CHAPTER 2

LITERATURE SURVEY

The large quantity of cups are produced from a sheet metal by using deep drawing process. In this process sheet metal blank is drawn over a die by a punch. The radial stresses are produced in the flange in radial direction, hoop stresses are produced in the flange in circumferential due to punch force applied on it [1].The blank is supported with sufficient blank holding pressure for avoiding the wrinkling in the flange[2]. For improving of process performance and stress analysis of the process which can be done by using special drawing processes such as hydroforming deep drawing process [3], hydro mechanical forming deep drawing process[8], counter pressure deep drawing process [15], hydraulic pressure augmented deep drawing process[16] .

In conventional deep drawing, the process in carefully selection of process parameters enable in drawing of a good quality cup at a higher draw ratio. The increase in the limiting drawing ratio is due to slight improvements in the tooling, optimum design of the radius of punch and radius of die and proper lubrication of the die surfaces [17]. The blank holder force is to be controlled at each stage of drawing of a cup.

In the principle of plastic theory, actions of plastic forming and hydro forming depends on the balance of forces that are opposite to deformation. The success of hydroforming action depends on the forming force, the blank holder force, geometry of work piece and coefficient of friction. Analysis of hydroforming at the plasticity area is possible because of actual knowledge application on deformation processing for unconventional or conventional processing as the values of individual parameters [15,18-23] can be compared.

In hydromechanical deep drawing , the strain force is achieved by fluid and then forming of final piece is obtained by hard tool. In hydroforming, the strain force is carried by fluid so form is defined by cast geometry. According to conventional drawing out, where there is contact between the working piece and tool, but in hydroforming there is presence of fluid contact between sheet metal and the tool and also it prevents the surface of metal sheet from failure so that the parts can get quality outside surface and covering of outside surface can be obtained.

The conventional deep drawing process is as shown in fig.2.1. In this figure the frictional forces and other forces are shown. In conventional deep drawing proces, the influence of friction depends on the lubrication at the contact surface between the preparing piece and tool. In an unpressed fluid like oil, it is used for a lubricating at the contact surfaces by which the friction influence is smaller and it directly influence on the value of force of forming and on the blank holder.

In the hydroforming process the force depend on the pressure of fluid and surface of contact at which the fluid acts. The Pressure force [4]can be obtained by

$$F_p^* = pA_p \qquad [2.1]$$

where F_p^* is the pressure force, p is the fluid pressure and A_p is the surface area of drawing.

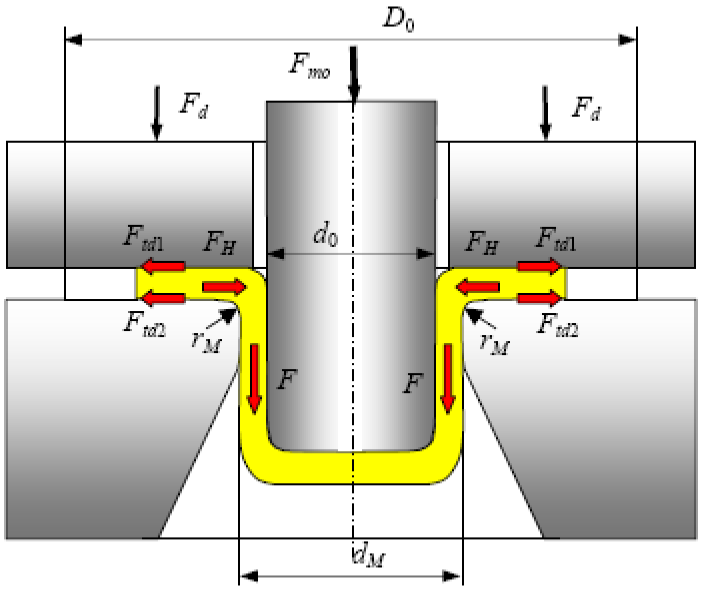

Fig.2.1 Conventional deep drawing process - frictional forces [1]

In the mechanical forming or conventional deep drawing process the force F [1] is given by

$$F = k_{sr} A_s \qquad [2.2]$$

where k_{sr} is the mean specific resistance , A_s is the area of contact surface The classical deep drawing process is needed higher intensity of strain force than in the hydroforming due to higher contact friction and smaller level of process energy utilization.

In the process of sheet metal forming by deep drawing out, when friction is observed, it is not possible to choose one value for coefficient of friction μ, that is adopted to all the points of working piece at the strain process. In the deep drawing process, the friction between sheet metal blank and blank holder, sheet metal and punch and in between the sheet metal and matrix radius of drawing out piece.

The stresses at the wreath of part in the area of angle can cause sheet metal wrinkles or bending occurrence. When there are very large wrinkles and they can not be flattened at the cycled edge of drawing out ring, material flow into the ring opening can be stopped and the part is destructed. Elimination of wrinkles on the wreath volume can be done by using sufficient blank holder pressure. This blank holder pressure value is also defined with in the limits. The wrinkles are occurred in flange when the blank holder pressure value is lower than the limit values and the destruction is occurred in the flange when the blank holder pressure value is higher than the limit values.The blank holder pressure can be changed in the defined limits.

In the hydroforming process the blank holder pressure [15, 24] is given by

$$P_h = 25\times10^{-3}\,\sigma_m\left[\left(\frac{D}{d}-1\right)^3 + 0.005\frac{d}{t}\right] \qquad [2.3]$$

Where P_h is the blank holder pressure, σ_m is the hardness of material, D is the diameter of blank, t is the thickness of blank and d is the diameter of punch or diameter of the piece that is drawn out

The blank holder force can be achieved by simple formula

$$F_h = P_h\,A_h$$

and $$A_h = 0.785\left[D_0^{\,2} - (d_M + 2r_M)^2\right] \qquad [2.4]$$

where F_h is the blank holder force, A_h is the contact surface area of blank holder , r_M is the corner radius on die , D_0 is the diameter of blank and d_M is the diameter of die opening.

The total force at the conventional or Mechanical deep drawing process [24] is given by

$$F_{mo} = F_p + F_{td} + F_{tk} + F_s \qquad [2.5]$$

Where F_{mo} is the total force in conventional deep drawing process F_p is the plastic forming force , F_{td} is the friction force of blank holder, F_{tk} is the splitting friction force of sheet metal over the radius of die opening and F_s is the bending force over corner radius on die.

F_{ho} is the total hydroforming force

At the hydroforming, the part height is increased due to placing of forming force. As the forming force placed is the function of increasing part height. The maximum forming force is obtained in the hydromechanical deep drawing process after the bending process. The total hydroforming force [15] is given by

$$F_{ho} = F_{mo} + F_{pf}$$

$$\Rightarrow \quad F_{ho} = F_p + F_{td} + F_{tk} + F_s + F_{pf} \qquad [2.6]$$

Where F_{ho} is the total hydroforming force , F_{pf} is the fluid pressure force.

The quality of process and stability depend on numerous process parameters like friction, blank holder application and so on in conventional or unconventional metal plastic processing. At the hydroforming, the significant influence on stability of forming and quality has the relation of force of axial strain and internal pressure of fluid. At the mechanical forming, stability of process depends mostly on conditions of tribology of real process.The process stable depends on the intensity of lubrication and well defined mean quality. The increase of contact tangential stress can appear as frictional force that leads the process into unstable area when it comes to holes and cutting out of material of working piece[22,24] due to changes of tribology stands.

In the hydroforming, contact friction is less as to compare with the mechanical forming. Hence it is not difficult to analyze the wear of lower tool at the process of forming with fluid as the surfaces are in contact with fluid region.Some of the sheet metal forming processes are replaced by hydromechanical deepdrawing process to which gives improved quality of the product. Hydromechanical deep drawing technology was first developed in 1890 [25]. However, the real development began after the second world war. Early research work began mainly in Germany and Japan.

In 1955, investigations done on hydromechanical deep drawing process by Japanese researchers. The pressure lubricated deep drawing was proposed by Kasuga et al. The radial pressure deep drawing method and hydraulic counter-pressure fluid-forming process was introduced by Nakamura and Nakagawa [15].German researchers started their work on above processes to prevent the fluid leakage between blank and die surface and on the die surface a seal ring was used [15, 26-27].

Kang investigated for forming of a box work pieces and parabolic shells with the help of hydromechanical deep drawing process and also the hydromechanical ironing process. In Harbin Institute of Technology, for hydromechanical deep drawing a new press of 2000 kN capacity has been installed. Also in a Hong Kong firm installed the specialized facilities on a capacity of press 5000 kN. Larsen [28] made some investigations into the hydrodynamic deep drawing process (aquadraw). The pressure fluid medium used is oil. When the fluid pressure is reached to threshold pressure, the oil is pressed out under the blank flange, the flow of oil acts as a lubricant and to obtain the minimum friction in between the die and blank flange. At the same time, the critical area of blank moves from its bottom part to the area around the radius of die. The pressure pump is used for pressurization of fluid chamber before the punch moves down to the blank. There is no contact occurred between the die radius and blank, which is the better in the deformation due to pressure pump and also saves time due to the deformation occurring before reaching the threshold pressure. The valve is used for regulating the fluid pressure. Experimentally determined the distribution of strains, the optimal preliminary pressure and the radius of die effect on the process.

The fluid assisted blank holder concept was introduced in deep drawing process by Yossifon and Tirosh [29]. The set up was similar to hydroforming process, a rigid punch and die used and fluid pressure is exerted on the flange. The hydromechanical deep drawing process required the higher drawing force and higher blank holder force compared with the conventional deep drawing process [26,30].This is main disadvantage of hydromechanical deep drawing process.

Bakagawa and Amino analysis [31], the following features of hydro mechanical deep drawing process [25,26-28,31,32]: (a) it has a holding effect of friction (b) it has a effect of resistance reduction (c) it has an effect of initial extension and this process can improve the limit of fracture (d) The process also has a prevention of wrinkle effect, the unsupported portions are subjected to bulging pressure, causing circumferential tensile stresses, which prevents wrinkles from occurring (e)The process is flexible [33].

The hydro mechanical deep drawing process reported by Buerk [26], the seal ring was used in between die surface and blank flange. The deformation is a mixing of stretching, bending and compressing. The fluid pressure is increased rapidly due to punch moves down and also the due to fluid pressure, the upward bead is formed at the free portion of the blank. The radial and compression structure produced in the flange is due to upward bead.

Some improvements were made to deep drawing by radial pressure when forming of the very long cups with conventional deep drawing process by Yang et al. [9]. The high drawing ratio is obtained with a separated radial pressure system which was used for getting a small difference between optimal chamber pressure and optimal radial pressure.

Hydromechanical drawing process was developed by SMG Engineering [33] and referred to it as active hydromechanical forming. It includes pre bulging, closing of the dies and increase of the fluid pressure. From this methodology, to avoid the buckling or vibration during running the large outer panel parts, it requires high stiffness and enhancement of stiffness. The new technology can be utilized for complex parts forming, the strain hardening is higher due to deformation can be improved. The quality product is improved due to increased stiffness, reducing in weight and costs. In the active hydro mechanical process, the active fluid medium is used an oil in water emulsion.

ABB [34,35] presented the boxes, cylindrical cups and shapes of parabolic parts in one step through fluid deep drawing process. This process has greater drawing ratio and less material thinning than conventional process.

Determination of the pressure of fluid in the chamber and this was used for lifting the surface of blank from the die radius in aquadraw process was given by Larsen [28]

$$P_f = 2k_0 t \left(\frac{2 \ln m}{r_d} \right) \qquad [2.7]$$

Where P_f is the fluid pressure , k_0 is the yield stress in pure shear, t is the thickness of blank , m is the drawing ratio and r_d is the radius of die opening.

Gelin and Delassus [30] reported a theoretical estimation of the pressure of fluid under the blank holder for the aquadraw process.

Determined the stresses in the blank and lubricant film thickness in the process and demonstrated the effect of fluid chamber volume in the process and blank velocity in radial direction.

A finite element analysis simulation of hydromechanical process was reported recently [36]. The simulation part of an automotive engine is oil pan upper was formed by an explicit non-linear finite-element code. Simulating the punch, blank, the die and the blank holder using shell elements. The path of pressure of fluid and the blank holding force were obtained by the simulation.

J. An, A.H.Soni [36], performed FEM simulations of drawing of long cups by using the radial pressure drawing process. The numerical simulations have predicted the chamber pressure optimum, the optimum radial pressure and the distribution of thickness. These authors [9] done on Finite element method analysis of the axisymmetrical deep drawing process.

Nakamura, et al. [37] reported the techniques applied in hydromechanical drawing the panels of automotive body. They discussed on how to integrate bending and drawing, how to use only one half die half, how to wrinkles are reduced and surface quality is improved.An Finite element analysis simulation [38] for fluid cell process for a flanging operation. In this process rubber die was used, the fluid pressure is passed through layers of membrane of the rubber to work piece. The punch role is replaced by rubber and the blank is forced to die contact and then performed the flanging operation.

Asakura et al. [39] performed the deformation process of punch less drawing with lateral fluid pressure of fluid using method of matrix by a numerical simulation. Under different tool conditions, behaviour of blank in the deformation and contact behaviour at die shoulder. Theoretically estimated the optimum die radius for punch less drawing process.

In hydraulic counter pressure deep drawing was carried out by the H.Amino, K. Nakamura, T. Nakagarva, [40]. The forming is done by the die cavity filled with fluid as shown in fig.2.2. As forming is carried out, the pressure of the fluid rises, the relief valve works so that the fluid flows out or the fluid flows out from the gap between the flange of the sheet metal and the die surface through the die shoulder.

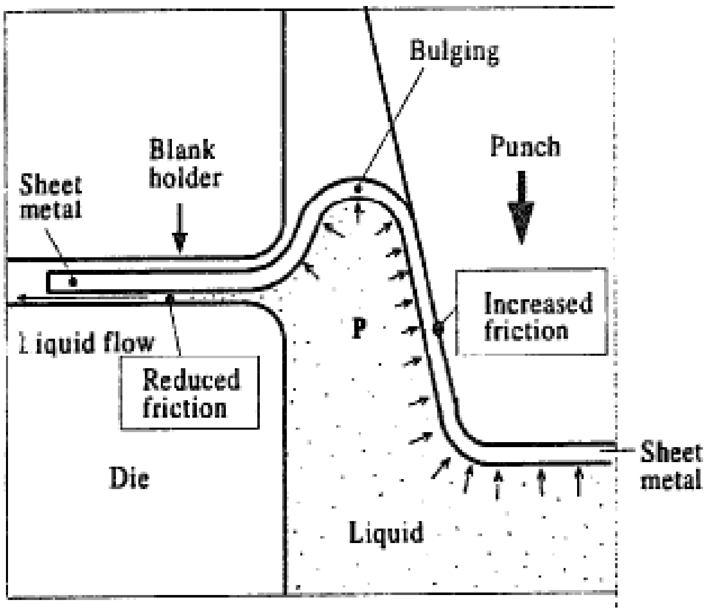

Fig.2.2 Hydraulic counter pressure deep drawing process [40]

The main difference between normal deep drawing process and counter pressure deepdrawing process is the die cavity filled with fluid and fluid pressure applied on flange during the forming.

The change of liquid pressure in counter pressure deep drawing process during forming of a flange [41]as shown in fig.2.3. In the beginning when the punch moves and enters the die and starts the forming, the liquid pressure increases rapidly. At the same time,the hydraulic pressure exerts on the sheet metal is to be pressed firmly against the base of the punch. The liquid pressure reaches the relief valve setting pressure. The valve allows the fluid and leaves from the valve. In addition to that, setting of the valve pressure to a strong level, through the die shoulder the liquid will flow outside from the flange part. The blank holder force mainly effects on conditions for fluid flows out from the flange.

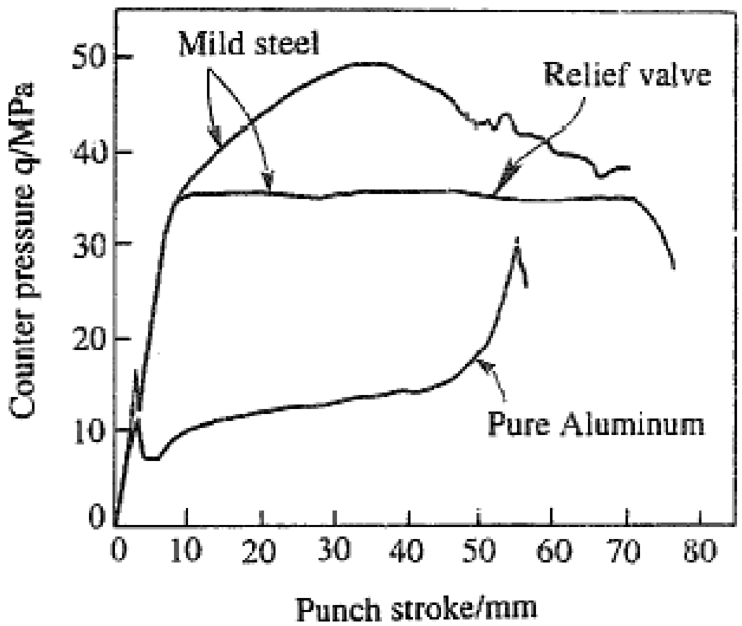

Fig.2.3 Variation of hydraulic pressure with punch stroke [41]

In whichever case, the punch moves, as the liquid flows out so that constant level maintained in the hydraulic pressure. The liquid pressure drops when the forming of flange reaches the final stages, the liquid flows out from the flange more easily.The punch force becomes high, in addition to that hydraulic pressure is added to the deep drawing force. To prevent the fluid flow from the flange, for that fluid pressure imposed on the flange a large blank holding force is required.

In hydraulic counter pressure deep drawing, due to fluid pressure the overhang section is stretched and the sheet metal is pushed against the side of the punch in the preliminary stages of the forming process. In the radial direction elongation is occurred and in circumferential direction absorption of extra material is occurred due to stretching. At the same time, the parts at risk of breakage move to the external circumference and rises in the breakage resistance. The elongation of the overhang section increases in the radial direction due to increase in the blank holding pressure, so that the extra materials in the circumference direction can be absorbed.

In counter pressure deep drawing process the tension in the flange in radial direction is to be increased in the forming process, and it reduces the spring back effect and also controls localized reduction in the thickness at the shoulder of punch. Furthermore, the side walls thickness increases towards the formed parts rims. It results in applying a greater tension in the radial direction throughout the forming process as well as on the external circumference and reduced in thickness of external circumference. The pressure of fluid is applied on the periphery of the sheet of flange, the flow of liquid to the portion of flange will occur readily more and performed deep drawing easily.

This process has advantages where forming restrictions are extent in large to be clear, in shallow complex shape forming surface distortion is prevented, difficulty in to form materials, female die is eliminated so die costs are reduced.

In a novel process recently developed by El-Sebaie and Yang et al. The effects of work hardening, anisotropic material properties and fluid pressure on the deformation are studied through the finite element analysis in this process [9,42].In the analysis of radial drawing of a flange in deep drawing process[42-44], the sheet metal blank thickness is assumed to be constant throughout the process. The plastic strains in radial $d\varepsilon_r$ and circumferential directions $d\varepsilon_\theta$ on the deforming metal in the flange at generic radius r are given by

$$d\varepsilon_\theta = d\varepsilon_r = \frac{dr}{r} \qquad [2.8]$$

using Tresca's yield criterion, it can be shown easily that:

$$\sigma_r - \sigma_\theta = \sigma_0$$

but $\sigma_r = \sigma_0 \ln\beta$ and $\sigma_\theta = \sigma_0 \ln\beta - \sigma_0$ [2.9]

where σ_r is the radial stress , σ_θ is the hoop stress, σ_0 is the yield stress and β is the drawing ratio.

The work done per unit volume on the flange element dW is given by $dW = \sigma_r\, d\varepsilon_r + \sigma_\theta d\varepsilon_\theta$

$$\Rightarrow dW = -\sigma_0\left(\frac{dr}{r}\right) \qquad [2.10]$$

The total plastic work done per unit volume of sheet metal deformed on the flange W is obtained by integrating the eq.(2.10) and applying limits D/2 to d/2, D is the diameter of blank and d is the inner diameter of cup we get

$$W = \sigma_0 \ln\left(\frac{D}{d}\right) = \sigma_0 \ln\beta \qquad [2.11]$$

The drawing stress in fluid forming process or unconventional forming process is given by

$$\sigma_D = \sigma_0 \ln\beta - P_a \qquad [2.12]$$

Where P_a is the pressure of the fluid pushing on the blank Periphery is, σ_D is the drawing stress. The drawing stress is reduced due to hydraulic pressure applied on the edge of the blank during the process. This effect helps in the initial stages of drawing process by drawing stress reducing to a value reached to the initial yield stress. Due to this at punch nose radius, initial thinning of the cup wall is reduced. In hydrodynamic deep drawing process the distribution of pressure of liquid through a circular plane with the gap g is maintained between rim block of die and blank holder is given by [45]

$$P_b = 1.9\frac{\mu q}{g^3}\ln\left(\frac{r_0}{r_i}\right) \qquad [2.13]$$

Where P_b is the pressure of liquid along the blank rim or liquid pressure loaded onto the lower surface of the blank, μ is the dynamic viscosity of liquid, q is the discharge of liquid, r_0 is the gap external radius and r_i is the gap internal radius. The discharge $q = \pi r_p^2 v$, in which r_p is the radius of punch and v is the speed of punch. In hydrodynamic deep drawing process assisted by radial pressure [46], the sheet drawing force F_D in the sheet deformation of sheet is given by

$$F_D = F_{P_1} - 0.785 d_p^2 P_S \qquad [2.14]$$

In which F_{P_1} is the total punch force, P_s is the pressure of liquid in the die cavity and d_p is the diameter of punch.

In this study, hydroforming process is analyzed for regular polygonal boxes. In this process the pressure of fluid with respect to punch stroke of punch is predicted. Z.Marciniak , J.L.Duncan [47] stated that, drawing stress of the cup body during hydrodynamic deep drawing process assisted by radial pressure at any time is given by following expression

$$\sigma_z = \frac{F}{\pi d_p t} = \sigma_r + \sigma_f + \sigma_w + P \qquad [2.15]$$

Where σ_z is the drawing stress of cup body, d_p is the diameter of punch, σ_f is the frictional stress due to blank holder, σ_w is the stress caused by bending and unbending, σ_r is the radial stress, P is the fluid pressure, t is the thickness of blank and F is the drawing force.

In a pure radial deep drawing process the coefficient of friction between the flange and both blank holder and die plays a major role. But in the case of deep drawing assisted by pressurized fluid the coefficient of friction between the flange and both blank holder and die is neglected. Hence blank holder pressure is equal to radial pressure of fluid [48,15].The blank holding pressure is used to prevent wrinkling that depends on drawing ratio, relative sheet thickness and material of sheet.

The magnesium alloys are generally divided into wrought alloys and cast alloys. For the comparison in between them, the wrought alloys are higher in strength and ductility than cast alloys.The magnesium alloys are specially considered for their lowest density 1.74gm/cm^3 and are mostly utilized for production of light weight materials which decrease the automobile weight in construction. Presently the automobiles parts are made from magnesium alloys through die casting.

The complex geometry of parts are manufactured from this technology of die casting. However, the required mechanical properties of these alloys are obtained in manufacturing by forming process. Using this technology for manufacturing these parts are characterized by mechanical properties which are advantageous and fine grained microstructures without pores [49].The restriction is obtained in processing of magnesium alloys using forming technology due to insufficient knowledge about technology of forming and also how to apply suitable parameters of process [50,51].

The application of sheet metal of magnesium components in construction of automotive body is to obtain a high potential. Substitution of magnesium alloy sheets in place of conventional sheet metals to obtain weight saving. The hydro forming and spin forming process are used for production of lighter vehicle structures by magnesium alloys than casting process [52]. The Siebel [53] investigated that formability of magnesium alloys increases when the range of temperature of magnesium alloys are 200 to 2258^{0}C. It also depends on the composition of alloying element. The magnesium alloys used in electronics, aerospace, automated material handling equipments, high speed computer parts and automobiles due to its specific strength is high and less weight [54,55].The magnesium alloys shows less ductility at room temperature and increasing in ductility and deep drawabilty by thermal activation[56-60].

Based on the above entire literature survey, the summary of the conventional deep drawing process and different types of hydroforming deep drawing processes is discussed. In this hydroforming deep drawing process the radial, hoop and drawing stresses are not expressed in terms of viscosity, shear stress of fluid and also effect of viscosity on these stresses are not studied. But in the hydroforming deep drawing processes viscosity is influenced on these stresses. Hence, in the present work I have developed the mathematical formulations for radial, hoop and drawing stresses in terms of viscosity and shear stress of fluid and also various parameters of the process. Then study on the effect of viscosity, blank radius, blank thickness, punch speed, fluid pressure and various parameters of the process on these stresses. The fluid pressure is estimated by Flotran CFD analysis software. The Evaluation of these stresses through fluid assisted deep drawing process from theoretical analysis and Ansys L-S Dyna finite element analysis simulation software and the results are correlated.