the blank.

4.4 Radial Stress Distribution In Az31b-0 Alloy Of R_j = 90 Mm Blank

In Ansys Flotran-CFD Analysis, the Pressure obtained for Caster oil for R_j=90 mm size blank under the punch velocity u=9 mm/sec is taken as the input load (i.e., P=101.609 N/m ^{2}) in Ansys Structural Analysis for the same size blank (i.e R_j=90 mm). Due to this Load, the Radial & Hoop stresses are developed in blank material. Figures 4.2 shows the Radial stresses at radius r=45& 55mm from the center axis of blank for R_j=90mm radius blank are shown respectively.

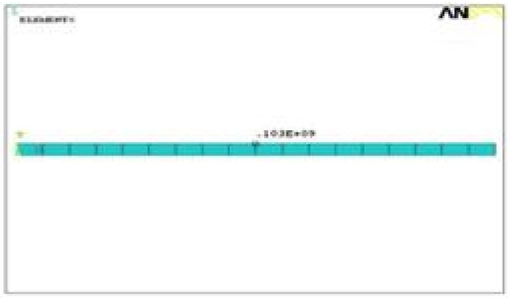

Fig.4.2Radial stress at r = 45mm for R_j=90mm blank

4.5 Hoop Stress Distribution In AZ31B-0 Alloy Of R_J = 95mm Blank

In Ansys Flotran-CFD Analysis, the Pressure obtained for Caster oil for R_j=95 mm size blank under the punch velocity u=9 mm/sec is taken as the input load (i.e., P=101.523 N/m ^{2}) in Ansys Structural Analysis for the same size blank (i.e. R_j=95 mm). Due to this Load, the Radial & Hoop stresses are developed in blank material. Figures 4.3 shows the Hoop stresses at radius r=45 & 55mm from the center axis of blank for R_j=95mm radius blank are shown respectively.

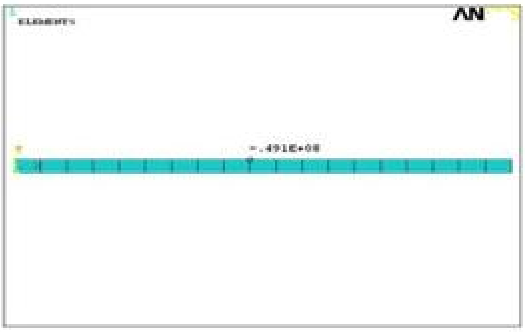

Fig.4.3. Hoop stress at r = 45mm for R_j=95mm blank

In Ansys Flotran-CFD Analysis, the Pressure obtained for Caster oil for R_j=95 mm size blank under the punch velocity u=9 mm/sec is taken as the input load (i.e., P=101.523 N/m ^{2}) in Ansys Structural Analysis for the same size blank (i.e. R_j=95 mm). Due to this Load, the Radial & Hoop stresses are developed in blank material. the Hoop stresses at radius r=65 & 75mm from the center axis of blank for R_j=95mm radius blank are shown respectively.

The Hoop stresses of magnesium alloy (AZ31B-0) blank of thickness, t = 3mm & R_j=95mm radius, with the radial distance *r* = 45, 55 , 65 & 75mm from the vertical center axis of blank are respectively. Due to viscosity of fluids, the shear forces are acted on the blank surface during the fluid assisted deep drawing process, so the Hoop stresses are Increases with increasing of the radial distance of the blank from the $_j$ob axis. Hoop stresses are also depends up on process parameters, yield stress of alloys and fluid pressure. From the magnesium alloy (AZ31B-0) of blank size R_j = 95mm with castor oil viscosity, it is observed that the range of Hoop stresses are 49 Mpa – 119 Mpa.

4.6 Comparison Of Deformations Of Various Blank Sizes

Fig. 4.4, 4.5 & 4.6 shows the deformations for the blanks sizes of R_j=90, 95 & 100 mm respectively. Here the deformation for the R_j=90 mm blank is 31.3 mm, for the R_j=95 mm is 36.5 mm & for R_j=100 mm blank the deformation is 41.7mm. The deformation is higher for the higher blank size. This is because of the reason that, for higher blank sizes, higher will be the Radial Stresses & also the blank holding force will be more. Thus the deformations would be higher for the higher blank sizes.

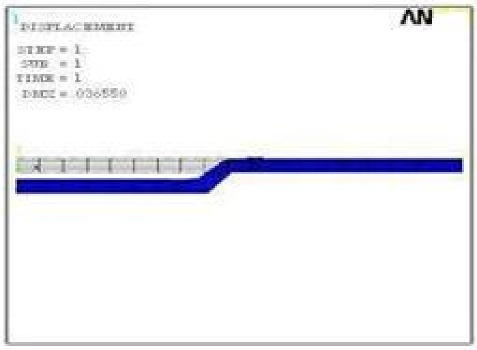

Fig.4.4. Deformation of R_j=90mm blank

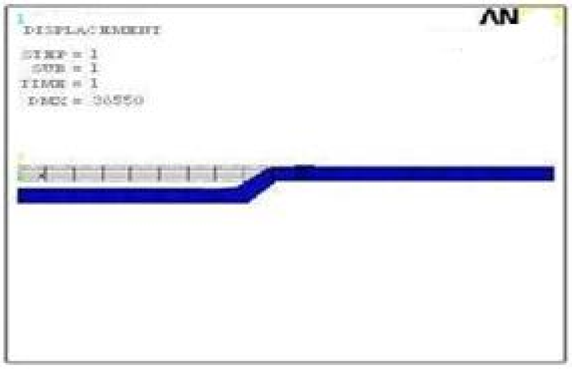

Fig.4.5 Deformation of R_j=95mm blank

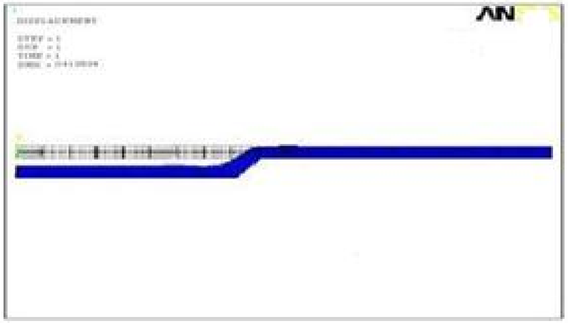

Fig.4.6 Deformation of R_j=100mm blank

4.7 Graphical Comparison Of Theoretical & Fea Radial Stresses For R_J=90, 95 & 100mm Blank Sizes

Fig.4.7 shows the comparison of Theoretical & FEA Radial Stress values for R_j=90 mm blank size. The FEA values are slightly higher than the Theoretical Values. The FEA values obtained are nearly 10-12 % higher than the Theoretical Values.

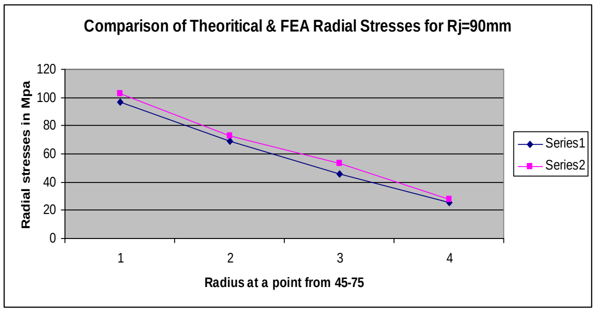

Fig.4.7 Comparison of Theoretical (series1) & FEA (series2) Radial Stresses for R_j=90mm

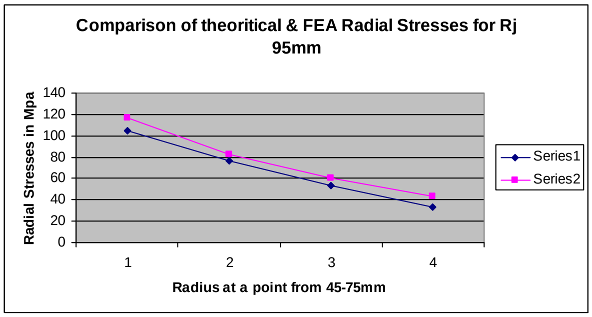

Fig.4.8 Comparison of Theoretical (series1) & FEA (series2) Radial Stresses for R_j=95mm

6. CONCLUSIONS

Deep drawing is one of the metal forming processes, it is widely used in industry for making seamless shells, cups and boxes of various shapes. The Hydraulic pressure can enhance the capabilities of the basic deep drawing process for making metal cups and this hydraulic pressure contributes positively in several ways to the deep drawing process. The pressure is generated in fluid due to punch movement within the fluid chamber and directed through the bypass path to blank periphery and is to reduce tensile stresses acting on the wall of the semi drawn blank. In this process the radial and hoop stresses are produced in the blank due to 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.

REFERENCES

[1] Panknin, W."Mulhouse, "Principles of the hydro form process," Mittleilungen der forschungrges Blechvererbeitung, Vol.24 pp.269-277 (195

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

[3] B.Larsen, "Hydromechanics forming of sheet metal", Sheet Met.Ind. pp.162-166 (Feb. 1977).

[4] S.H. Zhang, J. Danckert, "Development of Hydro-Mechanical Deep Drawing", Journal of Materials Processing Technology Vol. 83, pp.14-25 (1998).

[5] K.Nakamura, "Sheet metal forming with hydraulic counter pressure" in Japan, Ann. CIRP Vol.36 (1) pp.191-194 (1987).

[6] A. EL-DOMIYATI, M.A. SHABARAT, 1993 "Improvement of Deep Draw ability by Radially Pressurised Fluid", Int. J. Mach. Tools Manufact. Vol. 35, No.5. pp. 739-749,(1995).

[7] Lihui LANG, Joachim danckert, Karl Brain Nielsen," Investigation into Hydro dynamic Deep Drawing assisted by Radial Pressure part-I. Experimental Observations of the forming process of Aluminum Alloy", Journal of Material Processing Technology Vol.148 pp.119-131 (2004).

[8] Lihui LANG, Joachim DANCKERT and Karl Brain NIELSEN, "Forming Process of Strong An-Isotropic Material based on the Hydrodynamic Deep Drawing with Radial Pressure", J. of Mater. Sci. Technol., Vol.21 No.5, 2005.