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Design of Convectional Deep Drawing and hydro Forming Deep Drawing via Experimental Finite Element Analysis

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Abstact:

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.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 deepdrawing 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 t he 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 thecup, the drawing being performed in a simultaneous push-pull manner making it possibleto achieve higher drawing ratio‘s then

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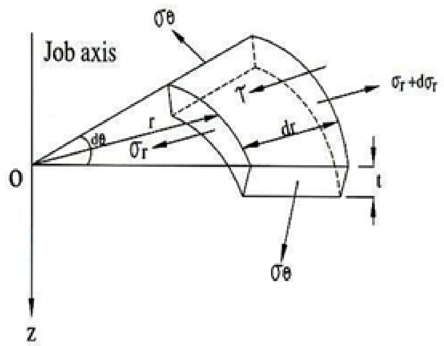
those possible in the conventional deep drawingprocess. The pressure on the flange is more uniform which makes it easiest to choose theparameters in simulation. The pressure in the die cavity can be controlled very freely and accurately, with the approximate liquid pressure as a function of punch position, 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, de lays the on set 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.

3.METHODOLOLY OF EVALUATION OF RADIAL & HOOP STRESSES:

Initially the Radial & Hoop Stresses are calculated theoretically in terms of viscosity of fluid using following equations. These equations are derived form the Thick & Thin cylinder theory in terms of viscosity.



3.1 EVALUATION OF RADIAL STR ESSES IN TERMS OF VISCOSITY:

$$\sigma_r = \sigma_0 \ln\frac{R_j}{r} + \frac{4 \neq u}{h + t}\frac{(R_j + r)}{t}$$

The equation (3.1), [7,15] represents the effect of viscosity of fluid on the distribution of Radial stresses in the blank during fluid assisted deep drawing process.

3.2 EVALUATION OF HOOP STR ESSES IN TERMS OF VISCOSITY:

$$\sigma_\theta = \sigma_0 \left(\ln\frac{R_j}{r} + 1\right) + \frac{4 \neq u}{h + t}\frac{R_j + r}{t}$$

The equation (3.2), [7,15] represents the effect of viscosity of fluid on the distribution of Hoop stresses in the blank during fluid assisted deep drawing process.

3.3 THEOR ETICAL EVALUATION OF RADIAL & HOOP STRESS ES:

Punch speed (velocity of blank) u =9mm/sec,
Height of the gap between the Blank holder & Die, h =12 mm,
Thickness of blank, t = 3mm,
Radius of blank rj= 90mm, 95mm and 100mm
Radial stresses at the point, r =45mm, 55mm, 65mm and 75mm
Type of materials used: Magnesium alloy (AZ31B-0)
Yield Stress of the Alloy, σ o= 140 Gpa
Type of fluid used: Caster oil
Viscosity ≠=0.985N–sec/m^2

3.3.1 RADIAL S TRESSES:

Radial stress distribution in Rj= 90 mm blank
At r 45 = 97019940.9 N/m^2
55 = 68879954.0 N/m^2
65 = 45499967.17 N/m^2
75 = 25524998.25 N/m^2
Radial stress distribution in Rj= 95mm blank

At r 45 = 104609950.6 N/m^2
55 = 76439947.47 N/m^2
65 = 53115960.6 N/m^2
75 = 33094428.93 N/m^2

Radial stress distribution in Rj= 100mm blank

At r 45 = 111791005.2 N/m^2
55 = 83697121. 01 N/m^2
65 = 60309562.3 N/m^2
75 = 40275457.31 N/m^2

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At r 45 = -42959453.82 N/m^2
55 = -71053338.05 N/m^2
65 = -94440896.77 N/m^2
75 = -114475001.7 N/ m
Hoop stress distribution in Rj= 95mm blank

At r 45 = -35390049.41 N/m^2
55 = -63483933.64 N/m^2
65 = -86871492.36 N/m^2
75 = -106905597.3 N/m^2
Hoop stress distribution in Rj= 100mm blank

At r 45 = -28208994.76 N/m^2

55 = -56302878.99 N/m^2
65 = -79690437.71 N/m^2
75 = -99724542.69 N/m^2

4.3 MAGNESIUM ALLOYS & ITS DES CRIPTION:

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Magnesium is the highest of the commercially important metals, having a 3 density of 1.74 gm/cm and specific gravity 1.74 (30% higher than aluminum alloys and 75% lighter than steel). 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°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. Thick sections are required to provide adequate stiffness, but the alloy is so light that it is often possible to use thicker sections for the required rigidity and still have a lighter structure than can be obtained with any other metal. Cost per unit volume is low, so the use of thick sections is generally not prohibitive. 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. Applications for magnesium alloys include use in aircraft,missiles, machinery, tools, and material handling equipment, automobiles and high-speed computer parts. On the other positive side, magnesium alloys have a relativelyhigh strength-to-weight ratio with some commercial alloys attaining strengths as highas 300 Mpa.

High energy absorption means good damping of noise and vibration.While many magnesium alloys require enamel or lacquer finishes to impart adequateconnection resistance, this property has been improved markedly with thedevelopment of high purity alloys. For this analysis Magnesium alloy considerednamely, AZ31B-0

4.3.1 COMPOS ITION OF AZ31B-0

Material Min- Ma x Compos ition %
Al : 2.5-3.5
Zn : 0.7-1.3
Mn : 0.2-1.0
Mg : Balance

4.3.2. MECHANICAL PROPERTIES AZ31B -0

Elastic Modulus (Gpa) : 45
Yield Strength (Mpa) : 140
Ultimate Tensile strength (Mpa) : 240
Poisons Ratio : 0.35
Hardness : 400-600 Hv (Rc 36-55)

4.4 FLUID US ED IN ANS YS FLOTR AN -CFD& ITS PROPERTIES:

Caster oil:
Density : 960 Kg/m 3
Viscosity : 0.985 N-sec/m 2
Olive oil:
Density : 910 Kg/m 3
Viscosity : 0.081 N-sec/m 2

4.5 STRUCTURAL ANALYSIS PROPERTIES US ED IN ANS YS:

Magnesium Alloy AZ31B-0:
Elastic Modulus : 45 GPA
Poisson‘s Ratio : 0.35

4.6 PROCESS PARAMETERS US ED IN ANS YS & THEIR VALUES:

The following process parameters and yield stress values of magnesium alloy are considered for evaluation of radial & Hoop stresses of magnesium alloy with given fluid for successful formation of cup in fluid assisted deep drawing process.

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Radial pressure of fluid = P,
Punch speed (velocity of blank) u =9mm/sec,
Height Between Blank holder & Die =12 mm,
Thickness of blank t = 3 mm,
Radius of blank rj= 90mm, 95mm and 100mm
Type of materials used: Magnesium alloy (AZ31B-0)
Type of fluid used: caster oil
Viscosity =0.985N–sec/ m^2

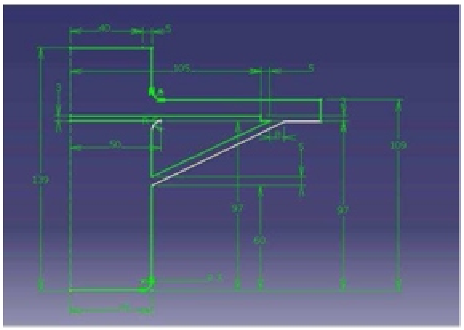

Fig.4.4 Hydro-Assisted Fluid Forming model Dimensions

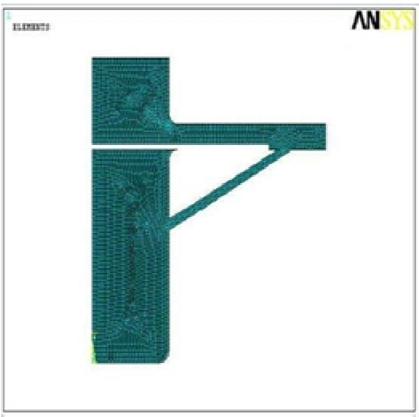

Fig. 4.6 Meshed Model of Hydro-Assisted Deep Drawing P rocess

4.10 LOADS AND BOUNDARY CONDITIONS OF HYDRO ASSIS TED DEEP DRAWING MODEL:

For any model in FEA, after meshing we have to apply Boundary Conditions and Loads.In Flotran CFD model, the loads and boundary conditions are Velocity and pressure. Here All velocities (both X & Y directions) are zero except at punch velocity line (where its value is 10 mm/sec and in this analysis its acts as a load) & the vertical Axis line where only velocity in X-direction zero (because punch moves vertically downwards so _v‘ in y dir. Is =! Zero).Figure 4.7 shows the Loads and boundary conditions of Flotran CFD model.

In which, Horizontal Arrow (red color) represents Velocity in X-Direction. Vertical Arrow (red color) represents Velocity in Y-Direction. Horizontal arrow which is in yellowish color (at top most) represents Pressure and where its value is Zero.

5. RESULTS & DISCUSSIONS

5.1 PRESSUR E VALUES OBTAINED FOR DIFFERENT FLUIDS FOR CORRESPONDING BLANK SIZES & PUNCH VELOCITIES:

For the AnsysFlotran-CFD Analysis, initially two fluids are considered,named Caster oil & O live oil. In this Analysis, for each oil the pressures are found fordifferent blank sizes (Rj=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 valuesfor corresponding blank sizes & punch velocities.

TABLE.5.1.PRESSURE VALUES OBTAINED FOR DIFFERENT FLUIDS FOR CORRESPONDING BLANK SIZES & PUNCHVELOCITIES:

S.NO	Radius of Blank Rj, mm	Radius at a point, r mm	FEA Radial Stress Values, Mpa	FEA Hoop Stress Values, Mpa
1	90	45	103	52
		55	72.5	75.8
		65	53.2	104
		75	28	129
2	95	45	117	49
		55	82.9	71.5
		65	60.5	96.9
		75	43.2	119
3	100	45	121	45.6
		55	91	67.2
		65	65.5	92
		75	53.6	109

5.14 GRAPHICAL COMPARISON OF THEORETICAL & FEA RADIAL STRESSES FOR RJ=90, 95 & 100mm BLANK SIZES:

Fig.5.31 shows the comparison of Theoretical & FEA Radial Stress values for Rj=90 mm blank size. The F EA values are slightly higher than the Theoretical Values. The F EA values obtained are nearly 10-12 % higher than the Theoretical Values.

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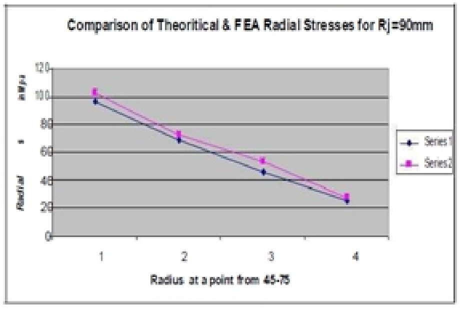

Fig.5.31 Comparison of Theoretical (series1) & F EA (series2) Radial Stresses for Rj=90mm

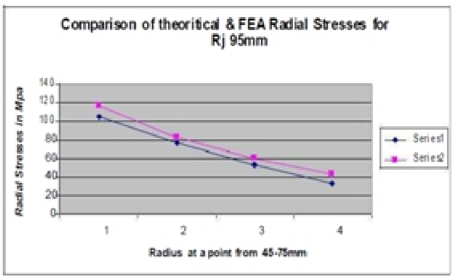

Fig.5.32 Comparison of Theoretical (series1) & F EA (series2) Radial Stresses for Rj=95mm.

Fig.5.32 shows the comparison of Theoretical & FEA Radial Stress values forRj=95 mm blank size. The FEA values are slightly higher than the Theoretical Values.The F EA values obtained are nearly 10-12 % higher than the Theoretical Values.

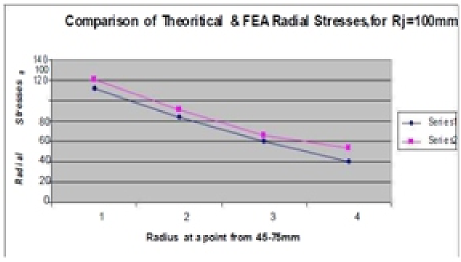

Fig.5.33 Comparison of Theoretical (series1) & F EA (series2) Radial Stresses forRj=100mm

Fig.5.33 shows the comparison of Theoretical & FEA Radial Stress values forRj=100 mm blank size. The FEA values are slightly higher than the TheoreticalValues. The F EA values obtained are nearly 10-12 % higher than the TheoreticalValues.

5.15 GRAPHICAL COMPARIS ON OF THEORETICAL & FEA HOOP STRESSES FOR RJ=90, 95 & 100 mm BLANK SIZES

Fig.5.34 shows the comparison of Theoretical & FEA Hoop Stress values for Rj=90 mm blank size. The F EA values are slightly higher than the Theoretical Values. The F EA values obtained are nearly 10-12 % higher than the Theoretical Values.

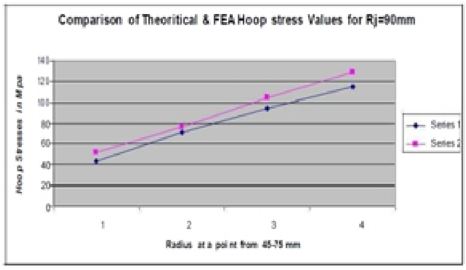

Fig.5.34 Comparison of Theoretical (series1) & FEA (series2) Hoop Stresses for Rj=90mm

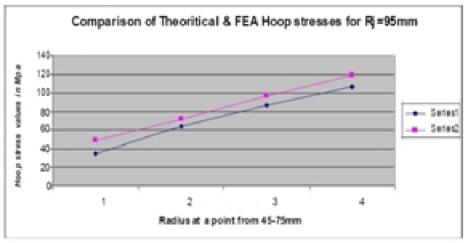

Fig.5.35 Comparison of Theoretical (series1) & FEA (series2) Hoop Stresses for Rj=95mm

Fig.5.35 shows the comparison of Theoretical & FEA Hoop Stress values for Rj=95 mm blank size. The F EA values are slightly higher than the Theoretical Values.The F EA values obtained are nearly 10-12 % higher than the Theoretical Values. The maximum stress value obtained from the Analysis should not reach the Maximum tensile strength of the Material. Here in this Analysis material used is AZ31B-0 whose maximum Tensile Strength is 240 Mpa. So the Maximum Stress value obtained here in this Analysis is 121 N/m 2 & it is much lesser than the maximum Tensile strength of material used. Thus the drawings produced are fracture less.

6.CONCLUSIONS & FUTURE SCOPE OF WORK:

Deep drawing is one of the metal forming processes, it is widely used inindustry for making seamless shells, cups and boxes of various shapes. The Hydraulicpressure can enhance the capabilities of the basic deep drawing process for makingmetal cups and this hydraulic pressure contributes positively in several ways to thedeep drawing process. The pressure is generated in fluid due to punch movementwithin the fluid chamber and directed through the bypass path to blank periphery andis to reduce tensile stresses acting on the wall of the semi drawn blank.

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In this processthe radial and hoop stresses are produced in the blank due to punch force applied onit, the shear stresses acted by viscous fluid on the both sides of blank, so apply viscosity phenomenon to this analysis.

The following conclusions are drawn from the present work:

1. The radial stresses are increases with increasing the radius of blank ofmagnesium alloy (i.e. increases if radius ‘Rj‘ of the blank increases). Butradial stresses are decreasing with increasing of radial distance (r) from thevertical axis of job (i.e. decreases with increasing the radial distance with inthe same job). These effects are due to viscosity of caster oil acted on theblanks of magnesium alloys during the forming process.

2. The Hoop stresses decreases with increasing the blank radius of Magnesiumalloy (i.e decreases with increasing the blank size, Rj) but the same hoopstresses are increasing with increasing the radial distance, r from the verticalaxis of the job.

3. The radial pressure of fluid acting on blank surface of alloys is equal to blank holding pressure & is for uniform deformation of blank during the process.Due to this eliminated direct metal to metal contact between the Blank, Die &Blank holder which is there in case of conventional deep drawing. Thus, thewrinkling is eliminated in blank due to the blank supported by highpressurized viscous fluid.

4. The radial stresses are high at, r is 45mm, low at r is 75mm and radial stressesare zero at r is equal to blank radius (at edges of blank). So the radial stressesare inversely proportional to the radial distance from job axis. The higher value of radial stresses gives the minimizing the drawing time and higher informing limits. These radial stresses are used to get better results offormability of magnesium alloy.

5. Radial stresses are increased with the increasing the blank size i.e., radius Rj,so the corresponding deformations also increased.

6. The Drawing Ratio produced is higher (up to 2.8) when compared to Conventional Deep-drawing Process (2.2)

FUTURE SCOPE OF THE WORK:

1. This Analysis can be carried out to get radial stresses & hoop stresses byvarying various parameters such as punch radius, punch velocity, and blankthickness.

2. This Analysis also carried out further by using various fluids which givesdifferent radial pressures on the blank, to get different forming limits.

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