# Numerical and Experimental Analysis of Draw Die Parameters for A Tapered Shell

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*Abstract*— **The research paper introduces experimentation and analysis of deep drawing die parameters of a tapered shell. The quality of components in the sheet metal forming is ensured by the material flow into the die cavity hence the project included drawbead to restrain and control the free flow of material. Drawing operations has been one of the basic operations in the mechanical manufacturing and production field. It has evolved since years and holds a profound type of manufacturing process. The operation consists mainly of components like a punch, die, blank and blank holder. These major components including their parameters are altered, modified, innovated and changed to obtain a wide range of products. The draw die industry caters from production of small cups to large vessels or containers. These products manufactured by drawing operations have a wide range of applications in households, commercial, industrial and even some special purposes. However every coin has two sides; along with all these positive aspects of drawing operation, it has many defects too. These defects decrease the production, increase the rejection rate of products as well as increase the cost. In this project, FEA method is put to use to design a draw bead in such a way that it will produce the desired component, A rectangular bead was analyzed for strain and thickness variation in a tapered shell draw. The stimulation results in validating the actual components to some extent. Special software available for industrial use of simulation of sheet metal forming "HYPERFORM" and "LS-DYNA" were used to model and analyze the forming process.**

***Keywords- Draw bead, Tapered shell, Die, Punch, Blank holder,FEA, Ls-DYNA, HYPERFROM, Blank diameter, Material thickness.***

## I. INTRODUCTION

The deep drawing operations have vast applications and are produced in multiple ways. Each type has its own advantages and disadvantages. A commonly used sheet metal forming process is deep drawing. In this process, hollow products are produced in 1-step drawing. Multi–step drawing processes are usually applied to forming parts that have geometrical complexity or formability problems and cannot be formed by 1-step forming [1]. Odell and Clausen [2] applied incremental strain theory towards analyzing the rigid-plastic axisymmetric deep-drawing process. The effects of work hardening, friction and normal anisotropy were also discussed also.

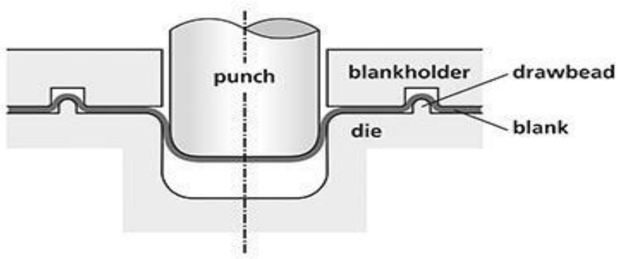


Fig. 1. Draw bead location

In a deep drawing sheet metal blank is dawn over a die by a radius punch. As the blank is drawn radially inwards the flange undergoes radial tension and circumferential compression [3]. 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 [4]. These wrinkles are observed in very large numbers in a tapered shell. The entire wall of the product exhibits wrinkling, which may lead to cracking of the product in further draws. Cracking may also occur in the first draw itself due to anisotropy of the material or uneven distribution of blank holder force.

## II. LITERATURE OUTCOME

Eary D.F [13] explains various techniques of press working. [10] S.C. Tang, 201 shows the axisymmetric deep drawing study. [3] N-M Wang proposed a mathematical model of draw bead forces for calculating the forces required to draw sheet metal parts of constant cross section. [4][3] Nine and Wang's study on draw bead in 1983 a theoretical model based on virtual work. was proposed by Chen [7] to calculate restraining forces produced by draw bead locating on stamping die surface. [5] A. Murli's study shows us that rectangular profile bead is more effective than circular profile bead. [9] A. V. Desai optimized the draw bead using the FEA method to reduce the thinning effect on blank caused due to the forming process. [8] Google study on various defects on sheet metal forming helped in analyzing and reducing the defects. [1] HYPERFORM software is used for functional study and simulations . [2] LS-Dyna(post) solver to observe strain and thickness function and distribution graph.

The work reported in this paper focuses on numerical analyses about a rectangular draw bead position on the die surface and their effect on the strain and thickness distribution over the taper cup. Numerical investigations are carried out using HYPERFORM and LS-DYNA to observe strain and thickness distribution. Experiments were conducted to validate the numerical results. The results obtained were used to validate the numerical findings.

## III. METHODOLOGY

### *A. Numerical method*

The problem statement of the product was firstly studied thoroughly and experimental solutions were proposed.

### *B. Experimental method*

Iterational study of die and blank are pre-processed using hyperform and were analyzed on LS Dyna and hyperform. The tapered punch and die were designed and material for the same was selected as Cast Iron. The dimension for diameter of the punch was 120mm and that for taper die was 122.7mm. The radius was 20mm. The blank diameter being 330.2mm of variable thickness 0.6, 0.7, 0.85mm respectively were used. The material on which the numerical iterations were carried out was cold rolled drawing steel (SS 202). Its properties are displayed in TABLE 1.

TABLE 1. Properties of SS 202

| Properties | Values |
|---|---|
| Yield strength | 275 MPa |
| Elastic modulus | 207 GPa |
| Poisson's ratio | 0.27-0.30 |
| Tensile strength | 515 MPa |

### *C. Numerical simulation*

For numerical simulation, physical contact between the two surfaces is mandatory for forming processes. All the simulations were implemented in hyperform, the parameters used as inputs are given as follows. Coefficient of friction 0.25. Stroke velocity of tool was taken as 2m/s. stroke distance was 35mm. Blank holding pressure 1000psi (70.307 kg/cm$^2$) in negative Z direction. Hyperform uses bending and load curves to control the flow of material on the drawbead. Output was obtained for the above conditions. Dimensions of the Rectangular drawbead given in Table 2 were inserted in Hyperform. The software uses AUTO POSITION command to maintain a uniform gap between blank and blank holders.

TABLE 2. Draw bead dimensions

| DRAWBEAD TYPE | RECTANGULAR |
|---|---|
| DEPTH | 4mm |
| ENTRANCE RADIUS | 1mm |
| GROOVE RADIUS | 1mm |
| GROOVE ANGLE | 2 degree |
| ENTRANCE ANGLE | 2 degree |

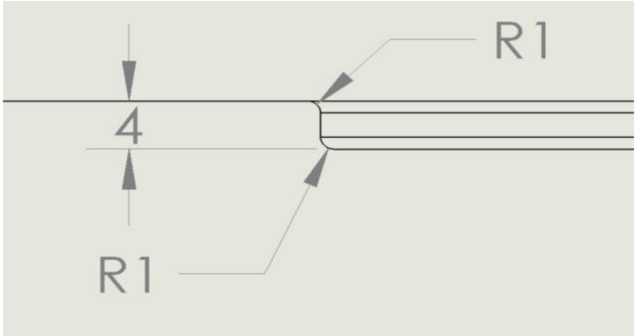


Fig. 2. Draw bead geometry

*D. Optimization of Draw bead Position* The positioning of the draw beads is important. The draw bead is positioned at various locations over the binder surface from the center of the die cavity. Initially at a distance of 31 mm from the end radius of the die cavity a rectangular draw bead of depth 4mm was created and numerical simulation was carried out. Effective strain, Von-Mises stress, maximum and minimum thickness were identified. The same process was repeated by positioning draw beads at different locations from 31 to 35mm in steps of 1 mm each and the outcomes are presented in fig. 3. All the outcomes are plotted against the draw bead position and shown in Fig 3. It is crystal clear from the graphs as the draw bead shifts away from the die cavity the effective strain and thickness increases whereas Von- Mises stress decreases. On further shifting the bead the trend goes in reverse direction. At one location (33mm) the curve direction gets changed, and this location is considered as an optimized position since effective strain is minimum, Von-Mises stress is minimum and thickness is maximum at a distance of 33 mm from end radius of die cavity a circular draw bead of depth 4 mm was created and numerical simulation was carried out. Effective strain, Von-Mises stress, maximum and minimum thickness were identified. Optimum position is identified

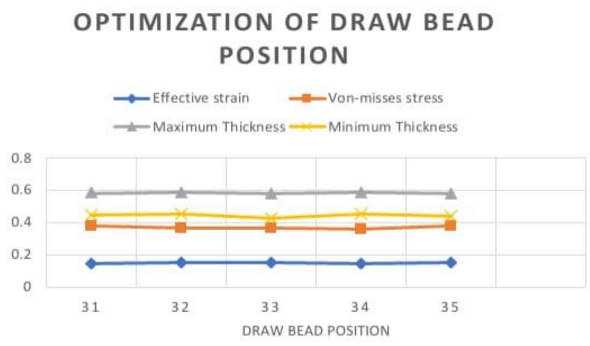


Fig. 3. OPTIMIZATION OF DRAWBEAD POSITION

*E. Numerical results*

Numerical results were conducted in two cases for the taper cup in rectangular bead.

(A) Taper cup forming without a Draw bead.

(B) Taper cup forming with a Draw bead.

Numerical results were evaluated by using post processing of LS-dyna to get respective forming limit diagram(FLD) and thickness and strain distribution diagram. The numerical results of the two cases are shown in the form of iteration for varying thickness of 0.6 mm respectively in following fig's.

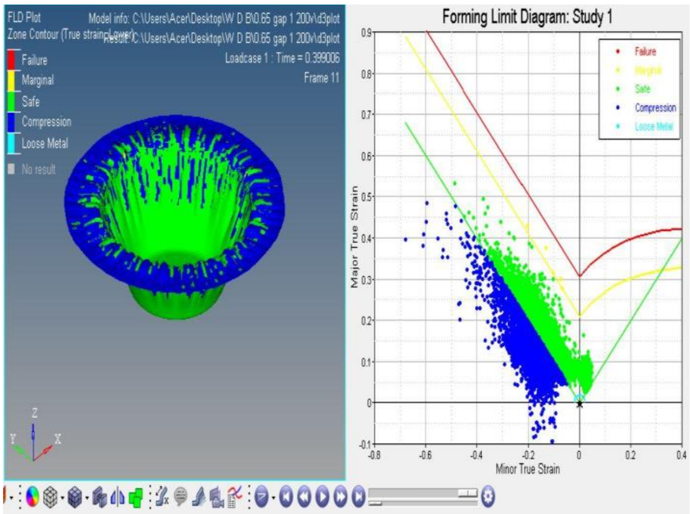


Fig. 4. FLD for 0.6 thickness(without Draw bead)

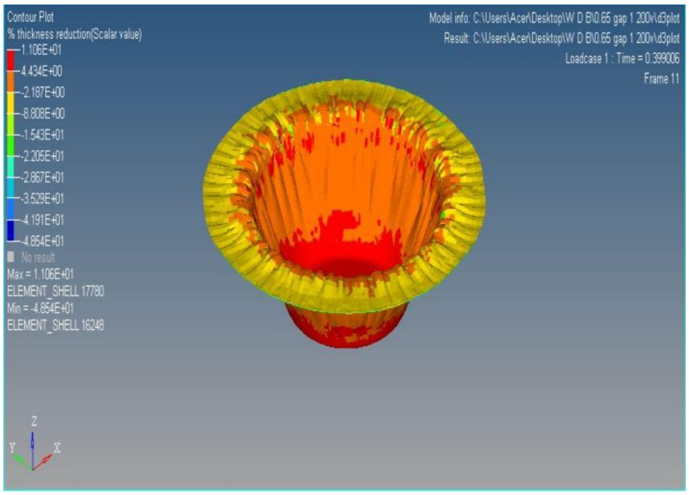


Fig. 5. % thickness reduction of 0.6mm(without Draw bead)

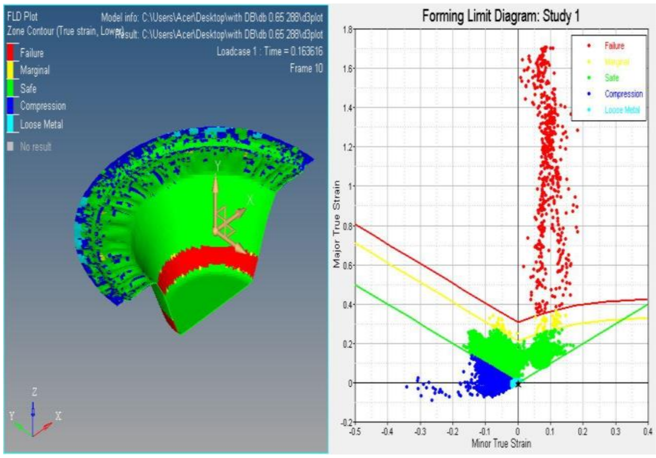


Fig. 6. FLD for 0.6 thickness(with Draw bead)

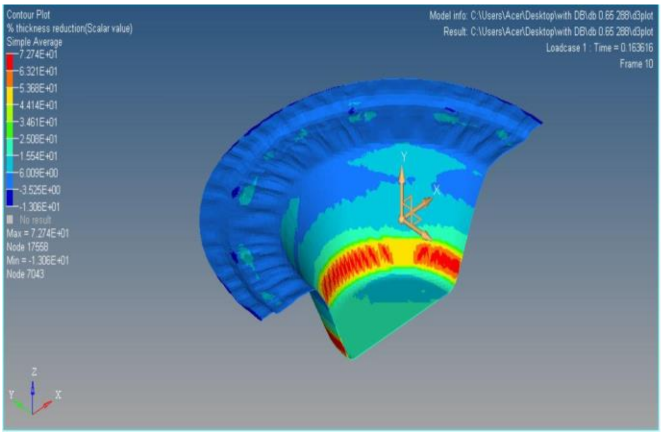


Fig. 7. %thickness reduction of 0.6mm (with Draw bead)

*Conclusion from simulation*

From the above fig.6 we can see that the FLD plot of the product with 0.6mm thickness is very safe but we can see large no. of Wrinkles formed on the face of the product.

For this we continued our simulation by introducing Draw bead on the die by fixing the position of the Draw bead at 33mm from the die edge.

The table below represents the % thickness reduction of material and results of FLD (forming limit diagram).

TABLE 3. Results for the %thickness reduction v/s FLD

| Material Thickness (mm) | % thickness reduction | FLD results |
|---|---|---|
| 0.6 | 70-75 | failure |
| 0.75 | 58-62 | Marginal safe |
| 0.85 | 48-50 | Marginal safe/ safe |

We can see that the % thickness reduction of 0.6mm material with the Draw bead is very high which leads to a very high amount of straining on the face. Which ultimately leads to failure as seen from the FLD curve. Similar is the case for 0.75mm material. But 0.85mm material has quit a less % thickness reduction. And is also 80% safe as seen from the FLD curve.

So from simulation results we can conclude that 0.85mm material with draw beads is best for production.

*F. Experimental work*

To validate the analysis obtained from FEA simulations, experimental verification is necessary. Draw die was designed and manufactured and then installed on the experimental setup. [14] Donaldson was used for the standard design procedure of a press tool. For drawing a taper cup of 120mm diameter and 130mm height from the flat sheet blank of 0.6, 0.75, 0.85mm respective thickness. Diameter of the blank was calculated to be 330.2mm. Die block was casted using cast iron. The diameter of the die block was 122.7mm including clearance. The taper angle of 14 $degree$. Height of die 130mm. Based on blank holding pressure, a hydraulic press of 100 Ton was selected. The ram speed of 20 mm/s having a maximum stroke length of 70 mm. The complete die set, which comprises die, punch and binder, was mounted on the hydraulic press with the help of suitable fixture as shown in Fig. 12.


Fig. 8.Practical draw die setup without draw bead

Experimental Iterations for a few number of taper cups were formed without draw bead were carried out for varying material thickness 0.6, 0.75, 0.85mm respectively.

Fig. 9. Practical draw die setup withdraw bead

Same procedure was carried out for a draw die having a draw bead at optimized location osf 33mm away from the end radius, taper cups were formed observations for the same were noted for material thickness 0.6, 0.75, 0.85mm. Fig. 9, Fig. 10, Fig. 11 respectively.

Fig. 10.. Semi-finished product with thickness 0.85mm (with draw bead)

Fig. 11.. Finished product with thickness 0.85mm (with draw bead)

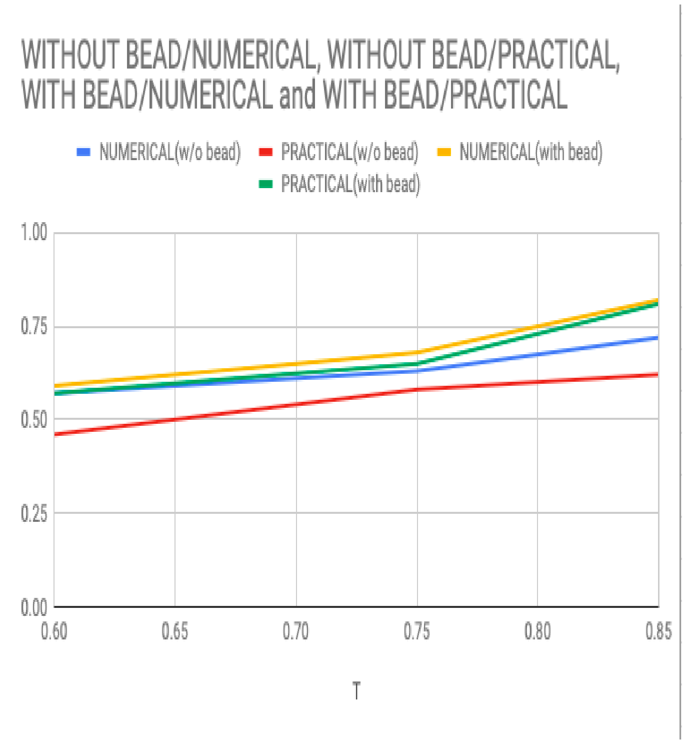


Fig. 12..Comparison of practical and numerical results

## II. RESULTS AND DISCUSSION

### *A. Numerical Results*

- Rectangular drawbead has been used to detect thickness and strain distribution pattern on taper cup,Using FEA and experimental analysis ,for which industrial software LS-dyna and HYPERFORM have been used. The numerical results are good with the experimental outcomes. Based on the following results comparison can be drawn.

### *B. Experimental results:*

Experiments were performed on the experimental setup of the draw die. Same iterations were carried out as that in the analysis. The results obtained in the experiment were having a close relation with those obtained analytically.

The numerical and experimental results are close and hence validated.

## III. CONCLUSION

Comparing from the above TABLE 4. comparison can be drawn.

- Drawbead location is crucial and very important for its effectiveness during forming processes. If the drawbead is too far away from the punch line then the restraining force required to control the flow of the material is insufficient, likewise if it is too close to the punch opening line then the material gets pulled over the bead easily.The simulations on software enabled us to try difficulty location and located on

- Optimization of draw bead location is not the only thing which provides better results, material thickness is also considered while introducing a draw bead. The tapered shell product fails even after introduction of draw bead profile when the material thickness is 0.6mm. A considerably finished product without wrinkles is obtained with draw bead at its optimum location and material thickness of 0.85mm.

- Further this study may be continued by altering the taper angles of the component. More taper the shell, more wrinkles on it are observed.

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