EXPERIMENTAL INVESTIGATION OF FORMING PARAMETERS FOR DEEP DRAWN SQUARE PART

PRIYANKA YEROLKAR¹ & C S CHOUDHARI²

¹PG Student, Department of Mechanical Engineering, AISSMS COE, Pune, India

²Department of Mechanical Engineering, AISSMS COE, Pune, India

ABSTRACT

The present work is an attempt to obtain sheet thickness uniform variation and its experimental verification in deep drawing processes. An EDD sheet is chosen as a test material which is commonly used in the automotive industry. Effect of deep drawing process parameters such as blank shape, blank thickness, load, dry/wet lubrication is optimized through experimentation and theoretically, using forming limit diagram (FLD), for a particular automotive component. Experimental results obtained are validated by using Autoform software. Optimized process parameters helped to form a square cup of uniform without any defects such as thinning, wrinkling, etc. Formability was investigated by drawing sheet with laser engraving of a circular grid pattern by forming limit diagram.

KEYWORDS: Deep Drawing, Square Cup, FLD, Circle Grid & Forming

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INTRODUCTION

Deep drawing is the process of transforming sheet metal into the desired shape by the action of a punch forcing the metal into a die cavity. Accurate control of material flow can avoid the dominance of compression and occurrence of wrinkling. Grid marking and measurement is one of the common experimental methods for deformation measurements. The concept of forming limit diagrams (FLD), introduced by Keeler (1964) and Goodwin (1968), represents the first safety criterion for deep drawing operations. It is a combination of major and minor strains at the onset of localized necking. Finite element software packages use FLD to evaluate the deformation of sheet metal parts, specifically in determining the limiting deformations such as necking and tearing.

PROCESS PARAMETERS CONSIDERED

Process parameters considered for design of setup for drawing of square cup are as follows:

Blank Shape

Drawing ability of square cups greatly depends on properties of sheet metal. Further, blank shape is one of the important parameters in a deep drawing process deciding the quality of the deep-drawn product, thickness distribution, forming limits, minimizing the defects. Quality of deep drawn product is possible with the use of optimised blank shape. Material cost of the product also can be optimised with the use of optimum sized blank shape. In this experimental investigation, two types of blank shapes are used, square shape and circular shape.

FORMING LIMIT DIAGRAM

Forming Limit Diagrams (FLD's) are an appropriate and useful tool in sheet metal forming analysis which show the combinations of major strain and minor strain in the sheet surface at the onset of necking failure. The sheet metal is

marked with circles of the same diameters on one side of the sheet metal blank using various methods before the forming process is carried out.

The forming process causes the patterns to deform by an amount that depends on the local deformation experienced by the sheet metal. After the sheet metal is formed, the circles will become an ellipse where material gets deformed. The longest dimension of the ellipse is the major axis and the dimension perpendicular to the major axis is called the minor axis as shown in figure 1. Thereby, grid measurements are carried out for the determination of strain. The Forming Limit Diagram (FLD) is constructed by using grid analysis, which may be used to study the forming properties of sheets. Strain analysis by grid marking is a practical method, which has been utilized effectively to solve major problems faced in metal forming. During sheet metal forming, various stresses are induced in the blank. These stresses produce non-uniform strains and may lead to wrinkling or fracturing in the formed part.

Figure 1: Ellipse Formed after Deformation (1)

$$Lf = e^{\frac{\epsilon}{100} + \ln(L_0)}$$

where, e= percentage elongation.

The above equation is used to generate the scale for Mylar tape using percentage elongation of the original diameter of circle. Thus, the scale is drafted with incremental diameters using AutoCAD software. Then, the drafting is printed on transparent sheet and cut into required sizes as like scale. After deformation, the final diameter of the ellipse i.e. major and minor diameter of the ellipse can be measured by a transparent strip known as Mylar tape. It is used to read under the magnifying glass for accurate measurement.

GEOMETRICAL PARAMETERS AND DESCRIPTION

Part model of square cup is designed in Catia having blank size of 150 mm by 150 mm, as shown in figure 2.

Figure 2: Part Model Considered for Analysis

To carry out simulation, the tool surface is developed considering the top surface as the master surface, punch, blank holder and cavity surfaces are developed in the 3D software using Catia V5 software. The.igs file of this surface is then loaded into auto form software. The loading condition is set using the mathematical calculations. Composition and

properties of blank material EDD 1079 are shown in Table 1 and 2 respectively. Process parameters such as load, blank shape, lubrication, blank thickness are considered for an experimentation shown in Table 3.

Table 1: Chemical Composition of Material

Material	% of material
Carbon	0.0540%
Manganese	0.4150%
Phosphorus	0.0240%
Sulphur	0.0110%

Table 2: Mechanical Properties of Material

Material	DD1079/ IS1079
UTS	410 MPa
YS	329 MPa
% Elongation	38%.
Coefficient k	0.07

Table 3: Input Parameters

	Lower		Middle		Higher	
Load	100 KN		105 KN		110 KN	
Blank Shape	Square	Circle	Square	Circle	Square	Circle
Lubrication	Dry	Wet	Dry	Wet	Dry	Wet
Blank Thickness(mm)	2	1	0.8	2	1	0.8

EXPERIMENTATION& TOOL SET UP

To validate the results of the numerical investigation, an experiment conducted with optimized parameters. The press used for experimentation is of 150 metric tons capacity, clutch operated, single acting hydraulic press. It is having Bed size 650 mm by 700 mm and stroke length of 500 mm. The prime mover of the press is an electric motor of 15 HP capacity.

(a)

(b)

Figure 3: Deep drawing Experimental Rig a) Inverted Die b) Tooling Assembly c) Lower Punch with Blank before the Drawing d) After Deep Drawing

RESULTS AND DISCUSSION

Results of experimentation and simulation are obtained in terms of thickness variation and forming limit diagram. The effects of sheet thickness, blank shape, and lubrication on formability are investigated.

The thickness variations predicted by the Auto form simulation and obtained from experiments for a cup drawn to a depth of 36mm. Lubrication increases the formability of the deformed component. The maximum interior zone of the cavity is shown in green colour which represents a safe zone with thickness and compression in control under the desired limits. The bottom corners are shown in yellow colour which represents thinning; this thinning around the bottom corners should be of concern which can be further controlled by the force applied on the die by the punch and the punch travel distance. The top flange of the square is shown in blue colour, which represents the compression that has occurred due to the bending force which has compressed the top border.

Figure 4: Formability Analysis of Deep Drawn SQUARE cup

Figure 5: Actual Part with Optimized Parameters

Laser engraving of 5mm diameter circles on the outer side of the drawn part is shown in figure 6. Observation shows that circles have changed into ellipse at deformed zone. With the help of magnifying glass, major strain and minor strain are measured by using the Mylar scale. Further constructing forming limit diagram as shown in figure 7- a, b, c for different blank thickness of 2mm, 1mm, 0.8mm, respectively.

Figure 6 Drawn Part a) Outer Side of Deformed part b) Circle deformation in the form of ellipse

Graph 7: FLD a) for Blank Thickness 2mm b) for 1mm c) for 0.8mm

CONCLUSIONS

In this investigation, experimentation is carried out for deep drawing of square cup and results are validated by the use of Autoform software. Formability is investigated by drawing EDD 1079 sheet in terms of forming limit strains to observe the effect of process parameters on square deep drawing and to obtain drawn part having a uniform thickness. The results have shown improvement in a safe zone along with a reduction in thinning which meets the objective of this experiment.

The deep-drawn square component manufactured with a load of 100 kN on square blank shape with dry lubrication was observed and component has been safely drawn without any thinning and slight wrinkle on the flange. Experimental results shows that the formability of material having a blank thickness of 2mm is better as compared with a material having a blank thickness of 1mm and the formability of material having a blank thickness of 1mm is better as compared with a material having a blank thickness of 0.8mm.

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AUTHORS PROFILE

Priyanka Yerolkar, PG student in Mechanical Engineering (Automotive Engineering) at All India Shri Shivaji Memorial Society's, College of Engineering, Pune, Maharashtra, India. Graduated in Mechanical Engineering from Dr. B.A.M. University, Aurangabad, Maharashtra, India, in 2015.

C S Choudhari, graduated in Mechanical Engineering from Government College of Engineering, Aurangabad, Maharashtra (India) in 1994, and Master's degree in Heat power Engineering. He has completed PhD in Mechanical Engineering from Savitribai Phule Pune University, Pune in 2019. Now he is working as faculty, in Mechanical Engineering Department at All India Shri Shivaji Memorial Society's, College of Engineering, Pune, Maharashtra, India. His area of interest is Refrigeration and Air conditioning, Thermal Engineering, Heat Transfer and Energy conservation. He is life member of Indian society of Technical Education (ISTE).