

ABSTRACT

The improvement in the deep drawing manufacturing process with latest methodologies leads to developments in the automobile and other sheet metal industries. Still today, this process of analysis and design is an art than science. This is due to involvement of large number of process parameters and their interdependence. This is one of the important significant manufacturing processes of sheet metal forming for producing a high variety of parts of automotive and parts of aerospace as well as products for consumers. Deep drawing process is the compression-tension forming process involving wide spectrum of operations and flow conditions. The deep drawing process features can be developed by fluid pressure for producing the metallic cups. In the fluid assisted deep drawing 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.

In the fluid assisted deep drawing process the hydraulic pressure is to be applied on the periphery of the blank in radial direction for successful formation of cup. The fluid is placed in the die cavity and punch chamber, which are connected through bypass path in the die. The gap is provided between the blank holder and die surface for the fluid and blank movement. The punch movement in the fluid chamber produces pressure in the fluid. This pressurized fluid is directed through the bypass path and acts radially on the blank

periphery. The blank is supported by pressurized viscous fluid in between blank holder and die surface within the fluid region in the gap and a fluid film is formed on the upper and lower surfaces of blank which reduces frictional resistance.

In this process the radial stresses are produced in the circular blank in radial direction and hoop stresses are produced in the circular blank circumferentially. These stresses are produced in the blank due to punch force applied on it. Then the blank is moved to center of the gap with in the fluid region. The shear stresses are acted by viscous fluid on the both sides of semi drawn blank surface. These shear stresses are equal in magnitude and direction on blank and these are acting towards the center of job axis. The wrinkling is reduced in the blank due to the support of high pressurized viscous fluid.

The height of the gap is more than the thickness of blank. The pressure of fluid is acting radially on surface of blank during the process. The radial pressure of fluid is controlled by the blank holder pressure. As these two pressures are equal, the deformation of blank is uniform to get a required shape and also it prevent the blank failure during deformation. In this process the uniform thickness of sheet is obtained even after deformation in plastic region. The pressure of fluid depends on punch speed and radius.

The products obtained in this process are with a good surface finish, high quality surface, high accuracy in dimensional and there

are no scratches developed on outer side of cup. It is possible to obtain drawing ratios higher than conventional deep drawing process.

In fluid assisted deep drawing a mathematical formulation is developed for the radial stresses, hoop stresses, drawing stresses and drawing forces of circular blanks with the parameters such as viscosity, blank radius, thickness and process parameters.

In the present process the magnesium alloys AZ31B-0, HK31A-H24, AZ61A-F and the fluids such as castor oil, olive oil and heavy machine oil are used. The influence of viscosity, process parameters, blank radius and thickness on radial, hoop and drawing stresses are studied. The fluid pressure is determined by using Ansys Flotran CFD software. The pressure of the fluid is acted radially on periphery of blank and it is also equal to blank holding pressure.

The radial stresses are determined for magnesium alloys blanks at different radii and constant thickness at different radial distances with castor oil as medium using radius of punch ($r_p = 25\text{mm}$) and radius of die opening ($r_d = 30\text{mm}$). The castor oil pressure is obtained from flotran CFD software and is 65N/m^2 at punch speed (u) = 10mm/sec .

The radial stresses decrease with increase in the radial distance of the blank from the job axis. The radial stresses increase with increase in the radius of blanks in magnesium alloys. Among the magnesium alloys high radial stresses are obtained in AZ61A-F alloy and least radial stresses are obtained in AZ31B-0 alloy.

And, also the radial stresses of magnesium alloys are determined

at constant radius and constant thickness of blanks with three fluid mediums such as olive oil, heavy machine oil and castor oil using punch radius ($r_p = 25\text{mm}$) and the results are compared. The fluid pressures obtained from Flotran CFD software for the fluids such as olive oil, heavy machine oil and castor oil are 4 N/m^2 , 29 N/m^2 and 65 N/m^2 respectively at punch speed ($u = 10\text{mm/sec}$) and radius of die opening ($r_d = 30\text{mm}$).

The radial stresses of magnesium alloys are inversely proportional to the viscosity of fluids. The highest radial stresses are obtained in magnesium alloys in olive oil and the lowest radial stresses are obtained in magnesium alloys with castor oil as medium.

Based on the fluid pressures, the radial stresses of magnesium alloys are inversely proportional to the pressure of fluids. The highest radial stresses are occurred in magnesium alloys with olive oil pressure and the lowest radial stresses are obtained in magnesium alloys with castor oil pressure. The higher radial stresses gives high drawing ratio and minimize the drawing time.

The hoop stresses are determined for magnesium alloys blanks at different radii and constant thickness at different radial distances with heavy machine oil using radius of punch ($r_p = 40\text{mm}$) and radius of die opening ($r_d = 45\text{mm}$). The heavy machine oil pressure obtained from Flotran CFD software is 58.47N/m^2 at punch speed ($u = 10\text{mm/sec}$).

The hoop stresses increase with increase in the radial distance of the blank from the job axis. The hoop stresses decrease with increase in the radius of blanks of magnesium alloys. Among the magnesium alloys high hoop stresses are obtained in AZ61A-F and least hoop stresses are obtained in AZ31B-0. The higher hoop stresses give higher forming limits.

The drawing stresses are determined for magnesium alloys blanks for different radius at different thickness of blanks with the heavy machine oil as medium using radius of punch ($r_p = 35\text{mm}$) and radius of die opening ($r_d = 40\text{mm}$). The heavy machine oil pressure obtained from Flotran CFD software is 35N/m^2 at punch speed ($u = 10\text{mm/sec}$).

The drawing stress in the cup wall at die entrance radius along the drawing direction is equal to radial stress occurred at beginning of die corner in radial direction. The radial stresses obtained at the radius of die opening in radial direction is equal to the drawing stress in the cup wall at die opening radius along the direction of drawing.

The drawing stresses increase with increase in the radius and thickness of blanks of magnesium alloys. Among the magnesium alloys the high drawing stresses are obtained in AZ61A-F and least in AZ31B-0.

The drawing stresses of magnesium alloys blanks at different radius and constant thickness with three different oils as medium using radius of punch ($r_p = 40\text{mm}$) and radius of die opening ($r_d =$

45mm) are determined and comparisons are made. The fluid pressures are determined from Flotran CFD software for the fluids of olive oil, heavy machine oil and castor oil are 14.134 N/m², 58.47N/m² and 121.24 N/m² respectively at punch speed of 10mm/sec.

The drawing stresses of magnesium alloys are inversely proportional to viscosity and pressure of oils. The high drawing stresses are occurred in magnesium alloys with olive oil medium and least drawing stresses are occurred in magnesium alloys with castor oil medium. Among the magnesium alloys highest drawing stresses are obtained in AZ61A-F and lowest drawing stresses are obtained in AZ31B-0.

Variation in fluid pressure is evaluated with different punch radius at constant punch speed for different oils such as olive oil, heavy machine oil and castor oil as medium in fluid assisted deep drawing process. The pressure of oils increase with increase in the punch radius. Among the three oils, the pressure produced is higher in castor oil and lower in olive oil. The pressure of oil depends on the viscosity. The induced pressure in the oil is higher with high viscosity oil and the generated pressure in the oil is lower with low viscosity oil.

Also the fluid pressure variation with different punch speed at constant punch radius for these three different oils in fluid assisted deep drawing process is studied. The fluid pressure increases with increase in the punch speed. The high pressures are obtained in castor oil and low pressures are obtained in olive oil. In fluid assisted

deep drawing process fluid pressure is the dominant parameter for failure and success of forming of cups from the cylindrical blanks. The undesirable wrinkles are formed in the flange due to an insufficient pressure of fluid and premature tearing produced in flange due to excess fluid pressure. So appropriate pressure of fluid is used for success in forming of cups in this process. This pressure of fluid is used to evaluate the blank holding pressure. The radial stresses, hoop stresses and drawing stresses depends on the process parameters, yield stress of magnesium alloys, fluid pressure and viscosity. In this analysis of process, there is no pump required for supplying the pressurized liquid to this process.

This research work is carried through mathematical modeling and finite element analysis. The results obtained with analytical solutions are correlated with that of finite element solutions and the variation is with in 4% to 6%.