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"A REVIEW ON FINITE ELEMENT ANALYSIS AND PARAMETRIC STUDY OF SHEET METAL COMPONENT BALL RETAINING COVER"

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ABSTRACT

A load cell is a force transducer. It converts a force such as tension, compression, pressure, or torque into an electrical signal that can be measured and standardized. As the force applied to the load cell increases, the electrical signal changes proportionally. The most common types of load cell used are strain gauges, pneumatic, and hydraulic[1]. A standard loadcell named cup & ball type which includes accessories like- Base, Blank, Metal Ball, Ball retaining Cover, Rubber Bellow & fasteners. Ball Retaining Cover is a deep drawn metal piece & an essential part of cup & ball loadcell used to locate the loaded metal ball at center point of loadcell for proper load transfer at centre of Blank. Ball Retaining cover strength, deformations, stresses generated etc. Are many fields that require research to transfer continuous load of metal ball to blank. In ongoing work parametric study & forming analysis of loadcell ball retaining cover is done which includes thickness, holding force, clearance between die & punch & die shoulder radius to find the best result which can fulfil the requirements. Software such as SOLIDWORKS2021 and ALTAIR HYPERFORM19 is used for modelling and analysing deep drawing of Ball Retaining cover. On comparing all the stress, strain, deformations at following criterias we can conclude that among all this criterias which is appropriate to design a Ball Retaining cover with great durability.

Key Words: *Loadcell, Ball Retaining Cover, Finite Element Analysis, Deep Drawing, Hyperform19.*

I. INTRODUCTION

In India & all over the world Loadcells are widely used in weighbridges, weighing platforms & many weighing applications to get best weighing results of any material. A load cell is a force transducer. It converts a force such as tension, compression, pressure, or torque into an electrical signal that can be measured and standardized. As the force applied to the load cell increases, the electrical signal changes proportionally. The most common types of load cell used are strain gauges, pneumatic, and hydraulic. load cells are the kind most often found in industrial settings. It is ideal as it is highly accurate, versatile, and cost-effective. Structurally, a load cell has a metal body to which strain gauges have been secured. The body is usually made of aluminum, alloy steel, or stainless steel which makes it very sturdy but also minimally elastic. This elasticity gives rise to the term "spring element", referring to the body of the load cell. When force is exerted on the load cell, the spring element is slightly deformed, and unless overloaded, always returns to its original shape. As the spring element deforms, the strain gauges also change shape[2]. The resulting alteration to the resistance in the strain gauStrain gaugeges can be measured as voltage. The change in voltage is proportional to the amount of force applied to the cell, thus the amount of force can be calculated from the load cell's output.

A standard loadcell named cup & ball type which includes accessories like- Base, Blank, Metal Ball, Ball retaining Cover, Rubber Bellow & fasteners. Ball Retaining Cover is a deep drawn metal piece & an essential part of cup & ball

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loadcell used to locate the loaded metal ball at center point of loadcell for proper load transfer at centre of Blank.
Loadcell is a sensitive weight sesning device and all the accessoris used in it are well designed for accurate sensing of weight, Blank, Base & Metal Ball are the major elements of Cup & Ball Loadcell but safety accessory like Ball Retaining Cover is also an essential part of Cup & Ball Loadcell, This accessory is used to locate the loaded ball at centre of loadcell blank for proper sensing of load. When ball is displaced from centre of blank ball reaining cover plays a major role to relocate ball at centre of loadcell blank. Ball Retaining Cover is a deep drawn metal piece having curved surface at top and mounting holes at bottom for tightening in blank. There are lots of possibilities to fabricate Ball Retaining cover through machining or casting process but due to unnecessary material removal from workpiece and time involvement we fabricate it through deep drawing application which saves material loss as well as time of manufacturing. Three-dimensional solid model of the Cup & Ball loadcell with Ball Retaining Cover is as shown in the below figure 1[1] & Ball Retaining Cover Solidworks Model is shown in figure 2.

Fig. 1 Cup & Ball loadcell with Ball Retaining Cover

Fig. 2 Solidworks model of Ball Retaining Cover

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II. Literature Review

1. Effect on the product finish in deep drawing process due to supremacy of punch force by Brathikan V M ,Jayabalu S, Gideon Devairakkam S, Prashanth P Kaviscidarth[01].Deep drawing among the forming process is considered superior because of its low wastage. The appropriate parameters to have an optimized drawing process must be found. A slight change in these parameters is cause major change on positive or negative side. In this, the punch forces mainly focused. This is the force used to draw the object. An experiment by varying punch force is made and investigate what happens in that resulting product. During the application of excessive force some failure like fracture thinning and cracks would occur. Experiment by varying load is done, and the outcomes are observed. The outcome of the experiment was noted. From this experiment it's found that the optimistic load to draw the object and to improve the processing speed. By this, the productivity and accuracy is improved. By doing this for various loads, many results were obtained which gave reliability of the results. In deep drawing, the punch force depends on the material and the thickness of the material used. Need of Punch force is directly dependent to the thickness of the blank material used. For the elongation of the product the punch force can be increased then the height can be increased at ease when operated at optimized conditions. Uneven speed leads to the distortion of the material and shell thinning.

2. A novel holding process for forming boxes by optimizing effect of BHF distribution by Hongsheng Zhang , Siji Qin[02]This research is aimed to adjust blank holder force (BHF) in different flange areas to eliminate wrinkles and cracks on rectangular box deep drawing product. The calculating formulae of the critical BHF in the flange area are derived by using the energy method and a wrinkle model parameter m effect on the critical BHF by is analyzed. It's shown that the critical BHF decreases with decreasing m as the same wrinkle height. Steel sheet of SPCC grade, thickness of 0.6 mm was used in the finite element simulation study. It's shown that the segmental blank holder technique is better than the conventional one. Finally, compared to the application of the single blank holder, BHF can be quite effective for preventing the occurrence of cracking and increasing the formability of deep drawing. For the deep drawing of box parts, pull and stretch are the main deformation characteristics of the flange corner area, which thickness changes significantly along the radial direction. And bending is the main deformation characteristic on the flange straight edge area, which is little during the deformation process.
The advantage of the multi stage blank holding (MSBH) technique is the suppression of wrinkling caused by excessive hoop stress, because BHF can be independently applied using the new blank holder. Since the radial and hoop distribution of BHF can be adjusted at the same time, the forming effect of drawn box can be better improved by using the new blank holder process.

3. Recent Developments and Trends in Sheet Metal Forming by Powst. Warszawy[03]Sheet metal forming (SMF) is one of the most popular technologies for obtaining finished products in almost every sector of industrial production, especially in the aircraft, automotive, food and home appliance industries.New forming techniques, numerical and empirical approaches are being developed to improve and develop new methods of sheet metal forming. Many innovative numerical algorithms, experimental methods and theoretical contributions have recently been proposed for SMF by researchers and business research centers. These methods are mainly focused on the improvement of the formability of materials, production of complex-shaped parts with good surface quality, speeding up of the production cycle, reduction in the number of operations. Some new developed sheet metal forming techniques are listed such as: sheet microforming, incremental sheet forming, flexible die forming, rubber pad forming, multipoint die forming, solid granular medium forming, electromagnatic sheet forming,electrohydrraulicforming,spinning& shear spinning.

4. Multistage forming analysis of spoke resonator end-wall by P Karma, N K Sharma, V Pare, A Chaturvedi, N Nigam, G V Kane.[04]This paper presents an elasto-plastic finite element analysis for single stage and multi stage forming of spoke resonator End wall. Numerical simulations were performed to investigate the effect of forming process parameters on localized thinning, residual stresses and study of failure such as tearing or wrinkling. The results of the analysis were used to assess the various forming process. The analysis showed that the multistage forming leads to better uniformity in thickness of component.

In this work the finite element analysis of forming operating under single stage and multi stage processes were carried

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out for spoke resonator endwall. Following points were noted from analysis:

• The comparison of reduction in thickness of contour showed that the maximum thinning occurred at center/ nose part of the endwall in single stage forming. While multi-stage forming analysis showed that the percentage thinning improved to under two-stage and three-stage forming operation respectively for the same geometry. The improvement in percentage thinning helped in uniformity of thickness of the spoke resonator endwall by employing proper design and selection of forming tool and multistage forming.

• High equivalent stresses were observed in endwall in single stage forming. In multistage forming (three-stage) maximum von Mises stress is recoded at edge of flange of magnitude. This is lower than the stresses induced in single stage forming however more than stresses noted in two-stage forming and due to strain hardening while plastic deformation.

5. Investigations into improvement in formability of AA5754 and AA6082 sheets at elevated temperatures by Panicker, S.S.; Panda, S.K.[05]The major outcomes from this comparative investigation on formability improvement during warm forming of AA6082 and AA5754 sheet materials are summarized as follows:

i. The lowest YS and UTS of both the materials were observed at 250oC and under the lowest strain rate. The exponential decrease in C value with increase in temperature showed significant enhancement of strain rate sensitivity at elevated temperatures. Total elongation of AA5754 at 200oC was higher compared to AA6082.

ii. Significant improvement in limiting strains at elevated temperature was observed at 200oC. The FLD at 200oC higher for AA5754 and AA6082, when compared to room temperature conditions. The bending strains developed due to sub-size punch showed negligible influence on the FLD at elevated temperature.

6. Development of experimental and theoretical forming limit diagrams for warm forming of austenitic stainless steel 316 by Hussaini, S.M.; Krishna, G.; Gupta, A.K.; Singh, S.K.[06]In sheet metal forming, the formability is limited by the onset of localized necking and it is important to know the limit up to which the material can be formed. Forming limit diagram (FLD) offers a convenient and useful tool to predict the forming behavior of the sheet metals, which can be enhanced by forming at elevated temperatures. This paper is focused on the development of FLD for austenitic stainless steel (ASS) 316 at 300◦C, which has been experimentally determined to be the most suitable temperature for warm forming of ASS 316. Experimental FLD has been constructed by performing hemispherical dome punch tests on different width specimens. Theoretical FLDs have been developed using Marciniak–Kuczynski analysis based on Hill's and Barlat's yield criteria and compared with the experimental FLD. Theoretical FLD based on Barlat's yield criterion is found to be in a close agreement with the experimental FLD. These FLDs can be used for designing various warm forming processes on ASS 316. This investigation focused on the development of FLD for ASS 316 at elevated temperature. ASS 316 has highest LDR of 2.47 and less thickness variation at 300◦C, which shown that the material is more formable at this temperature.

7. The analysis of multistage deep drawing of AA5754 aluminium alloy byM.Packo,M.Dukat, T. Sleboda, M.Hojny[16] analyze the manufacturing of asymmetrical, box type part made of 2.5mm thick AA5754 O/H 111 Aluminium alloy . The component is consists of small corner radius on side surfaces and at bottom of the part, which preclude its production in single stage forming. Therefore, multistage forming is adopted. The aluminium blank is pressed by single action hydraulic press of max. Capacity 200 ton and the simulation performed on software eta/DYNAFORM. The simulation results for thickness distribution were compared with real deep drawing and the difference does not exceed 10%. Further results are concluded:

- The thickness distribution is not uniform. The largest contraction occurs in central areas of the corner of the box.
- The phenomenon of wrinkling of the side wall is very disadvantageous in respect to significant thinning of draw piece corners. The elimination of wrinkles by changing the geometry of semi-finished product or by the application of draw beads.

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- After first stage forming, rapid increase of the drawing force was observedfor second and third stage.This phenomenon occurs due to increase in strain hardening and reduction in radius of draw piece corners and side surfaces.

8. Effect of die design parameters on thinning of sheet metal in deep drawing process by H.Zein, M.El-Sherbiny, M.Abd-Rabou, M.ElShazly [10] discussed that, in sheet metal forming,the determination of thickness distribution and the % thinning of the blank can decrease the cost of production by saving material and production time. The thickness distribution can helps to remove excessive material from where the less stresses are induced. A circular cup shaped geometry of size 224mm diameter and 1mm thickness is used for simulation of deep drawing process by ABAQUS/Explicit FEA software using Hills anisotropic yield criteria to determine the effect of various parameters

9. Analysis on effect of die fillet radius and draw bead on hemispherical cup forming G.M Bramhakshatriya, S.K Sharma , B.C Patel [12] , explain the effect of draw beads on forming of a hemispherical cup of size 174mm diameter and 1.02mm thickness. The work reported in this paper is focused on analysis by using different die shoulder radius with circular draw bead and without draw bead and their effect on strain and thickness distribution. The analysis was carried out on HYPERFORM with HILLORTHOTROPIC TABULATED model [23]. From the analysis it had been seen that:

- Thinning is more in middle section where stretching takes place and gradually thickness increase towards the bottom section.
- The maximum thickening occurs in flange region due to compressive strain.
- Application of circular draw beads reduces the thinning in bottom and side portion of the cup.

10. Evolution of the plastic anisotropy with straining and its implication on formability for sheet metal Y.G An, H.Vegter, S., P.RomanoTriguero [09] explain the evolution of the plastic anisotropy with straining and its implication on sheet metal formability. In sheet metal forming plastic strain ratio (r-value) is an importantparameter. Theuniaxial tensile test is performed to measure length and width strain and r-value is fitted by linear regression within a certain strain range. Y.G An et al. plotted the relationship between the incremental r-value and strain for different tested material such as forming steel DC04,Annealed steel DC06IF, and continuously annealed High formable steel DX57.For DC04 incremental r-value in all three direction decreases with increase in strain. The r-value is in decreasing order from transverse direction, rolling direction and diagonal (450) to the rolling direction. For DC06 it decreases in order from transverse direction, diagonal to rolling direction and rolling direction and for DX57 the r-value is greater in transverse direction and lowest in diagonal to the rolling direction. So, it is clear that the incremental r-value is not constant for most of the materials. It is not only depends on materials but also depends upon the direction of straining.

11. Effect of Process Parameters on Spring Back In Deep DrawingSachin S Chaudhari [07] has investigated the effect of various parameters like die shoulder radius, Blank thickness, punch nose radius and blank holding force on spring back. The conclusion from this paper is that:

- Thespring back percentage is very less when die shoulder radius is greater than or equals to the 10 times of blank thickness.
- They found spring back percentage is less for punch nose radius greater than six times of blank thickness and higher for nose radius is less than four times of thickness.
- It is investigated that the spring back value decreases as the blank holder force increases.
- The spring back value decreases with increase in blank thickness.

12. Effect of blank holder force control in deep drawing process of magnesium alloy sheet Shoichiro Yoshihara, Ken-ichiManabe, Hisashi Nishimura [17] investigated acircular cup deep drawing process using a magnesium alloy material. Shoichiroyoshihara et al. performedan experiment on improvement in limiting drawing ratio at 300oC by controlling a variable blank holding force (BHF) during process and verified by using a finite element method simulation. A blank of 69.3 mm diameter, 0.5mm thickness and drawing ratio 2.1 is selected for the experiment. Shoichiro Yoshihara et al. concluded the comparative results of effect of constant BHF and variable BHF on limiting drawing ratio (LDR), which are listed below:

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- For constant BHF, requirement of punch load is higher than the variable BHF.
- In case of variable BHF the cup is drawn without any fracture and wrinkles.
- The limiting drawing ratio in variable BHF is higher than that in constant BHF and it is improved from 2.1 to 2.14 in variable BHF.
- In case of constant BHF thinning is takes place from punch shoulder part to wall part of the cup while in case of variable BHF, thickening and thinning of cup is suppressed.

13. A Simplified Approach to Estimate Limiting Drawing Ratio and Maximum Drawing Load in Cup Drawing by Daw-KweiLeuand Jen-Yu Wu[19] explain the effect of normal anisotropy ($\overline{R}$), and strain hardening exponent (n) on the limiting drawing ratio using either the experimental studies or the numerical models. The anisotropy is important in symmetrical draws. Whiteley's and Leu's equation signifies that the LDR depends on $\overline{R}$. The higher $\overline{R}$, thebetter is the LDR. It was also concluded that LDR does not depend in any significant manner on the strain hardening exponent.

14. Metal forming and The finite element method by Shiro Kobayashi, Soo-Ik Oh, TaylanAltan[20] In this book Shiro Kobayashi et al explain the metal forming processes, aanalysis and technology in metal forming, and Finite element formulation steps from element discretization to the numerical solution of global equation for metal forming problem.Plastic anisotropy, in plane deformation process, axisymmetric out of plane deformation, punch stretching and deep drawing process, non quadratic yield criterion also explained by Kobayashi in this book.

III. Problem Identification

Ball Retaining Cover is widely used in all Loadcells and consumed in bult quantity but this product have following problems for mass production that is identified and elaborated below:-

- Cost of current Ball Retaining Cover is high due to its Stainless Steel Material.
- Buffing/Polishing is also an additional process to make final product which consume time & money.
- Deep Drawing of SS material required more drawing force.
- % thinning in Stainless steel material is also high.

III. Problem Definition

Following problems are being solved:-

- To reduce cost of Ball Retaining Cover.
- Design a Ball Retaining Cover with the help of SOLIDWORKS Software.
- To conduct material analysis by using different materials in order to obtain a correct material for the Ball Retaining Cover capable of deep drawing Operation
- To Conduct Stress Analysis in different sections of the Ball Retaining Cover to find the load conditions and deformations in the designed Cover.

IV. Proposed Methodology

In present work Ball Retaining Cover is modelled and analysed by using SOLIDWORKS 2021 and ALTAIR HYPERFORM19 software respectively. AISI SS304 & CRDQ(ASTM A619) are the materials which are taken into consideration for analysis. Steps follow in methodology flowchart shown below:

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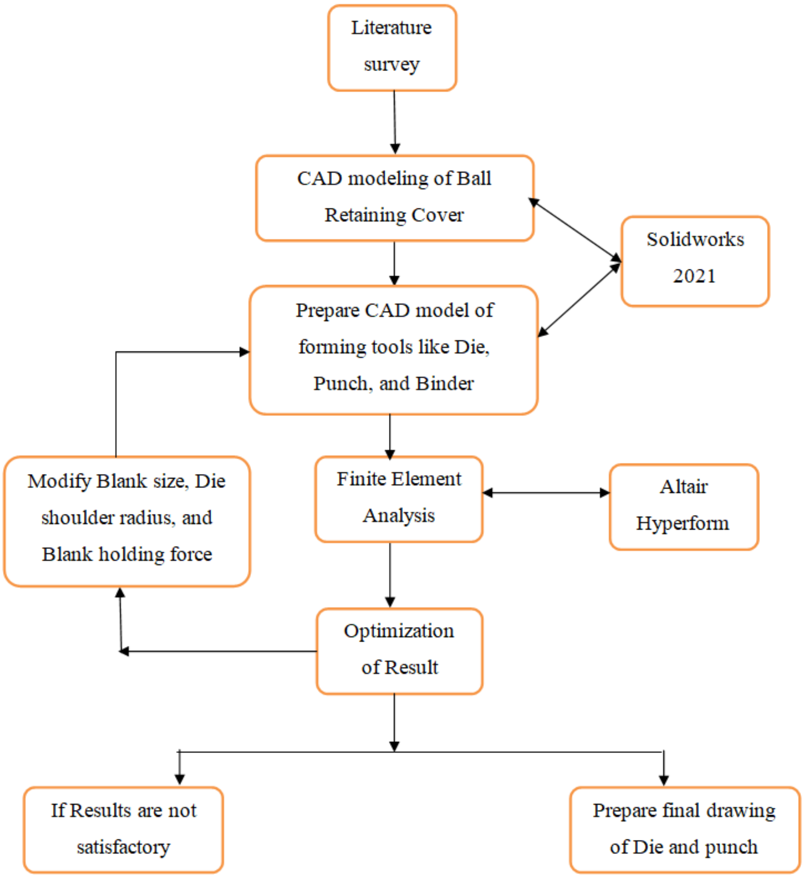

V. CONCLUSION

Finite element analysis has been performed on sheet metal "ball retaining cover" and results are optimized by varying design parameters to form a quality product. Material selection also done by performing FEA analysis. It has been observed that:

- The CRDQ (ASTM A619) steel is suitable to forming ball retainer.
- Stresses are reduced from 473.4MPa to 468.3Mpa.
- %Thinning Reduces from23.16% to 21.52% by fixing the parameters like Blank thickness 1mm, Blank holding force 15kN, Clearance 40% of thickness and Die Shoulder Radius 5mm.

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