Design and Development of Mounting Bracket

Y. V. Thokale[1], P. G. Karajagi[2], S. R. Kulkarni[3]

***Abstract*—this paper highlights the development of a2.6mm thin sheet metal mounting bracket with Hole Extrusion process using finite element analysis. Excessive thinning generated due to ironing and occurrence of defects such as necking, tearing, wrinkles, scoring were identified in simulation using Auto form software and avoided them in manufacturing of component taking various experiments. The effect of hole diameter on the height of flange was investigated. Simulationwere carried on component with different material properties and thickness, identifying the process and comparing the results with actual. Though the attempt is aimed for designing the sheet metal component using the CAE technology to make it cost effectiveand time efficient, identifying the problem areas through software simulation results and prepare the query report and suggest modifications in the product design.**

Key words —Hole extrusion process, Drawing process, simulation, sheet metal

I. INTRODUCTION

HOLEextrusion is a process in which a thin sheet with a pre-cut hole in the center is clamped around its periphery by a blank holder, the sheet is hold firmly between the blank holder and the die, the punch is then force to travels down tomake contact with and enter the hole to expand this hole and stretch the material, thereby forming a cylindrical collar or hollow flange component around the punch,this is hole extrusion or plunging process. This kind of parts is used in auto motive sheet metal industries for examplea longflange is needed when an increase of bearing surface is required or more thick flange is required when an internal threading is cut after the hole extrusion process. In our case the flange supports the suspension part which is held in between the hole in contact with other parts so the requirement of large hole with defect free flange becomes necessary. During the flanging process the sheet is bend twice one against the punch radius and then against the die radius. The greatest strain is in the periphery area of the expanded hole. The deformation increases the diameter of the hole and the wall thickness decreases. However the tensile stress in the circumferential direction at the edges of the flange hole is the main cause of the defects in the flange, such as necking, thinning, tearing or crack formation.To satisfy the geometric requirements, parameters and occurrence of defects, several researchers have focused onstudying the effect of the initial hole diameter and the clearance between the punchand the die.The variation of the initial hole diameter is considered among the solutions to control both the flange height and the flange thickness. By decreasing the initial hole diameter the part subjected to the deflection increases. Hence the flange height may increase while the flange thickness may decreases and vice versa. This solution may also affects significantly on the final shape of the flange in the case of thick sheet metal. In thin sheet metal, it also affects the magnitude of tensile stress in the circumferential direction at the edge of the flange. Necking and crack correspond to weak tensile stress magnitude. While for more tensile stress, tearing and fracture are the main defects found.

1. Yogesh v Thokale, *PG student, Mechanical Dept. Siddhant College of Engineering, Pune, India.* (E-mail: thokale.yogesh7@gmail.com).
2. Prof P. G. Karajagi, *Head of Mechanical Dept. Siddhant College of Engineering, Pune*
3. Prof. S. R. Kulkarni,*PG coordinator Siddhant College of Engineering, Pune*

II. LITERATURE REVIEW

The hole extrusion process and problems related to it have been studied widely by Several researchers.Huang and Markus Bambach [1] have perform hole extrusion process using incremental sheet forminginstead of conventional flanging process. Using CNC control tool and taper bar, this process is good to achieve longer flange, but this process is mainly applied for proto type or small batch of production, for mass production it will be slow and expensive. Hela [2] has analyzed in the conventional hole-flanging process on thin sheet metal by varying both the initial hole diameter and the clearance, thicknessratio.Practical diagrams were proposed toexploit the geometrical and forming parameters as well as the state of the flange.Kacem [3] the effect of the clearance-thickness ratio on the hole-flanging process was investigated to determine the occurrence of ironing.The effectof the hole-flanging condition on the punch load, the forming kinematics, the flange geometry and theboring quality was studied. Tang [4] analyzed the hole-extrusion process using a finite-element analysis with four different types of punch shapes, and found that the strain found during flanging process is not affected by the punch shape but rather by the maximum punch load, which latter depends on the punch shape.

The finite-element method is found to be the most powerful method of analysis for its flexibility and accuracy. It does surly overcome the complications and the non-linearity of the process and theoretically provide proper information of the design of tools and process control.

III. Geometrical parameters and description

Currently the bracket is an thin 2.6mm sheet metal part made out of material Fe410 material grade MM13 410 with outer diameter 140mm extrusion outer diameter 89mm total height 34.6mm. The fig.3.1 shows the CAD model of the mounting bracket.

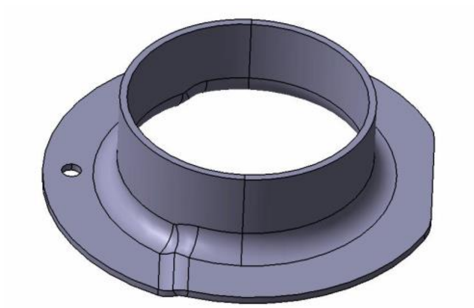

Fig.3.1 CAD model of the mounting bracket.

According to the usual hole extraction process a thin sheet with a pre-cut hole in the center is clamped around its periphery by a blank holder, the sheet is hold firmly between the blank holder and the die, the punch is then force to travels down tomake contact with and enter the hole to expand this hole.Fig.3.2 shows the tool geometry parameters of the hole extrusion process.

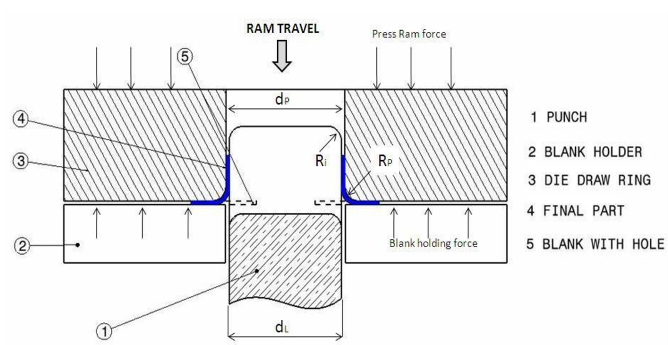

Fig.3.2tool geometry parameters of the hole extrusion process.

A. Abbreviations

D = blank diameter 170mm
T = material thickness 2.6mm
d_1= part inside diameter 83.8mm
d_P= part outside diameter 89mm

For material Fe410,
UTS = 410 Mpa
Y_S = Yield strength 275Mpa
k = coefficient 0.07

B. Mathematical Calculations

2.1.1 Radius of draw ring (R_P)

$R_P = 0.8[(D - d_1) \times T]^{0.5}$
$= 0.8[(170-83.8) \times 2.6]^{0.5}$
$= 11.97 \approx 12\text{mm}$

2.1.2 Clearance (C) - the clearance between the punch and die it is one of the important parameter this value may be define on the type of material and thickness coefficient k for steel sheet is taken as 0.07

$C = T + k\,(10\,T)^{0.5}$
$= 2.6 + 0.07\,(10 \times 2.6)^{0.5}$
$= 2.95\text{ mm}$

2.1.3 Blank holding pressure (Pd)

$Pd = 0.67\{[(D/d_1)-1] + (d_1/200T)\}\,(UTS)$
$= 0.67\{[(170/83.8)-1] + (83.8/200 \times 2.6)\}\,(410)$
$= 579.45\text{Mpa}$

2.1.4 Blank holding force (Fd_1)

$Fd_1 = (\pi/4)\,[(D^2 - d_1 2]\,Pd$
$= (\pi/4)\,[(170^2 – 83.8^2]\times 579.45$
$= 9956454.93 \times 10^{-6}$
$= 9.956\text{ Ton}$

2.1.5 Cupping strain factor (E)

$E = [(D/ d_1) +1] \times 0.5$
$= [(170/ 83.8) +1] \times 0.5$
$= 1.51$

Deformation efficiencyn_C of draw process is selected from the graph in Fig.3.3 based on Cupping strain factor (E)
From graph we have n_C= 0.20

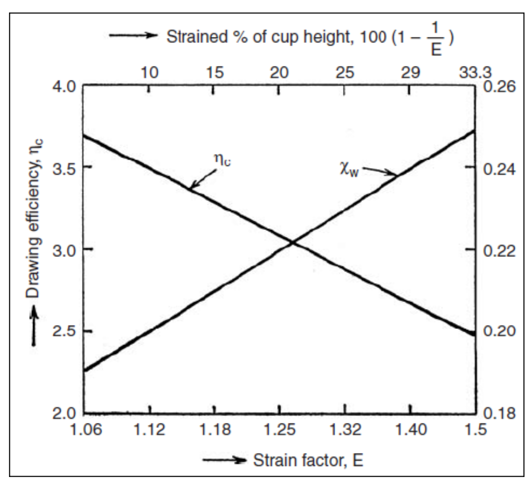

Fig.3.3.Deformation efficiency for draw process.

2.1.4 Draw force (P_{draw})

$P_{draw} = \pi\, d_P\, T\, Y_S n_C \,\text{In}\,(E)$
$= \pi \times 89 \times 2.6 \times 275 \times 0.20 \times \text{In}\,(1.51)$
$= 15.99\text{ Ton}$

IV. FINITEELEMENT ANALYSIS

According to the mathematical calculation the loading condition was set and simulation was run as per the usual hole extrusion process using auto form software. The part was mesh with fine meshing value with outer side as a master. The Fig.4.1 shows the part in mesh condition.

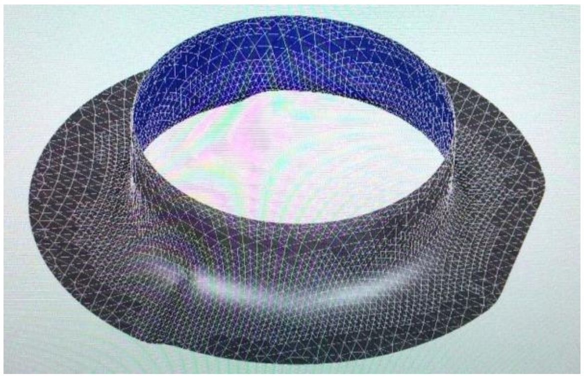

Fig.4.1Meshed model

The results obtain were not satisfying showing high strain on the periphery of the extrusion hole which was not acceptable as per the functionality of the part and the automotive standard. The Fig.4.2 shows the results of simulation with high stress at the outer periphery of extrusion which will cause thinning greater than 20 percent of part thickness in the highlighted area.

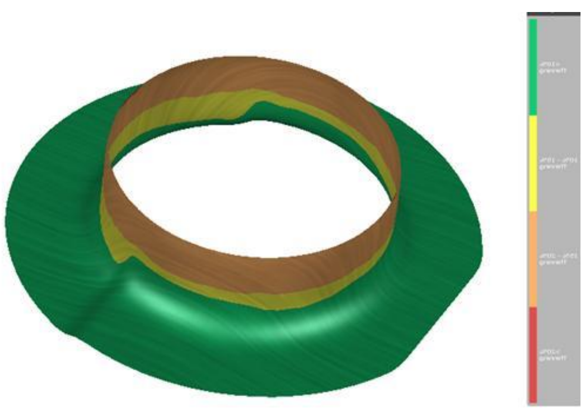

Fig.4.2thinning results

On basis of the simulation results we tried various no of iteration by changing the material grade from DP590 which is high strength material to low grade material like BSK46 and Fe410also varying the blank holding force , punch radius and clearance to let flow of the material easy, but came with same simulation results.

MATERIAL	C	Mn	P	S	Si	AL	YS(Mpa)	TS(Mpa)	Elongation
DP590	0.09	1.01	0.01		0.28	0.04	430	600	3.4
BSK46	0.12	1.4	0.03	0.03	0.1		451	490	21
Fe410	0.2	1.3	0.045	0.045			255	410	17

Table.4.1. shows Material properties and Chemical combination.

The simulation was run for all material and the results obtain are shown in graphical format in Fig.4.3 showing better results in 2stage process

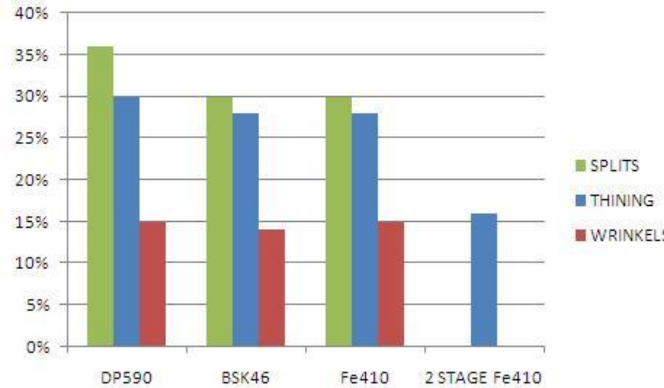

Fig.4.3graphical representation of simulation results

V. EXPERIMENTATION

Considering the simulation results obtain, experimental setup was set and experiment was conductedon 250T press and various iteration was taken, shear blank was developed and loaded in the tool to form the extrusion hole, the part for was compared with results,we found that the height of the flange is very large, for large hole size the flange height do maters for large hole, it increases the stress in the part causing large amount of thinning and necking in the periphery region.But the product requirement was such that we cannot compensate with the height of the part and also if softer material is taken the tensile strength in part will be too low to resist the load coming on it. According to results we introduce a step in the process by adding a half height of a draw and the pending half in the Extrusion process that is 2 stage process. This will reduce the height of the part and the stress induce will be reduce. Again the loading condition was set for draw process and the simulation was run, the results of the simulation are shown in the Fig.5.1 showing small necking in the radius area.

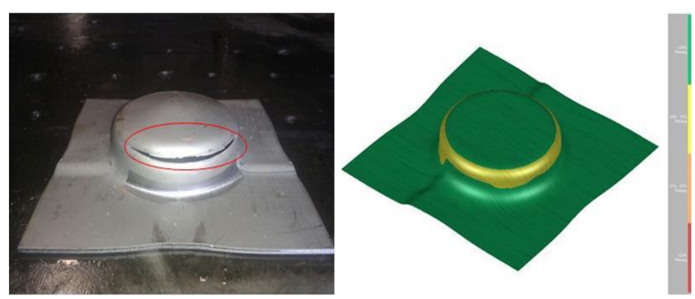

Fig.5.1Compare results for draw part

This necking result was resolve by increasing the punch radius in the design which then shows good results and by applying lubrication in actual also made improvement. Some wrinkle was also observed by changing the blank holding pressure which was further reduced. 8 percent of thinning was observed in some area which was acceptable as per the automotive standard.

The finite-element method is found to be the most powerful method of analysis for its flexibility and accuracy. It does surly overcome the complications and the non-linearity of the process and theoretically provide proper information of the design of tools and process control. The actual and the analytical results were also compared and found the similar results. Then the draw part was further trim by making a hole in middle and in next process the further required height of the part was obtain in two stages. Thus the stress induce were reduce in two steps by forming an draw up to half stage and then the hole was trim and in next process the actual hole extrusion process takes where further height is obtain without any sheet metal defects and maintaining the strength of the part as per the requirement. The Fig.5.2 shows the actual part produce in the further process and the results were satisfying.

Fig.5.2actual parts from trim & extrusion process

The strain level on the form parts are also be checked on the FLD curve which is also known asforming limit curve which shows the forming behavior of the part and the major and minor strain produce or which can be sustain by the part. It helps the designer to improve the forming process and easy tryout of the dies.Fig.5.3 shows the forming limit curve within the green portion is under limit as it moves towards the red portion the cracking or thinning is observed on the part. This curve in short determines the safety limit of the part.

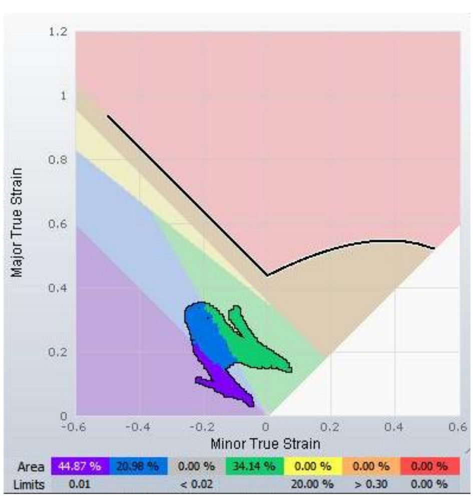

Fig.5.3forming limit curve

VI. TESTING SETUP

Further validation of the parts is done by testing the produce part with the CAD model there are various method to test the parts some of the important and highly preferred test is discuss bellow

A. *Circle grid analysis*

CGA also known as Circle grid analysis is a method of measuring the strain level on surface of the sheet metal part after it is form. The circle grid is the known diameter and after from the circle gets deforms or stretch to the elliptical shape by measuring the length of ellipse major & minor strain can be calculated. This method is help full to find how close the part is going to crack or fail.

B. *Coordinate measuring machine*

In this process a CAD model is set with no of points on the surface of which the angularity, flatness and deviation is checked with the actual part produce in the process within particular tolerance limit. These set points checked on actual part with tolerance limit is form in tabular formats and report is generated. Points with limits are acceptable or else part is rejected or correction is made on part.

C. *Testing fixture*

Here a testing setup in made with 3mm gap surface and using micrometer or Go/No go gauges and filler gauges gap between the part and fixture is check by clamping the part on the setup and measuring at particular set location and a report is generated.

D. *Engineering inspection*

Normal inspection is carried out by using the micro meter, gauges and vernier caliper to measure the thickness of the part, to measure the thinning in the part, visual inspection is done to check wrinkles & scoring on the parts.

VII. RESULTS & DISCUSSION

- Simulation was run as per the usual hole extrusion process showing high stress in the periphery region showing thinning and cracking.

- Same process was repeated using DP590, BSK46 and Fe410 material, thinning and cracking were again observed.

- Draw process was introduced and found necking at the radius. Results were also comparing with analytical solution. Problem was resolve by changing design content.

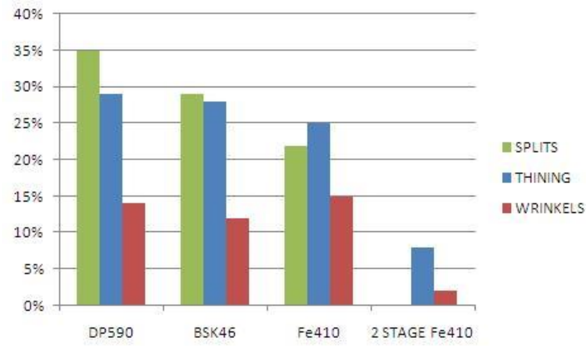

Fig.7.1graphical representation of results observes in experiments.

- After correction at final iteration the results shows good comparisons with simulation results

VIII. Conclusion

- The strain produce at the top of flange completely depends on the size of the hole and the flange height by varying height results vary and by changing material properties and thickness results may achieve but may affect requirement of part. Experiment results found good results with actual.
- The finite-element method is the most powerful method of analysis for its flexibility and accuracy. Resultswere comparedand found almost similar.
- The finite-element method helps improving the design as well as manufacturing process of the tool design. It guides designer to achieve better and cost-effective results in quick time with accuracy.

Acknowledgement

Author would like to take this opportunity to express sincere and whole hearted thanks to my guide Prof. S. R. Kulkarni PG coordinator Siddhant Collage of Engineering, Pune.for his valuable guidance through-out the process. We would also thankful to Prof P. G. Karajagi Head of Mechanical Dept. Siddhant Collage of Engineering, Pune for continuous encouragement during this work. We are extremely thankful to Dr. S. S. Khot, Principal of Siddhant Collage of Engineering, Punefor his help provided during this work and S. Gaikwadfrom Icon Technologies, Pune for giving the opportunity to work on project

References

[1] Markus BambachandGerhard Hirt, “A new process design for performing hole-flanging operations byincremental sheet forming,” Institute of Metal Forming, RWTH Aachen University, Intzestrabe 10, 52056 Aachen, Germany81 (2014) 2305 – 2310. *24 October 2014.*

[2] Hela, Soussi, Masmoudi, Narjes, “Analysis of geometrical parameters and occurrence ofdefects in the hole-flanging process on thin sheet metal,” National EngineeringSchool of Sfax, University of Sfax, B.P. 1173, 3038. 26, Feb2016.

[3] Ahmed Kacem, AbdelkaderKrichen, Pierre-Yves Manach, “Occurrence and effect of ironing in the hole-flanging process,” 211 (2011) 1606–1613. *11, May 2011*

[4] S. C. Tang, “large elasto-plastic strain analysis of flange hole forming,” engineering and research staff ford motors. Dearborn MI 48121 USA 13(1981)363-370. 18, April. 1980.

[5] IvanaSuchy, Handbook of die design,(Mcgraw Hill publication, United States of America,2006)