Prediction of Thickness Distribution in Sheet Metal Forming by Modified Limiting Dome Height Test with and without Blank-Holding Force

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***Abstract*—This study aims to investigate the forming behavior prediction of AISI 1008 materials using Experimental Data and simulation. Forming behavior can be understood using thickness distribution also, by which strain localization and strain distribution in the sheet metal can be studied. In this present work, the difference in the thickness distribution for different drawing ratio i.e. D/d ratio is observed. The experiment has been done using modified limiting dome height test i.e. "LDH" for different case which includes Blank holding force and without blank holding force with different blank size. In LDH test, the mechanical properties are considered in different directions i.e. rolling direction (r0), perpendicular direction (r90) and transverse direction (r45). The strain paths are chosen from Two Different blank size from drawing to stretching condition; total points have been taken for the consideration of LDH test accordingly. Circle grid marking is done on the blank by laser marking and readings is taken in the different direction. Experimental work is compared with the software HYPERFORM for the validation of the work. Experiment's thickness Data are obtained by taking reading at each circle grid. Thickness distribution are compared for better investigation of the formability among both the cases.**

Keywords— LDH test, circle grid analysiss, thickness distribution, hyperform simulation.

I. INTRODUCTION (SHEET METAL FORMING)

Sheet Metal Forming has a characteristic of changing the sheet metal into a desired shape without necking or crack moreover it has the capability to form the material plastically as appeared in fig 1. The process parameters and material's property have a basic role in most of the sheet metal forming operation have a fundamental role in the majority of the sheet metal forming operations. Material properties, likestrain hardening coefficient, yield strength, anisotropy, elastic modulus etc. decides the quality of forming and also the process parameters as punch and die geometry, oil, punch speed and blank holding force decides the quality of forming of the procedure. For a successful sheet metal forming operation there must be a suitable material selection and determining optimum forming parameters. Accomplishing easy to complex parts like stamping, blanking, puncturing, shaping, explosion, begetting, tube bending and pressing is the basic sheet metal forming process. Application of sheet metal parts in car and aviation created by forming have a good quality to weight proportion and they are even strong from material to material, forming limit changes for a defined procedure and geometry. Without failure of workpiece the deformation should be perfect is the basic concern of this process. In this manner, innovative work are done keeping in mind the end goal to assess forming limits of the sheet metals.

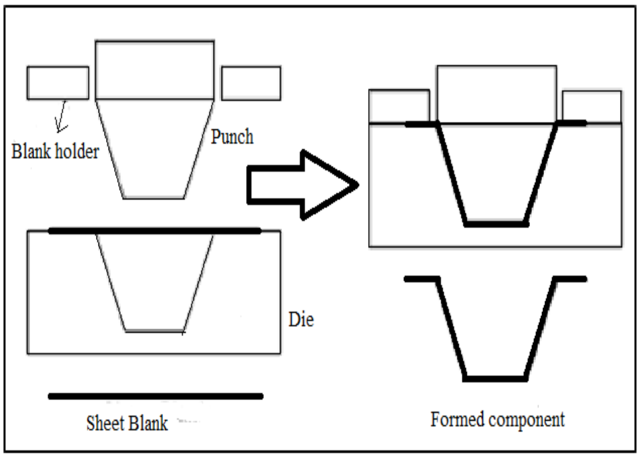

Fig 1.Conventional Stamping Process

Circle Grid Analysis

Circle grid analysis (CGA) is a technique for measuring the strain levels of sheet metal after the part is formed by drawing or stamping. A circle grid of particular diameter is etched to the sheet metal surface. The diameter's difference between the major strain and minor strain from the original diameter is the Strain's amount to be calculated. The two direction in which one direction (major strain) and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

compressing the diameter in the other direction (the minor strain) the forming process deforms the circle. The material utilized in die try-out must have different or marginally lower, forming properties than the production material.

Circle Grid Patterns and Size

Circle grid patterns have been used to mark the grid in different forms like square and circle which can be etched either closely or little far from the each circle. Generally the circle grid which are closely together are most preferable to do the experiment. It becomes more convincible to decide strain gradient precisely. After the deformation of the specimen the circle grid pattern is formed into oval. The major axis and minor axis of the circle is seen by the change in strain. Circle with 5mm diameter is believed to be perfect size of the circle grid.

II. EXPERIMENTAL WORK AND EXPERIMENTATION - LDH TEST

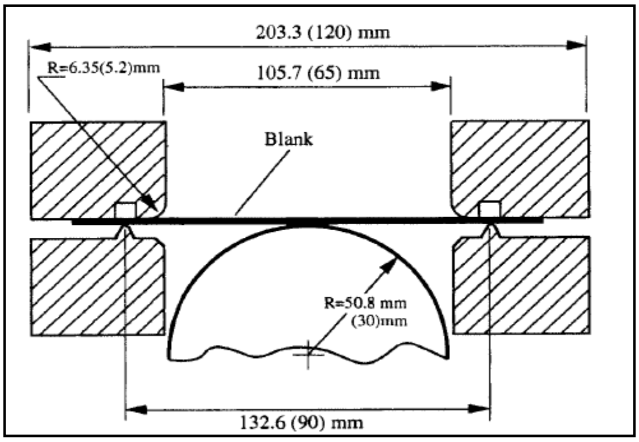

Fig 2 Limiting dome height test [3]

To simulate more effectively the fracture condition (plane strain) LDH test is developed found in most of the stamping process. 101.60mm diameter punch of hemispherical shape is used in this test and sheet-metal strips with varying width are stretched over punches which are clamped rigidly in a blank holder. Grids of small circle (5mm diameter) are marked on the metal strips and closest to the fracture, the width strain is measured. At some critical blank width this width strain is minimum of the sheet metal. At the critical blank-width, the height at which the dome fails shows a minimum height. This height is known as limiting dome height near plane strain (LDH0) and as a formability index it is extensively used. With the total elongation which is observed in a tensile test, LDH test results correlates well and also with the stamping behavior LDH test results also correlates well.

This test is most popularly used in the industries as the LDH test is able to simulate the most critical strain-state observed in the stamping.

A. Cad Model

Before manufacturing of the limiting dome height tool in tool room, drawings and model of the limiting dome height is prepare on Pro-Engineer software as per the dimension mentioned in the ASME. After making the models, drawing of limiting dome height forming punch, forming die and binder is given to the tool room for manufacturing the tool for the test of LDH.

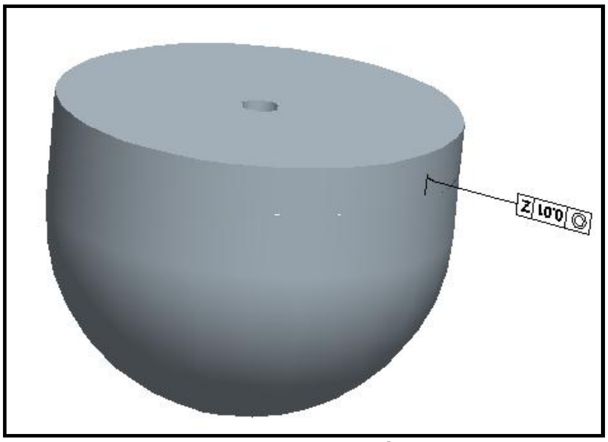

Fig 3. Forming Punch

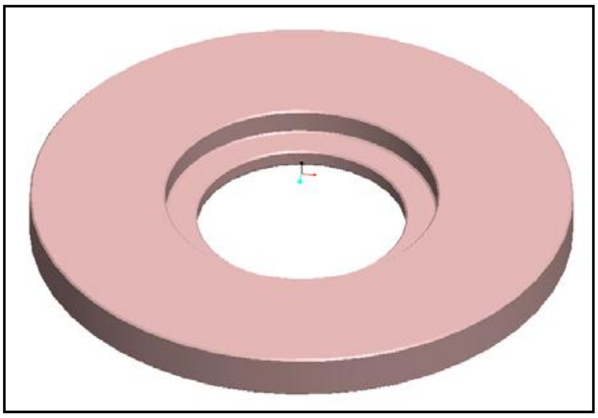

Fig 4. Binder

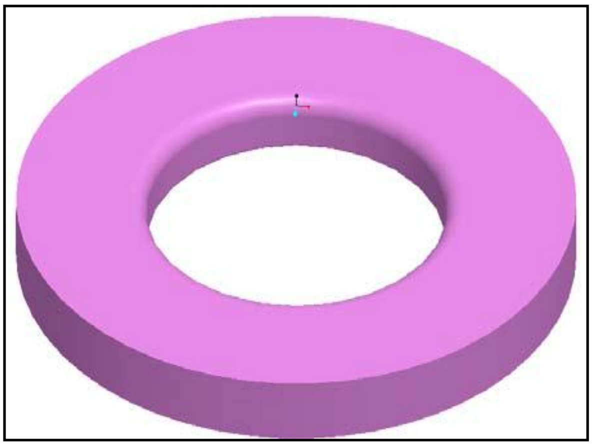

Fig 5. Die

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ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

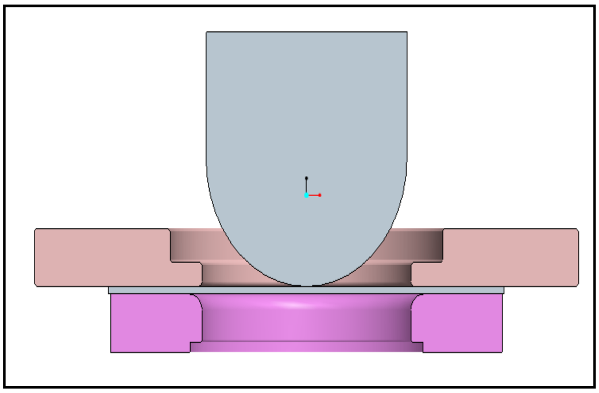

Fig 6. Assembly in PRO-E

B. Press Specification Which is used for Experiment Work.

- Manufacturer: - Chinfong.
- Model: - OCP-110
- Capacity: - 110 tons
- Slide Area: - 650 * 520 mm
- Bolster Area: - 1150 * 680 mm
- Main Motor: - 7.5 Kw

For performing the test, LDH tool is clamped on the Press slide of the mechanical press. Binder used in the tool is clamped in the tool and movement of the binder is given by the 4 nos. of Nitrogen Gas spring with the capacity of the 35 KN. LDH punch and binder is clamped with the upper tool of the LDH tool and the die is clamped on the lower tool of the LDH tool. During the test of the blank, press run at the 45 SPM.

C. Blank Specification Used for Experimental Work

- Blank Material: - AISI 1008
- Steel Mill: - Essar Steel
- Blank thickness: - 2.50mm
- Blank Dia.:- 219mm and 192mm
- Blank Qty: - 3 piece of 219mm and 2 piece of 192mm

D. Experimentation Details

Table 1. Specimen 1

Blank diameter	219mm
Blank Thickness	2.50mm
Blank holding force	35KN
Speed	45 SPM (strokes per minute)

Table 2. Specimen 2

Blank diameter	192mm
Blank Thickness	2.50mm
Blank holding force	0KN
Speed	45 SPM (strokes per minute)

Table 3. Specimen 4

Blank diameter	192mm
Blank Thickness	2.50mm
Blank holding force	35KN
Speed	45 SPM (strokes per minute)

Table 4. Specimen 5

Blank diameter	219mm
Blank Thickness	2.50mm
Blank holding force	0KN
Speed	45 SPM (strokes per minute)

Table 5. overall experimental table.

	D/d= (Blank dia. /Punch Dia.)	Blank-holding Force (KN)
Specimen 1	2.15	35
Specimen 2	1.89	0
Specimen 3	1.89	35
Specimen 4	2.15	0

E. Thickness Measurement Set-Up

Thickness of the deformed specimen is measure with the help of dial indicator. The below Figure 7 shows the dial indicator mounted on top. Arrangement is done in such a way that the difference at every strain can be measured.

Fig 7. Thickness Measurement with Dial Indicator

F. Deformed Specimen of LDH Test (With blank-holding force)

Circular blanks etched with grid marks have been taken for the trial. The blank without circle grid marking is used until the necking occurs. Fig 8 shows the evidence of onset of necking in the specimen. The necking has occurred at 351mm shut height.

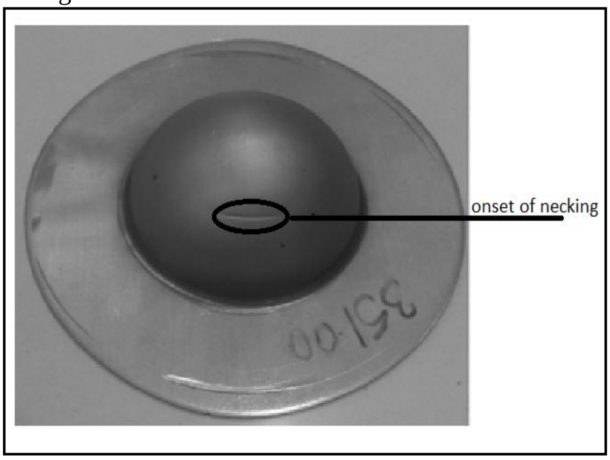

Fig 8. Onset of Necking

After the evidence of onset of necking the shut height is increased by 0.2mm so the fracture of material occurs as shown in fig 9.

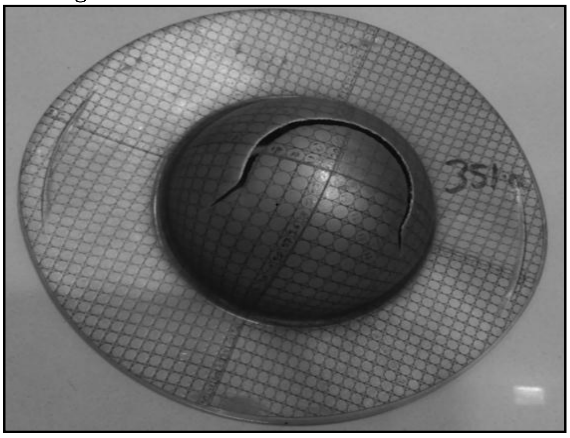

Fig 9. Shut height increased 0.2mm After Necking (219mm diameter)

After the failure of the specimen, the different etched blank is used and the shut height is increased with 0.5mm after necking and similarly the test is carried out for the different blank size and different condition of blank holding and without blank holding force. The necking does not takes place in 192mm diameter and also in without blank holding force.

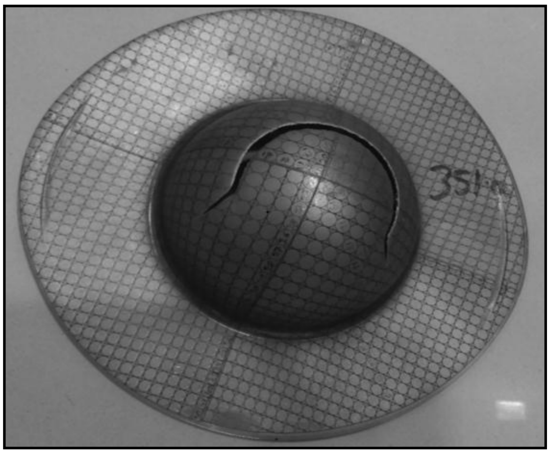

Fig 10. Shut height decreased 0.5mm after Necking (219mm diameter**)**

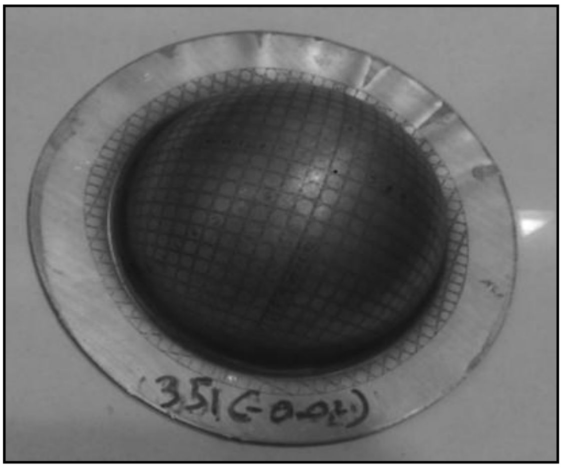

Fig 11. With blank holding force (192mm diameter)

G. Deformed Specimen of LDH Test (without blank holding force)

In the case of non-blank holding force the stripper plate of the LDH tool is not used hence the blank holding force applied becomes zero as a result the wrinkles are formed at the flange.

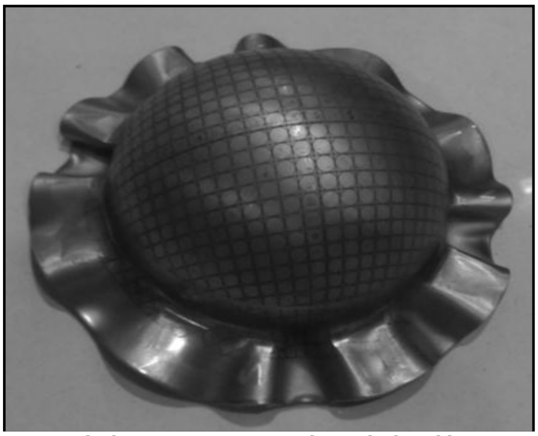

Fig 12. Blank Diameter 219mm without Blank Holding Force

III. HYPERFORM SIMULATION

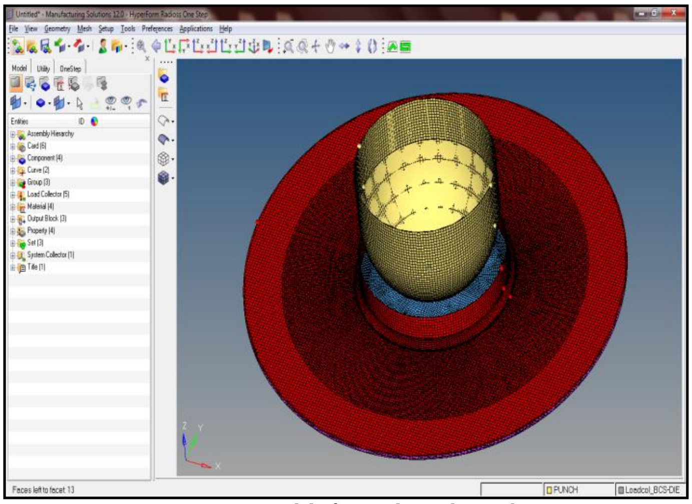

Fig 13. CAD model after applying the mesh

A. Thickness variation

- For blank diameter 219mm**.**

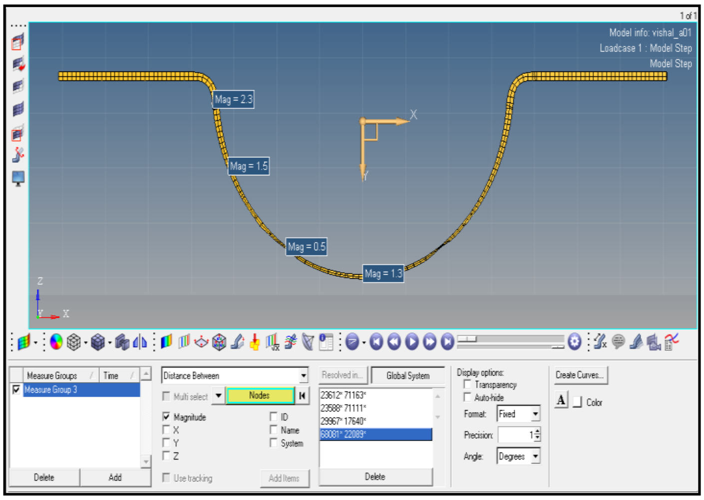

Fig 14. Thickness Variation of Deformed Specimen in HyperForm

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- For blank diameter 192mm.

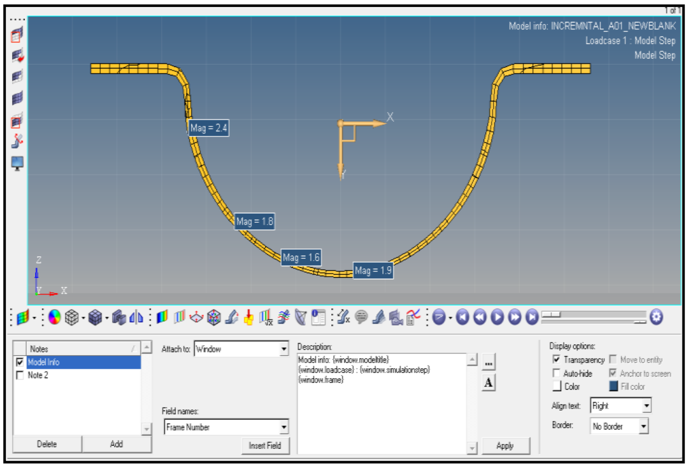
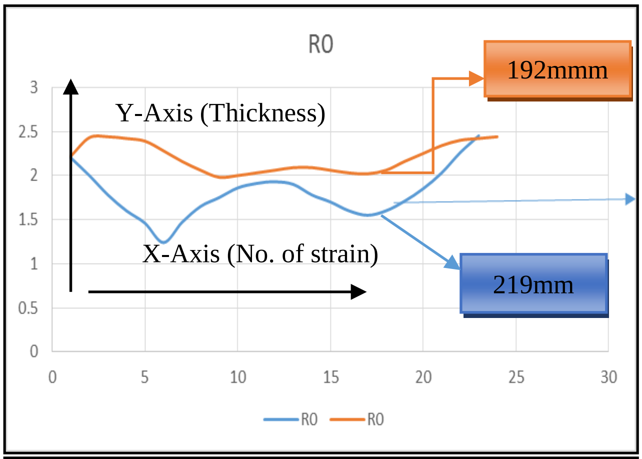


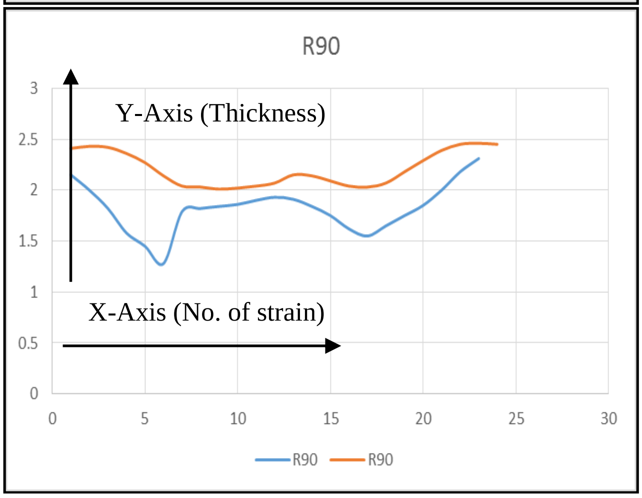
Fig 15. Thickness Variation of Deformed Specimen in HyperForm.

IV. RESULTS:-

A. Mechanical press thickness variation graph.

- Blank diameter of 219mm and 192mm with blank holding force





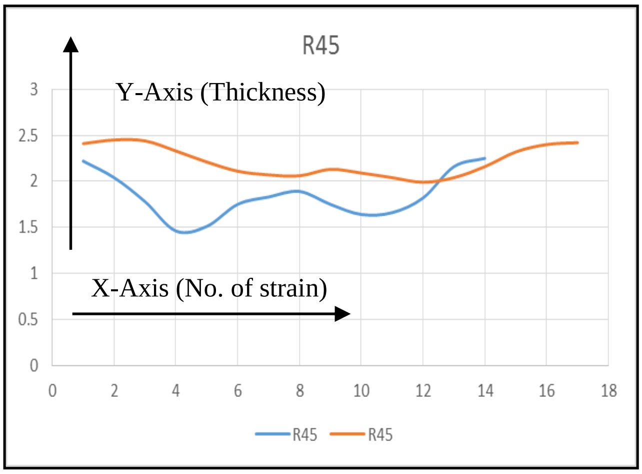
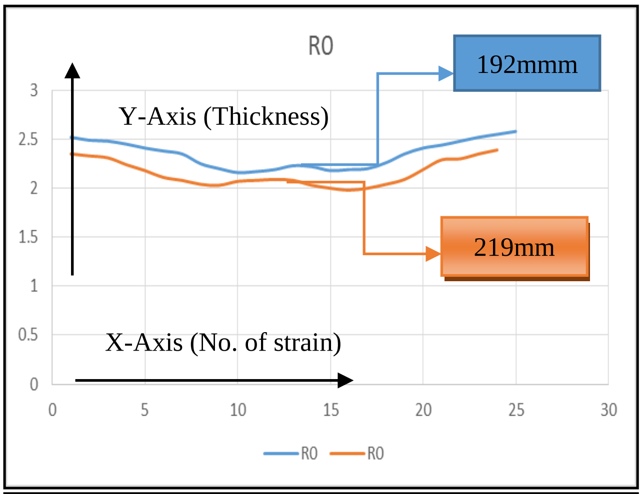


Fig 16. Thickness distribution of Blank diameter 219mm and 192mm with blank holding force for mechanical press

- Blank diameter of 219mm and 192mm without blank holding force



International Journal of Engineering Research & Technology (IJERT)
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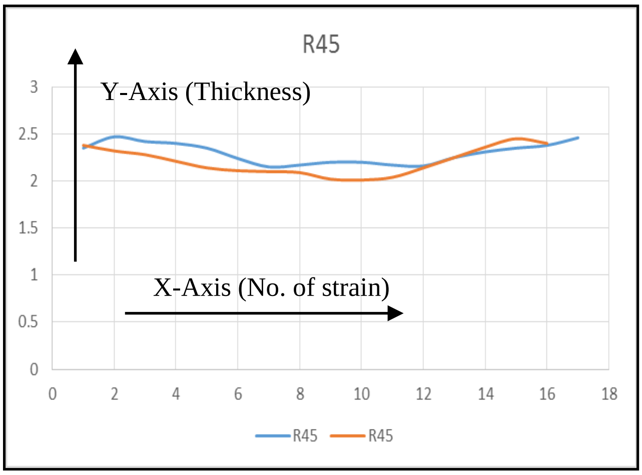


Fig 17. Thickness distribution of Blank diameter 219mm and 192mm without blank holding force for mechanical press

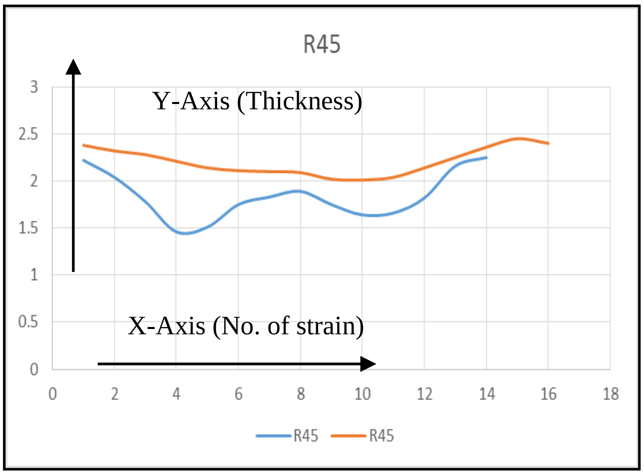
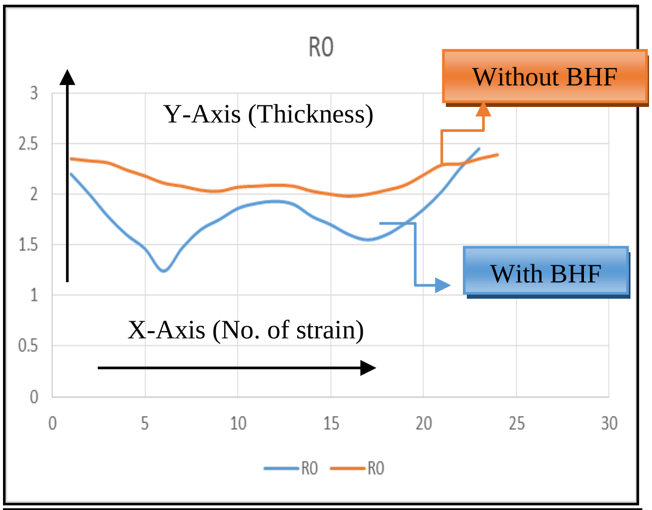
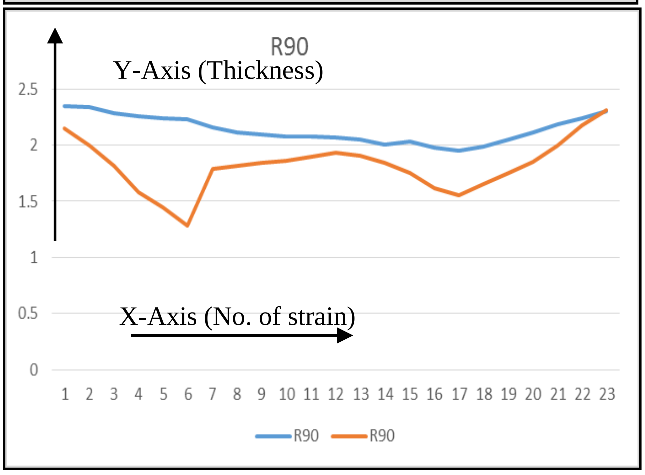


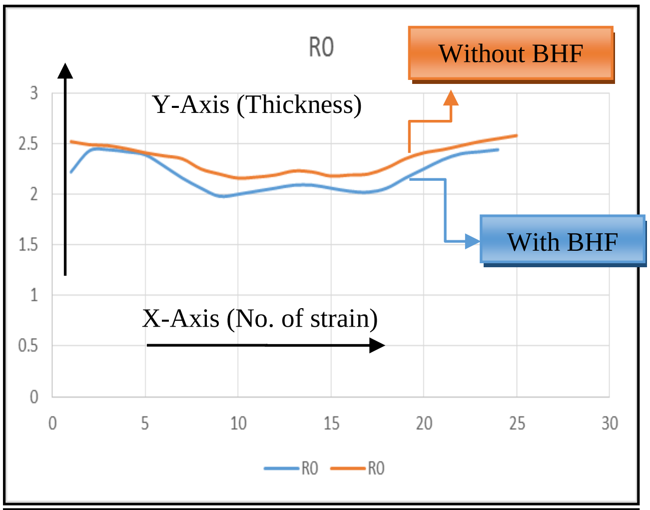
Fig 18. Thickness distribution of Blank diameter 219mm with and without blank holding force for mechanical press

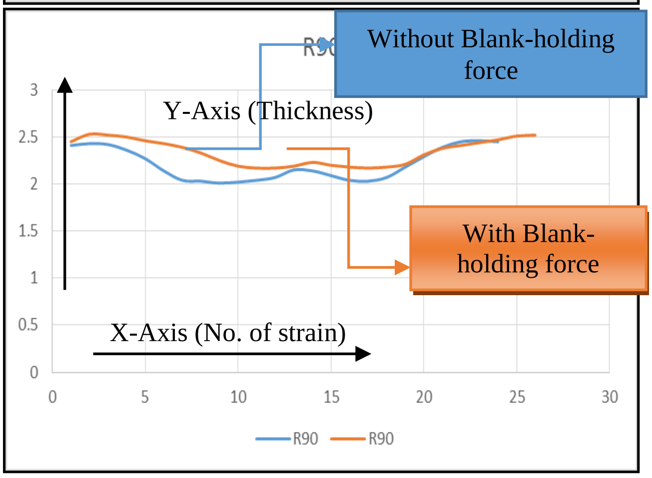
- Blank diameter of 219mm with and without blank holding force.





- Blank diameter of 192mm with and without blank holding force





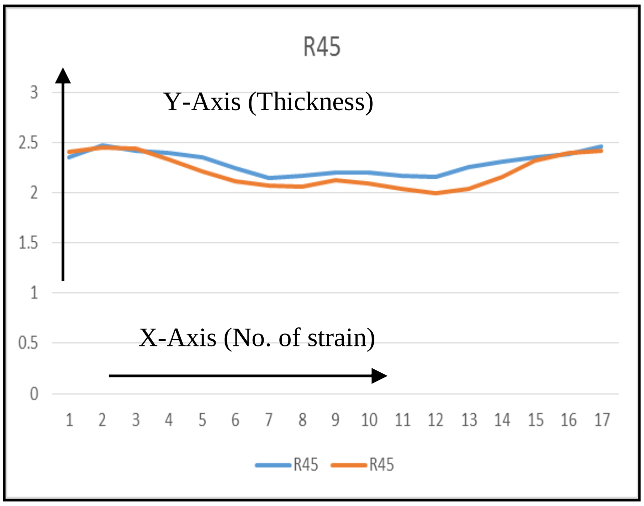


Fig 19. Thickness distribution of Blank diameter 192mm with and without blank holding force for mechanical press

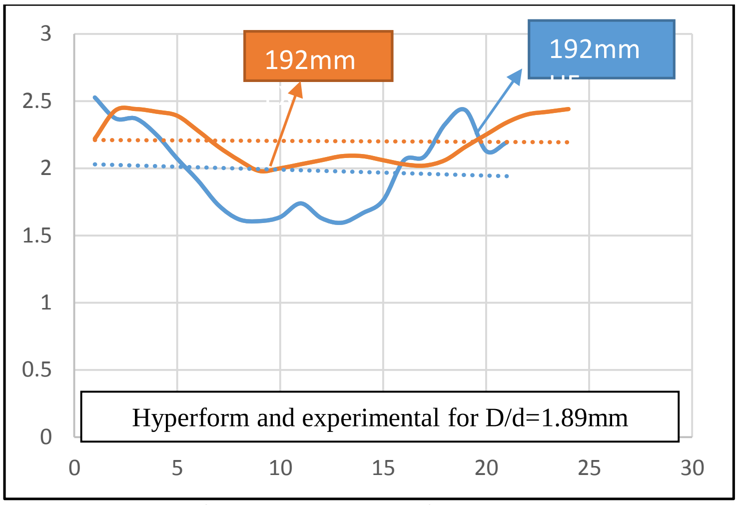


Fig 22. Comparison of Thickness Distribution of blank diameter 192mm in hyperform and experiment.

B. Comparsion of hyperform and experimental thickness distribution.

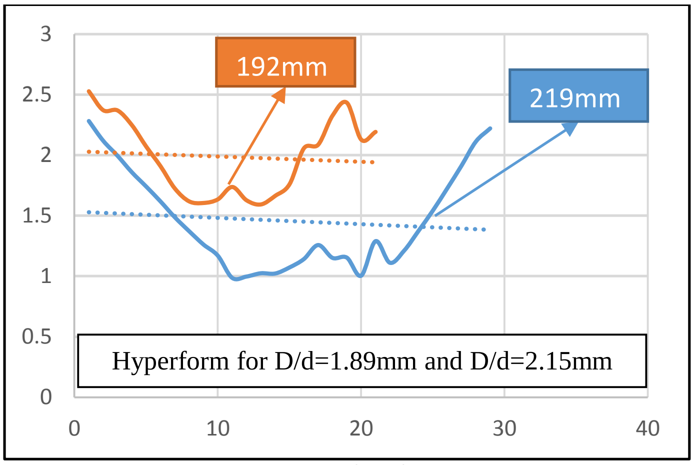


Fig 20. Thickness distribution in Hyperform for Blank dimeter 192mm and 219mm.

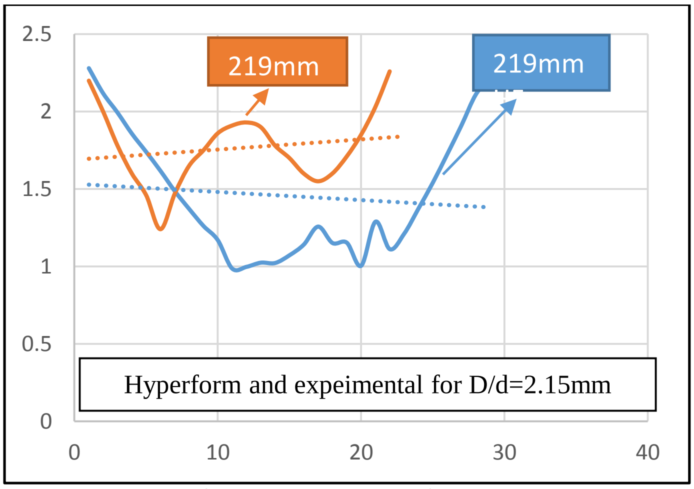


Fig 21. Comparison of Thickness Distribution of blank diameter 219mm in hyperform and experiment.

With Blank-Holding Force “t = thickness” (original t = 2.50mm)								
	D/d=2.15				D/d=1.89			
	Mx. t	Mn. t	Mx. %	Mn%	Mx. t	Mn. t	Mx. %	Mn%
R0	2.2	1.55	12	38	2.44	1.98	2.4	20.8
R90	2.15	1.55	14	38	2.43	2.01	2.8	19.6
R45	2.22	1.46	11.2	41.6	2.45	1.99	2	20.4
AVG.	2.19	1.52	12.4	39.2	2.44	1.99	2.4	20.26
Without Blank-Holding Force “t = thickness” (original t = 2.50mm)								
	D/d=2.15				D/d=1.89			
	Mx. t	Mn. t	Mx. %	Mn%	Mx. t	Mn. t	Mx. %	Mn%
R0	2.35	1.98	6	20.8	2.49	2.16	0.4	13.6
R90	2.35	1.95	6	22	2.5	2.17	0	13.2
R45	2.38	2.01	4.8	19.6	2.47	2.15	1.2	14
AVG.	2.36	1.98	5.6	20.8	2.48	2.16	0.53	13.6

V. RESULT DISCUSSION FOR THE THICKNESS VARIATION

The thickness variation behavior shows the following points:

- Thickness variation is more in the bigger blank diameter
- Thickness variation is more in the case when blank holding force is applied comparatively when blank holding force is not there.
- Behavior of the thickness variation is same for all the cases only the values of variation changes.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

The Hyperform results are effected by

- Grid location difference varies in hyperform and experimental deform specimen.
- Input to the Hyperform
- Cage raw material property
- Friction

VI. CONCLUSION:

1. Thickness variation increases with increase in Draw Ratio for both the cases i.e. with and without Blank-holding force. The difference in maximum and minimum thickness variation is as follows:.

With Blank-holding force: -	D/d=2.15	26.8%
	D/d=1.89	17.8%
Without Blank-holding force: -	D/d=2.15	15.2%
	D/d=1.89	13.1%

   Such phenomenon observes due to increased resistance to material flow with increased D/d ratio.
2. For D/d=2.15 and D/d=1.89 thickness variation is more in the condition of blank-holding force compare to NO Blank Holding force.
3. Highest Thinning :
   - With blank holding force:

   Reducing D/d from 2.15 to 1.89 (14%); is reduced by 50%.
   - Without blank holding force:

   Reducing D/d from 2.15 to 1.84 (14%), highest is reduced by 34%.
4. The thickness trend line follows the same pattern by hyperform as well as experimental.

VII. ACKNOWLEDGEMENT.

We would like to thank Harsha Engineers LTD. India, for the support given to the U.V. Patel Collage of Engineering for the M.Tech dissertation work which was carried in the organization we would also like to thank Mr. V.P. Mashroo of Harsha Engg, for the constant support and inspiration.

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