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Numerical and Experimental Analysis of Fuel Tank for Thickness Variation in Deep Drawing Process

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ABSTRACT

Thin sheets of metal are shaped by applying pressure through dies in sheet metal forming process. A definite advantage of sheet-metal parts is the uniform thickness of the material, which can be controlled up to a close range with tolerances. Tolerances for die-punched holes can be considered quite impressive. Sheet-metal parts are often of utmost importance as covers and liners in electrical products, where they provide for radio-frequency (RF) shielding as well. With covers made of plastics, the particles of RF shielding material can be added to the plastic melt or later spray-applied to the inner surfaces of finished products. However, this can become impractical or too costly. The magnetic or nonmagnetic properties are additional factors to be considered in sheet-metal design and use. The resistance of the material to heat and fire along with its capability of heat dissipation are exceeded only by ceramics.

Keywords: Fuel Tank, formability, thickness variation, Hyper Form.

I.INTRODUCTION

Deep Drawing is widely used in industry for producing automobile and aircraft body parts, household applications and auxiliary parts in construction industry. The method is very suitable for producing large volume of simple shaped parts, like cups, cans and vessels. Deep drawing process is affected by many factors, like impurities in material properties, tool design, operating speed and lubrication. Improper setting of these parameters leads to defects in deep drawing process. In manufacturing processes the main goal is to obtain defect free end product. Design of the process leads to improve the manufacturing process. The designer must have knowledge about possible problems and their solutions during production. Plenty of research is reported on the process parameters to obtain better quality products.

II.LITERATURE REVIEW

Najmeddin Arab (2013) analyzed the deep drawing of axi-symmetric cylindrical cup. The strains in the radial and circumferential directions have been measured. A correlation on the flange thickness variation by taking into account the work hardening with the experimental values has been searched. The optimal process parameters in the sheets obtained in the simulation were compared with experimental results for various forming conditions. With this regard, the numerical simulations were conducted using the finite element method for cup shaped components with flange. Thickness distribution is obtained for entire cup along with flange. The results obtained from this numerical analysis are compared with experimental findings and results of other researchers. Experimentally thickness distribution is obtained by measurement at various locations in half cut cup along with flange region. [5]

Najmeddin Arab (2013), researched a new method to analysis the axi-symmetric forming condition of sheet metal in the conditions of thickness change and deformation hardening and this method is applied for analysis deformation of thin ring plates.[4]

Ismail Abu-Shah (2013) examines the mechanics of deformation and failure of sheet metals during drawing of circular cup-shape parts. For this purpose, series of drawing experiments on 0.7 mm-thick 0.034C steel blanks are conducted using a single geometry of the cup-shape die. The drawing stroke is incrementally increased at 1.0 mm/sec until fracture of the drawn cup is detected. Blank holder clamping force (BHF) and die clearance settings are varied between 70 to 100 KN and 0.6 to 1.0 mm, respectively. Effects of these parameters on non-damage draw ability limit of the blanks are quantified. The resulting punch force-displacement curve displays three distinct stages. An initial stage represents elastic-plastic deformation of the hardening steel blank. Continuous drawing into the cavity further stretches the blank with tensile-like biaxial deformation resulting in the observed linear punch force-displacement response. In the last stage, the observed deviation of the punch force-displacement curve from linearity is associated with damage of the drawn cup. Fracture of the part occurred when a constant punch force is registered. The limit punch force and limit drawing depth vary linearly with BHF. While the location of fracture is influenced by the magnitude of BHF, fracture of the drawn cup-shape parts is dominated by instability through formation of diffused necking band, ductile failure and shear fracture, as evident from the observed shear lips.[2]

Shishir Anwekar (2012) presented the single stage deep drawing process of thin walled, mild steel, conical back plate of radial impeller of blowers is approached by means of a finite element analysis. Simulation of the drawing process for determining stress distribution in the drawn component for a particular displacement is explained. The distribution of stress in the drawn component is obtained. The study was conducted by using ANSYS12.0, in which, two models have been tested. Both models constructed solely out of axisymmetric, quad 4 node, PLANE 42 elements which have been used to simulate the drawing process of drawing quality mild steel IS2062 grade. The experimental analysis is carried out on two different flat plates having thickness 3 mm and 5 mm from which the conical back plate is manufactured. This study will be beneficial to the tool designer and the manufacturers doing work in this field.[3]

Assempour (2003) presented a new methodology for complete solution of general shape deep drawn parts. Evaluation of forming severity, estimation of the punch load and prediction of the thickness variation are the major results obtained in this work. The punch work is the summation of the homogenous work of flange deformation and bending and frictional works. To evaluate the strain energy of the flange, the so-called matrix method of slip line is used. To overcome the weakness of slip line field in prediction of the thickness variation, the so-called genetic algorithm has been adopted. In this procedure, the actual velocity field has been computed and used in energy formulation. The predicted thickness strain, punch load and forming severity have been compared with some published experimental results.[1]

III.PROCEDURE FOR FORMING ANALYSIS / PROCEDURE

Following procedure is generally adopted for the formability analysis.

4.1 Create 3D model of the component to be analyzed.
4.2 Import the 3 D file into Hyper Form.
4.3 Clean up the geometry.
4.4 Mesh the geometry / part.
4.5 Orient the part.
4.6 Assign the material to the component.
4.7 Create constraints.
4.8 Define the blank holder
4.9 Save and run the simulation.
4.10 Load the results in Hyper View
4.11 View the results.

IV.CASE STUDY: FUEL TANK

4.1 CAD Model of Fuel Tank Top-Bottom

Cad model of fuel tank top as well as bottom can be shown in figure 4.1 and figure 4.2.

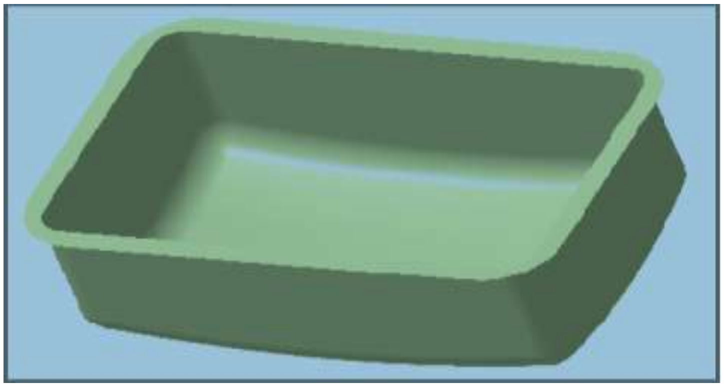


Figure 4.1: Cad model of fuel tank top

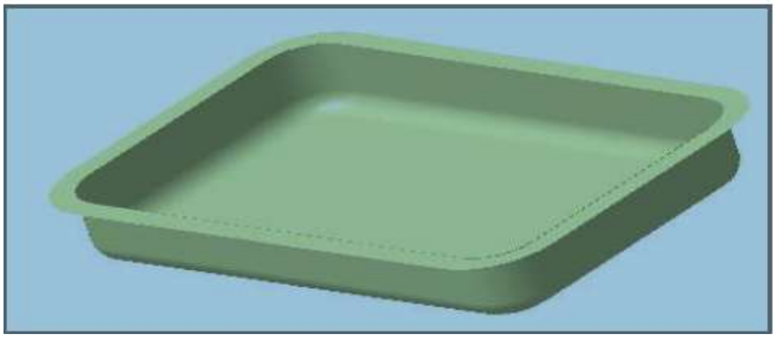


Figure 4.2: Cad model of fuel tank bottom

4.2 Analysis of Fuel Tank Top- Bottom

In this analysis the feasibility study of deep drawing process, blank development, strip layout and thinning percentage is done, from which it is decided whether to opt for incremental analysis or otherwise.

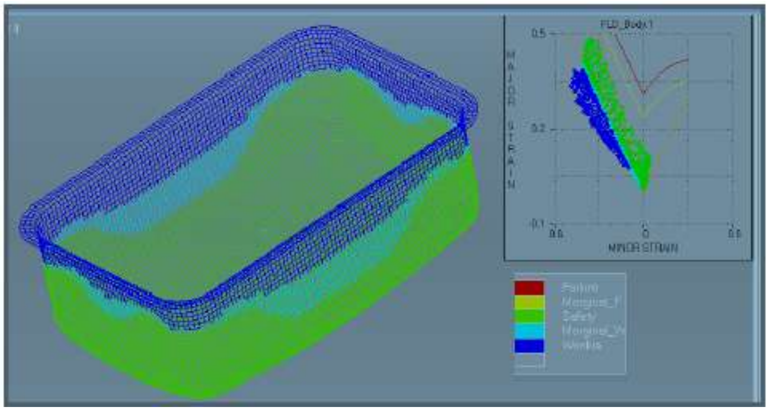


Figure 4.3: Feasibility of fuel tank top

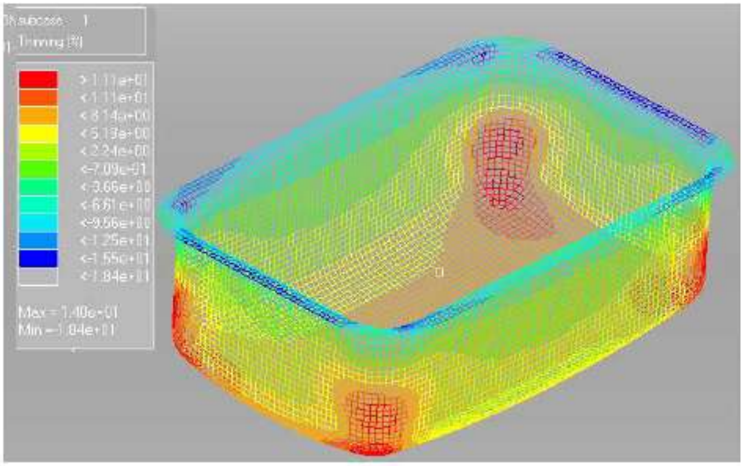


Figure 4.4: Thinning percentage in deep drawing process of fuel tank top

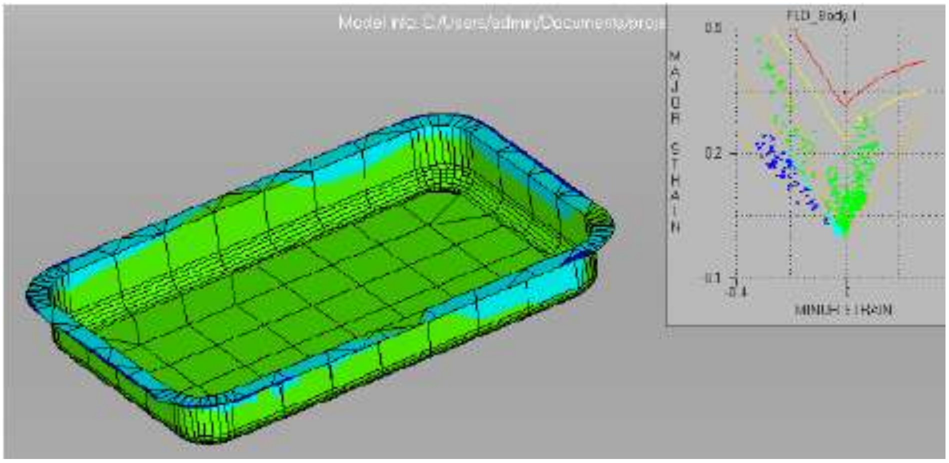


Figure 4.5: Feasibility of fuel tank bottom

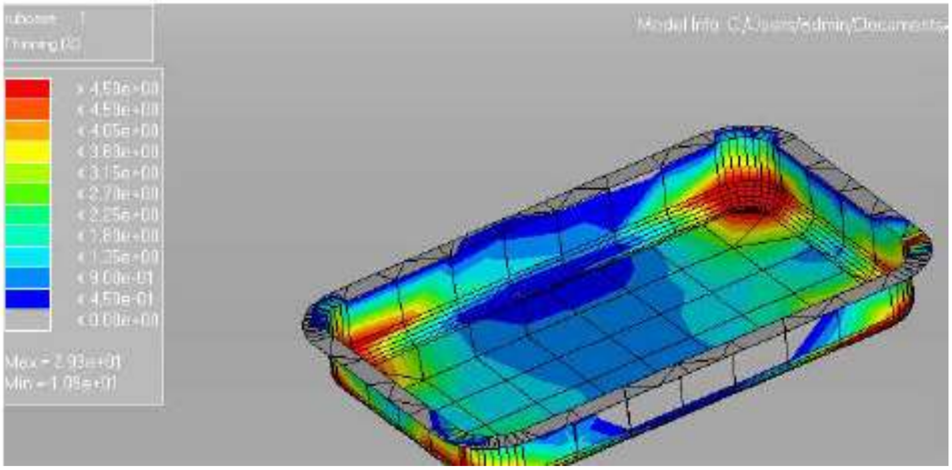


Figure 4.6: Thinning percentage in deep drawing process of fuel tank bottom

Inference:

1. From figure 4.3 and figure 4.5, there is no failure take place, all portion of fuel tank top and bottom are in safe region.

2. From figure 4.4 and figure 4.6, it shows that the percentage of thinning is less than 20% hence fuel tank top and bottom

4.3 Experimental Method

For the validation of most Finite Element Analysis modeling, experimental verification is very important. This experimental work is divided into two stages:

1. Apply BHF as per calculation in simulation process on mechanical and hydraulic press.
2. Measurement of thickness

The blank holding force is spent in deforming the work piece alone. Drastic change in the shape of blank in drawing however necessitate additional force ranging from 20% to 40% of the drawing force for keeping the blank under blank-holder pressure to prevent the wrinkles in the drawn cup. So the press capacity should be about 30% more than the drawing force. For simulation and experimental method extra deep drawing (EDD) material is used. Experiment is carried on hydraulic machine.

V. RESULTS AND DISCUSSION

5.1 Statistical Analysis

On the basis of analysis conducted using Hyper Mesh software the outputs are obtained from Hyper View Post-processor. The following types of outputs are obtained.

1. Thickness Variation
2. Effective Plastic Strain
3. Von Mises Stress

Based on the observations, simulation was carried out. For measuring the parameters of interest 10 location of the cup were selected as shown in figure 5.1. At every location thickness is measured.

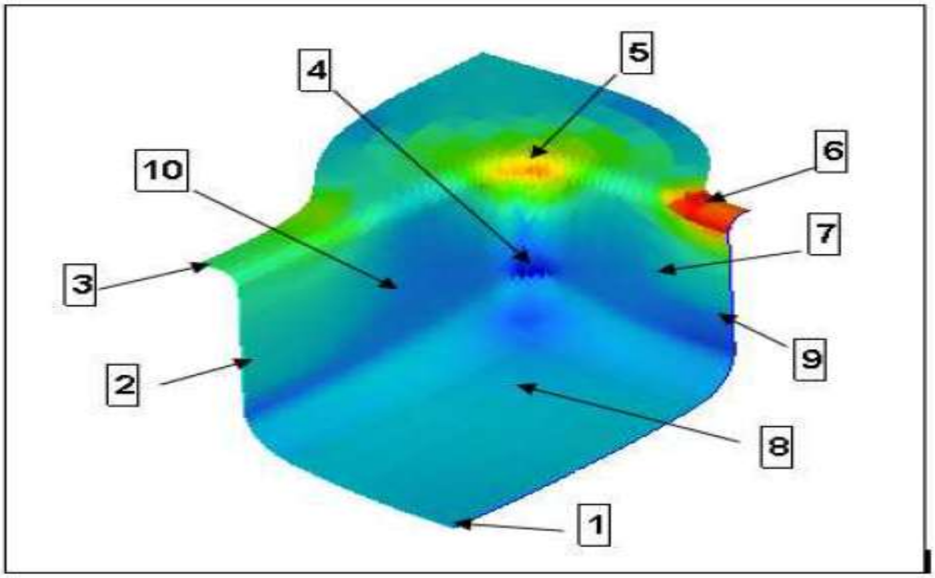


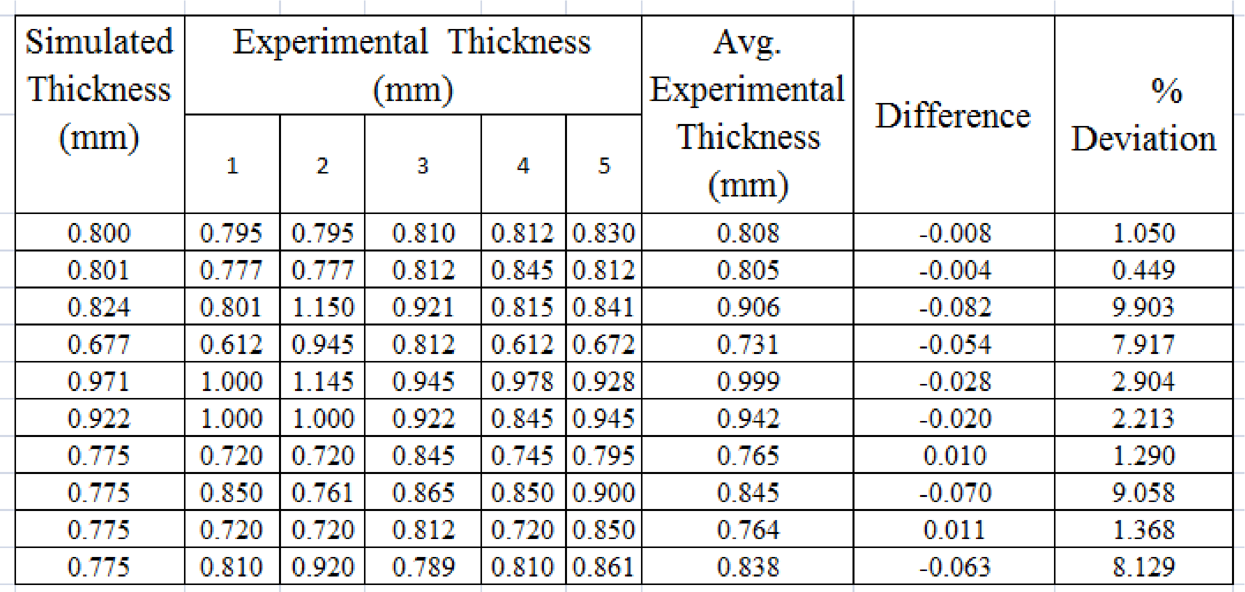
Figure 5.1: Ten different location on ¼ portion fuel tank top-bottom

To validate the outcome of FEA, experiments were conducted and fuel tank is formed. After formation of fuel tank the thickness was measured along the cross section at 10 locations as shown in figure 5.1. If the percentage deviation between simulated thickness value and experimental thickness value is less or equal to 10% then the simulated results obtain are correct is considered.

5.2 Comparison of Simulated and Experimental Thickness of Fuel Tank Top and Bottom Experimental analysis of fuel tank top and bottom done by considering the EDD material.

5.2.1 Simulated and Experimental Thickness of Fuel Tank Top using Hydraulic Press

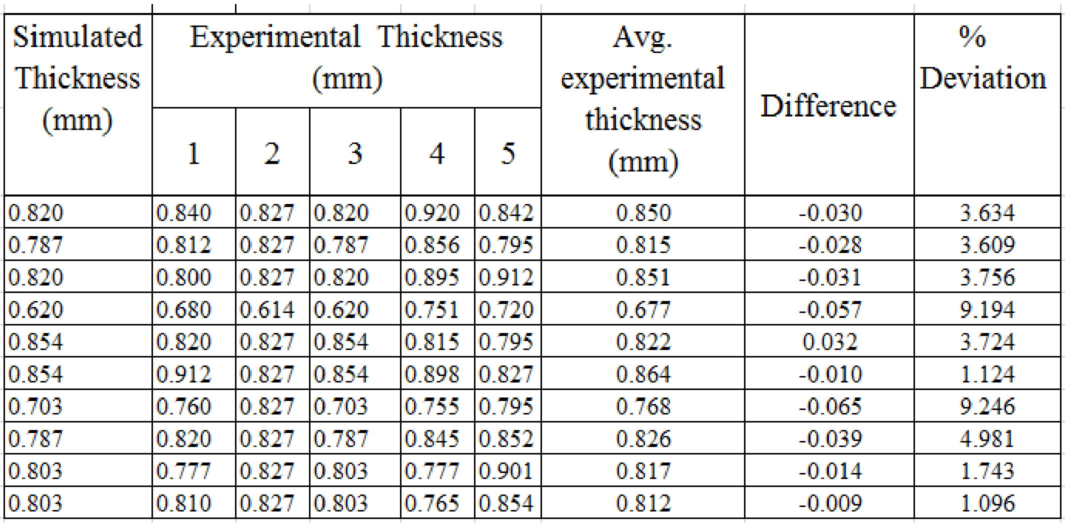
Table 5.1: Percentage deviation of simulated and experimental thickness for fuel tank top



Simulated Thickness (mm)	Experimental Thickness (mm)					Avg. Experimental Thickness (mm)	Difference	% Deviation
	1	2	3	4	5			
0.800	0.795	0.795	0.810	0.812	0.830	0.808	-0.008	1.050
0.801	0.777	0.777	0.812	0.845	0.812	0.805	-0.004	0.449
0.824	0.801	1.150	0.921	0.815	0.841	0.906	-0.082	9.903
0.677	0.612	0.945	0.812	0.612	0.672	0.731	-0.054	7.917
0.971	1.000	1.145	0.945	0.978	0.928	0.999	-0.028	2.904
0.922	1.000	1.000	0.922	0.845	0.945	0.942	-0.020	2.213
0.775	0.720	0.720	0.845	0.745	0.795	0.765	0.010	1.290
0.775	0.850	0.761	0.865	0.850	0.900	0.845	-0.070	9.058
0.775	0.720	0.720	0.812	0.720	0.850	0.764	0.011	1.368
0.775	0.810	0.920	0.789	0.810	0.861	0.838	-0.063	8.129

5.2.2 Simulated and Experimental Thickness of Fuel Tank Bottom

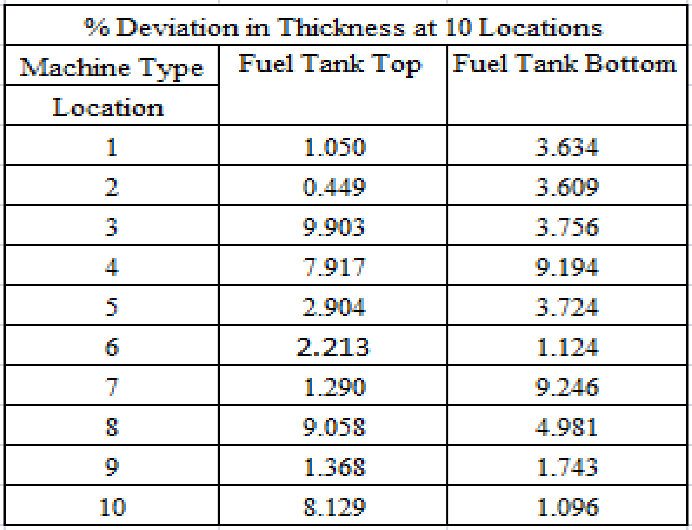
Table 5.2: Percentage deviation of simulated and experimental thickness for fuel tank bottom



Simulated Thickness (mm)	Experimental Thickness (mm)					Avg. experimental thickness (mm)	Difference	% Deviation
	1	2	3	4	5			
0.820	0.840	0.827	0.820	0.920	0.842	0.850	-0.030	3.634
0.787	0.812	0.827	0.787	0.856	0.795	0.815	-0.028	3.609
0.820	0.800	0.827	0.820	0.895	0.912	0.851	-0.031	3.756
0.620	0.680	0.614	0.620	0.751	0.720	0.677	-0.057	9.194
0.854	0.820	0.827	0.854	0.815	0.795	0.822	0.032	3.724
0.854	0.912	0.827	0.854	0.898	0.827	0.864	-0.010	1.124
0.703	0.760	0.827	0.703	0.755	0.795	0.768	-0.065	9.246
0.787	0.820	0.827	0.787	0.845	0.852	0.826	-0.039	4.981
0.803	0.777	0.827	0.803	0.777	0.901	0.817	-0.014	1.743
0.803	0.810	0.827	0.803	0.765	0.854	0.812	-0.009	1.096

5.3 Summary of percentage deviation of Fuel Tank top and bottom

Table 5.3: Summary of Percentage Deviation in Fuel Tank Top and Bottom.



% Deviation in Thickness at 10 Locations		
Machine Type	Fuel Tank Top	Fuel Tank Bottom
Location		
1	1.050	3.634
2	0.449	3.609
3	9.903	3.756
4	7.917	9.194
5	2.904	3.724
6	2.213	1.124
7	1.290	9.246
8	9.058	4.981
9	1.368	1.743
10	8.129	1.096

Inference :

1. The simulated thickness values and experimental thickness values are nearly same and there % deviation is below 10%, hence the results are obtain from the simulation are correct.

2. The % deviation is calculated for the material EDD. There % deviation is below 10%, hence it also applicable to the other material like Deep Steel, Deep Drawing Steel.

VI.CONCLUSION

6.1 Conclusion

A finite element model for simulating the deep drawing process without the presence of draw bead, with the presence of circular draw bead for fuel tank is developed. Simulations were carried out for finding out the effect of draw bead in thickness .The major conclusions are as follow:

1. To validate the FEA outputs cups were formed using hydraulic press .Considering the ¼ part of fuel tank and thickness were compared with FEA results. The deviation between them is almost less than 10%.
2. Optimum blank holding forces are required to produce wrinkle free component.
3. When circular draw beads are used in deep drawing process, minimization of thickness variation, wrinkling and tear –off problem.
4. The plastic bags used during deep drawing process, due to which the scratches obtained on component or heat generation can be reduce.
5. The material D due to their chemical properties that can tear or wrinkling take place most of the cases. The EDD material is costly and DD Material is less costly as compare to EDD but both materials show same performance, hence it is recommended that for the fuel tank the DD Material is also suitable.

6.2 Future Scope

1. Throughout the study it is observed that some of the areas can further be investigated and can be developed. In the presented study, the experiments were performed on the fuel tank only. But the behavior of other type of industrial component can be analyzed.
2. A majority of products of automobile and aircraft industry are manufactured by drawing process. Products of these industries can be taken for analysis work. Investigations on non symmetrical work pieces can be conducted.
3. Other type of industrial component can also be analyzed.

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