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Formability Analysis of Sheet metal Component using CAE

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ABSTRACT

Sheet metal forming problems are typical in nature since they involve geometry, boundary and material non-linearity. Drawings part involves many parameters like punch and dies radius, clearance, lubrication, blank holding force and its trajectories etc. So designing the tools for part drawing involves a lot of trial and error procedure. To reduce number of costly trial error steps, the process can be simulated by using finite element packages. Even the finite element package gives an approximation towards the solution. The dissertation work is relevant in the context of developing a cost effective component with a lower lead time through the phase of Design, Development, Trials and Testing, Pilot lot production & Regular supply. In this dissertation work, the significance of three important deep drawing process parameters namely blank Holding force, die arc radius and punch nose radius on the deep drawing characteristics was determined. Existence of thickness variation in the formed part may cause stress concentration and may lead to acceleration of damage. The finite element method is a powerful tool to predict material thinning deformations before prototypes are made. In this dissertation work, the combination of finite element method and Taguchi design of experiments and analysis of variance has been applied to analyse the influencing process parameters on Thinning in automotive Oil Cap.

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I. INTRODUCTION

1.1. Background

Deep drawing is also a process of forming sheet Metal through a forming die with a punch. Metal in the area of the die shoulder undergoes a lot of stress, and will result in wrinkles if a blank holder is not used to control the flow of material into the die. Material is usually thickest in the area where the metal loses contact with the punch - the punch radius - and thinnest in the areas where stresses are greatest. Deep drawing is often used to produce metal objects that are more than half their diameters in height. The metal is stretched around a plug, and then moved into the die. [1]

During deep drawing process, blank under the blank holder was drawn into the deformation by the punch. The main concern of the deep drawing industry is to optimize the various process parameters in order to get a complete deep drawn product with least defects. Failure of deep drawing parts during deep drawing processes usually take place in the form of wrinkling, tearing or fracture. The effect of the blank shape and the blank holder force on wrinkling, fracture was investigated. Wrinkling, fracture limits have been determined under the current process

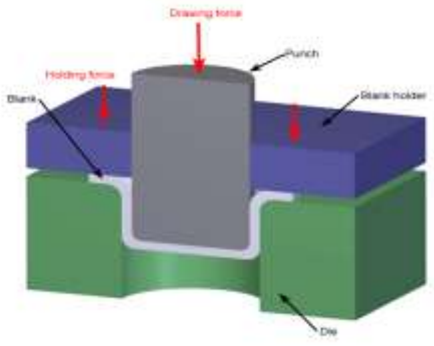

Fig 1.1. Draw-tool nomenclature

Conditions and BHF control methods have been developed to improve formability and to increase the attainable cup height. Wrinkling defect generally occurs at the flange and is generated by excessive compressive stress that causes the sheet to buckle. Wrinkling and tearing or rupture thus defines the deep drawing process limits. For this problem, many variables affect the deep drawing process, these include material properties, die design, friction conditions, drawing ratio, BHF, punch corner radius, die corner radius and punch speed. [2]

Production of pressings is realized using forming Machines, which ones act by force onto initial blank through forming die. Therefore they change its initial flat shape onto semi-finished or final product. Forming processes force parameters knows enable to technologists – forming processes designers and forming machines designers to dimension forming machine and forming die components. Besides, experimental research of forming forces allows process optimization, because they are complicated Multi-factors systems. [3]

In sheet metal forming process many factors have to be considered such as drawing force, blank holder force, friction force ....etc. The energy source for this deformation may be a hydraulic press at one end of the scale, mechanical press, or a high – explosive charge at the other. Deep drawing is a process in which a blank or work piece is usually controlled by a pressure plate, forced into and/or through a die by means of a punch to form a hollow component in which the thickness is substantially the same as that of the original material. The draw beads are one of the most important parameter to control the material flow and thus the part quality in the sheet forming process. [4]

Deep drawing is an important process used for Producing cups from sheet metal in large quantities. In deep drawing a sheet metal blank is drawn over a die by a radiuses punch. As the blank is drawn radially inwards the flange undergoes radial tension and circumferential compression. 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. Radial tensile stress on the flange being drawn is produced by the tension on the cup wall induced by the punch force.[5].

II. LITERATURE REVIEW

Mr. Amit D. Madake [1] said that sufficient research and deliberation using the proven QC tools backed up with CAE software support (HYPERFORM) has offered a feasible solution to the problem at hand. Steel material like HCHCr (High carbon High Chromium) & OHNS (Oil Hardening non Shrinkage) grade for both punch and die block to suit the components having EDD (Extra Deep Draw) is recommended per the practices found in the industries. The operating condition involving the magnitude of blank holding pressure is varied and the results analysed.

R. Venkat Reddy [2] said that Circular pans have been formed from the EDD steel alloys. The effect of process parameters such as initial blank shape and the blank holding force on the final part quality (i.e., wrinkling, fracture) has been investigated. It is to avoid wrinkling of blank by selecting the correct BHF's, decreasing friction, increasing the tool edge radius and reducing the deep drawing depth all together in one operation.

Gyadari Ramesh [3]investigate for a given set of punch die and working conditions there exists an optimum blank holding force which prevents the wrinkles and at same from the stresses induced in the cup is minimum. Blank holding force decreases with increase of coefficient of friction for a small range of coefficient of friction and a linear relation exists. With the increase of die radius up to a certain value Optimum BHF drastically reduces beyond that it remains constant.

Fuh-Kuo Chen [4] said that the draw-wall wrinkle occurred in the stamping of a motorcycle oil tank part was analyzed by the finite element simulations. The finite element analysis indicates that an uneven stretch between two unleveled portions is the major reason to cause the wrinkle problem. The defect-free production part and the good agreement between the simulation results and measured data confirm the effectiveness of using the finite element simulations as a substitute for the expensive method of actual die try-outs.

C. Loganathan [5] proposed this paper deals with the deep drawing of circular blanks of three different grades of annealed, commercially pure aluminium sheets of different grades, namely ISS 19000, ISS 19600 and ISS 19660, having a thickness of 2.00 mm, into cylindrical cups through Conical die using a flat bottomed punch. The critical percentage change in thickness at the onset of wrinkling is different for different aluminium grades because of the change in chemical composition.

H. Zein [6] said that Prediction of the forming results, determination of the thickness distribution and the thinning of the sheet metal blank will decrease the production cost through saving material and production time. The die shoulder radius and punch nose radius is depend upon of times sheet thickness so it is required to optimise the radius of die and punch.

R. Venkat Reddy [7] present the principal aspects that effect of various factors like BHF, punch radius, die edge radius, and coefficient of friction on the wrinkling of cylindrical parts in deep drawing process. The initiation and growth of wrinkles are influenced by many factors such as stress ratios, the mechanical properties of the sheet material, the geometry of the work piece, and contact condition. It is difficult to analyze wrinkling initiation and growth while considering all the factors because the effects of the factors are very complex and studies of wrinkling behaviour may show a wide scattering of data even for small deviations in factors. In the present study, the mechanism of wrinkling initiation and growth in the cylindrical cup deep drawing process is investigated in detail.

Y. N. Dhulugade [8] . This paper highlights development of draw component and the change made in product design due to manufacturing and assembly reasons considering the design intent; and also the advantages of using various CAE software's used in designing draw tools. It helps reducing the complete product development cycle as compared to what happens with conventional methods. Lesser effort and ease to model the complete setup and important features with different design parameters, improved the product development without compromising quality. Thorough attempt is aimed for design sheet metal draw die using the latest technology to make it time and cost effective, identifying the problem areas through analysis results and Based on the analysis prepare the query report and suggest revisions/ modifications in the product design. Finally, work out the best die design to produce defect-free components based on the inputs received. Thus using the CAE software one can design economical die because the design changes, modifications and challenges can be observed and solved in the initial phase of the design only.

III. PROBLEM DEFINITION

The Sheet metal industry is faced with a host of Challenges while developing a Tool (Die) for a Forming or a Deep Draw operation. The operation is critical in nature and calls for high competency on the part of Design as well as the material and the process factors.

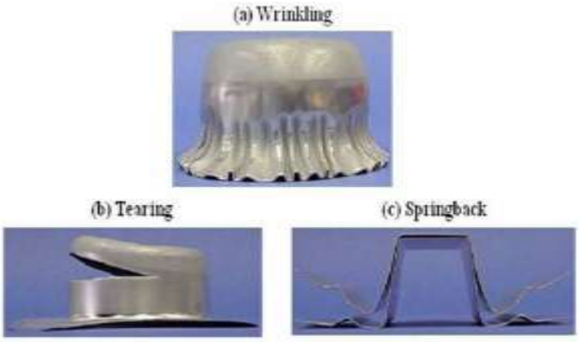

Fig 3.1.Different defects in sheet metal [8]

WRINKLING
- Compressive instability
- Blank holder pressure too tight
- Draw radius too large
- Unbalanced blank holder pressure[11]

TEARING
- Material undergoes fracture.

Reasons:
- Punch-die clearance too small
- Very high BHF [FRACTURE]
- Draw radius and blank holding surface
- Scratched
- Punch nose and draw radius too small [2]

THINNING
- Uneven flow of material into the die cavity

Reasons:
- Clearance between punch and die too little, Too great or uneven.
- Blank holder pressure too great.
- Lubricant inadequate or unsuitable.[5]

SPRING BACK
- When the bending stress is removed at the end of the deformation, the material tends to regain its original shape. This is referred to as `elastic recovery' i.e. the Spring back. [1]

3.1 Controlling sheet metal forming processes

In order to better understand the deep drawing Process, namely how it is influenced by the main Process parameters and the type of defects, it is Necessary to know the forces and stress states that Occur during the process. In the following sections some details about the force, stresses and process parameters will be briefly described.

3.1.1 Spring back

The spring back is measured as the difference between the final shape of the part and the shape of the forming die which, as previously mentioned, defines the part' shape at the end of the forming stage. Figure 3.4 shows an example of the different final shapes obtained after a deep drawing process, performed with the same tools and process conditions, using two blanks with different material properties, to better understand the importance of this phenomenon. This phenomenon plays an important role in process design, because wrong part dimensions is a problem to the assembly process, increasing the amount of scrape and, consequently, the part's cost. Nowadays the numerical prediction of the spring back is still a research challenge, trying to achieve the required accuracy, necessary to be able to apply numerical strategies for its minimization. However, during the last years many studies have focused on this subject and, consequently, the numerical simulation has made significant progress. In this context, several tests have been proposed in order to better evaluate the spring back phenomenon under different process conditions. [1]

3.1.2. Wrinkling & Tearing

Wrinkling defect generally occurs at the flange and is generated by excessive Compressive stress that causes the sheet to buckle. [11] Wrinkling is one of the major defects in sheet metal forming, together with tearing, spring back and other geometric and surface defects.. Here the importance of material models on the prediction results have been discussed. In most of the finite element analyses (FEA), accumulated computational error can be treated as an artificial imperfection in the system to initiate the wrinkling, but the necessary magnitude to initiate wrinkling is problem dependent. [08]

3.1.3. Tools geometry

The tools geometry is an important and difficult problem in sheet metal forming. The limit drawing ratio and the residual stress are greatly linked with the tools geometry, particularly the shoulder radius. Their surface condition is also essential to reduce the friction and give a good appearance to the final part. The tools should not mark, damage or weaken the final part. Therefore, the absence of contours in the project parts can make easier the conception of the tools and the parts. Thus, a geometry study should be developed in function of the material used. [1]

3.1.4. Drawing force

As the drawing process progresses the force increase and reaches to peak and begins to drop until it reaches the fracture point. It is observed that the fracture point is not at the maximum load condition but it is after that. The maximum principle stresses occur at fracture rather than at point of maximum load, material fails after the maximum load due to its ductile properties. [1]

3.1.5. Blank-holder forces

Wrinkling is one of the major defects in sheet metal forming, together with tearing, spring back and other geometric and surface defects. [13] The main goal of using a blank-holder is to control the blank sheet flow and avoid wrinkling. A too high value for the blank-holder force leads to materials rupture, but a too low blank-holder force allows the sheet wrinkling. Therefore, it is of paramount importance to find the appropriate value for the blank-holder force. Higher values of blank holder force also contribute for a higher punch force and reduce the thickness on the cup's wall. [1] The range of blank holder force between tearing and wrinkling depends on the material properties, drawing ratio and the geometry of the cup to be drawn. The high value of the strength coefficient (K) of the chosen material limits the deep drawing process with a constant blank holder force, because a high-value leads to excessive thinning and a low-value leads to wrinkling. The mechanical behavior of the blank and decreasing area of the flange require the blank holder force to Change accordingly. [12]

3.1.6. Deep drawing speed Deep drawing speed has a greater influence in the deformation process. The Use of a high drawing speed can lead to rupture, but a slow speed is also not possible in industrial processes, because in industry time is money. This parameter is directly linked to the material's mechanical behaviour and, consequently, to the deep drawing forces. The strain rate sensitivity indicates if a material is sensitive to the strain rate or not. A material that shows the same stress-strain curve for increasing strain rates is say to present a null strain rate sensitivity. If the stress-strain levels increase with the strain rate the material presents positive strain rate sensitivity, otherwise is negative. Therefore, a material that presents positive strain rate sensitivity will present higher punch forces for higher punch speed. However, this characteristic can change with temperature. [1]
3.1.7. Lubricant conditions evolution The lubricant conditions play a key role in minimizing the tool's wear and in reducing the friction. Proper lubricant conditions reduce the formation of scratches on the sheet and also reduce the friction coefficient. However, the lubricant conditions depend from parameters like temperature, sliding velocity and pressure. These parameters have a greater influence in the fluid's viscosity and, consequently, in its elasto-hydrodynamic deformation. [1]

3.1.8. Draw radius
Deep drawing is an important process used for producing cups from sheet metal in large quantities. In deep drawing a sheet metal blank is drawn over a die by a radiused punch. As the blank is drawn radially inwards the flange undergoes radial tension and circumferential compression. 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. [5] If possible the radius on the punch is made the same as the part print radius. The same is true of the radius on the die. Many times, however, these radii are too small and increase the severity of the drawing operation. [11]

3.1.9. Limiting Draw Ratio (LDR)
Deep drawing can be done in single draw or multiple draws. When it is completed in multiple draws then, it is called re-drawing. Number of draws can be calculated by taking ratio of initial blank diameter to the required diameter of the cup which is known as Limiting Draw Ratio (LDR). [13]

IV. METHODOLOGY

Tool development for form component is very costly process and it will take lot of time if we go conventionally. So we can use latest technology such as FEA during the design phase so that problem areas in forming can be easily pointed out through analysis results which will make our work, time and cost effective. And based on analysis report tool designer can suggest revisions/ modifications in the product design which will help tool designer to design a tool which will produce defect free components based on the inputs received. Without these efforts the die design and the processing could end up as costly and complicated assignment. Draw Component may face challenges such as, Wrinkling, Tearing, Thinning, Spring-back. While the die designer attempts to design a draw die, the process for drawing entails the use of hydraulic press since the rate of deformation has to be controlled throughout the operation of draw [19].The draw die should be built to tackle the problem of wrinkling especially prominent at the top corners; tearing along the sides of the corner and the bottom area; while thinning is associated along the corner edges prone to uneven flow. And the problem of spring back may occur due to elastic recovery of material. The rejection amounts to a loss of man hours of the hydraulic press, skilled labor, special material (DD or EDD quality for draw) and other resources directly or indirectly associated with the process. After determining process sequences and process parameters the forming dies are designed using sophisticated CAD systems. However still we don't have any evidence whether the designed tool will provide the right component and as it is die goes for tri-out and automatically it consumes time and cost and it will effects on the final cost of the die [7]. If the die tri-out goes well and component received matching to the requirements, the die will go for production, on the other hand if die tri-out fails and component showing some splitting and wrinkles, die set needs to be reworked. It means firstly rework the die construction by changing the die parameters such as draw radii drawing clearance etc. even if the problem not solved we have to think for new die design and process planning. In some of the cases the
4.2. Solution for the problem
Decreasing the lead time for product development along with the cost and time is the real challenge to the industry but it can be achieved with the latest CAE techniques such as simulation. The deep drawing process is nowadays frequently used manufacturing technology in the industrial sphere. Many factors influence on a procedure of the forming process. These factors include for example the holding force. In order to optimize this process, numbers of tests have to be done. Their results may predict problematic or critical areas of the final product. Due to this in the industrial practice, numerical simulations are often used and they are based on finite element method (FEM) analysis and different time integration schemes. [6] Forming processes are generally expensive, for this reason there is a great amount of researches studies related to their optimizations. Indeed, the coupling of

4.3. Areas to Check
The areas where a necking failure or fracture is occur on a stamping can be predicted with analysis during the development and die tryout period for new stampings . Once the areas found to thin leading to development team goes to the product design stage to modify the product parameters so more we go back the design and development costs are increasing indirectly. [7]

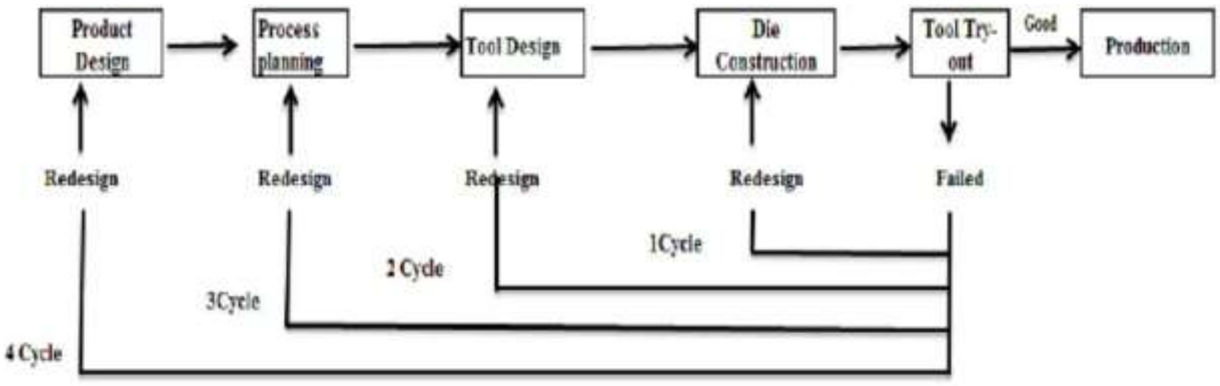

Fig4.1: Die design by conventional method

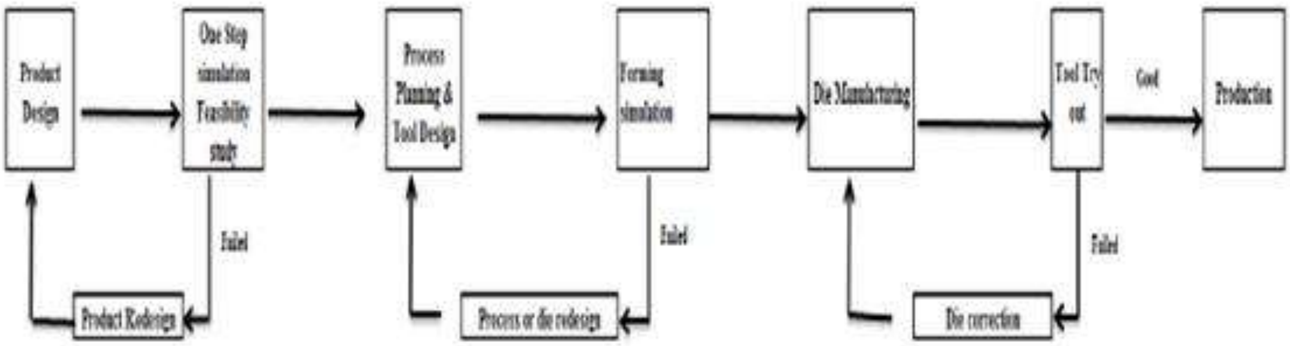

Fig4.2: Die design by CAE technique

4.1. Conventional Practices for die design and
Development As shown in following figure 4.1 in previous days the method used for process planning and die designing will becoming costly due to some reasons. Initially the process planning is done when the final product design received from the product designer and after that tool is designed, die construction is made and finally tool is shifted for tri-out this is what conventional method of die design for a particular product. If everything goes well and if the drawn parts matching to the required part then the die is sent to production. On the other hand if tri-out fails and part showing undesirable results then development team goes for die reworking and if problem not solved after die rework, new die design or new process planning is required, in some cases product design is also changed and in all this activities the lead time go on increasing as well as cost and time. All this happens because problem observed at the last stage of the development. [8].

Simulation software's with mathematical algorithms for optimizing the process parameters is widely increasing in various fields of forming. It was demonstrated that this kind of coupling reduces and improves the products cost [10]

The schematic diagram for process planning and die design using these techniques is shown below in schematic figure 4.1 Efficient use of simulation techniques from the earliest stage of product development to give feedback from each step to make the necessary corrections and improvement when it takes the least cost, with this approach stamping defects can be minimized or eliminated before die construction and try-out. If any correction or redesign is needed it can be done immediately, in very short time, thus it lead to a much smoother die try-out and to shorter lead times with less development costs.[7] failure are identified, regular checks should be made, this permits corrective action to be taken before a necking failure becomes visible. Causal factors for a pronounced increase in thinning include:

- Excessive blank holder force.
- Material problems such as a lack of draw ability.
- Material too thin.
- Scored die surfaces. [8]

4.4. Die Tryout Procedure A skilled die tri-out technician will optimize the metal flow by making a series of trial parts and reworking the blank holder as needed. In some cases, it is necessary to increase punch radii with the approval of the product designer. [8]

4.5. Benefit of Minor Product Changes Minor product changes are often highly beneficial to reduce or eliminate the occurrence of fractures. [8]

V. DESIGN PARAMETER

5.1. Consideration of Design Parameter of Deep
Draw dies this seminar work would focus on eliminating the Design problems arising out of incorrect selection of values for the variables / parameters. The parameters affecting the quality of the component produced could be listed as:

- Blank holding pressure
- Radii at Die entry & punch nose

- Material of the component
- Thickness of sheet Depth of Form/ Draw
- Use of Mechanical or Hydraulic Press
- Shape of the blank

The following factors may be calculated with formulas:
5.2 Calculation of Blank Diameter & Trim

Allowances
D =$\sqrt{(d^2 + 4dh})$
Where
D = blank diameter
d = punch diameter
h = cup height
Final Blank diameter =Development blank diameter +Trim allowance
5.3 Calculation of Percentage reduction
Percentage reduction = D-d/D
x100... (2)
5.4 Calculation of Thickness to diameter ratio
Thickness to diameter ratio = T/ D
x100.. (3)
5.5 Calculation of drawing force
F =Π d t σy (D/d – c) Newton's
Where, c= drawing force constant

5.6. Calculation of stresses in Deep draw

Zone –I (bottom of punch zone)
At this zone there is no stress induced without BHF and with BHF, tensile stress will be induced.

Zone 2 (deformation zone)
Whatever the deformation required for converting the blank into cup shaped is obtained in zone -2 only. So it is called as deformation zone.

Zone-3: (flange portion) Without BHF: Tensile stress in two direction and compressive in 3rd direction.

With BHF: Tensile stress will be induced. The stresses induced in zone 2 must be greater than yield and less than ultimate. Hence it is required to determine the magnitude of stresses induced in zone 2

$$\sigma = \frac{Force}{Area} = \frac{P}{\frac{\pi}{2}[b^2-(d-2t)^2]} \text{ ……………………(3)}$$

5.7. Draw & Punch radius
The Draw radius usually ranges from 4 to 10 times the Blank thickness. [21]
Therefore, Radius of Draw Die = Rd =4.5 x 1.2 = 5.4 mm.
The Punch radius usually ranges from 3 to 4 times the Blank thickness.[21]

Therefore, Radius of Punch = Rp =3 x 1.2 = 3.6 mm

5.8. Drawing speed
Our material is EDD CRCA Steel so our drawing speed is 60Ft per min as per below standard table taken from tool design data book.

5.9. Press Tonnage or Press capacity
Press Tonnage can be calculated by using following formula,
Press Tonnage = Draw Force + Blank Holding Force (B.H.F)

5.10. Blank Holding Force
Blank Holding Force (B.H.F.) = 25 % of Draw Force

5.11 Calculation of shut height.
H = Die thickness + Lower shoe thickness + Punch Height + Punch Plate thickness + Upper shoe thickness – Penetration of Punch in Die .

5.12 surface finish of die Important to reduce the friction between tool surfaces and metal been drawn. It allows materials to flow through tools more easily. Usually a very good surface finish of the Die is preferred, because this reduces the scoring marks or scratch marks on the final part. Usually a Ra value of at least 5 to 3.2 microns is recommended for the die surface, in practice.

VI. ADVANTAGES

6.1 Advantages of deep drawing

- Deep drawing is especially when producing high volumes of part. It is useful for mass production.
- Tool construction cost is lower in comparisons to similar manufacturing process like progressive die stamping.
- Deep draw products give the significant strength & minimal weight.
- Deep draw process is used for product
- geometries that are unachievable through other manufacturing process.
- Deep draw process is most useful for creating circular, rectangular, square & more complex geometries of parts.
- It is having rapid cycle time. Large quantities of products are easily manufactured.
- Deep draw process is viable production solution for any manufacturing process means only single sheet of meat required for draw parts.
- There is no any machining operation required after draw operation in draw drawing.

6.2. Advantages of finite element simulation

- Predicting metal flow and final dimensions of the formed part.
- Preventing flow induced defects such as excessive thinning and wrinkling predicting limit strains.
- Improve part quality and control of geometrical complexity.
- Reducing die try-outs and lead times & Reduce rejection and improving material yield.
- Reduce the need for costly shop floor trials and redesign of tooling and processes.
- Improve tool and die design to reduce production and material costs.
- Shorten lead time in bringing a new product to market.

REFERENCES

[1] Mr. Amit D. Madake1, Dr. Vinayak R. Naik2 Development of a Sheet-Metal Component with a Forming

Die Using CAE Software Tools (Hyper form) For Design Validation and Improvement, Shivaji University, India.

[2] R. Venkat Reddy, Dr. T.A. Janardhan Reddy, Dr. G. C. M. Reddy, Optimization of Blank Holder Force to Control Wrinkling and Fracture of Cylindrical Cups in Deep Drawing, International Journal of Engineering Trends and Technology- Volume3Issue5- 2012, pp. 1.

[3] Gyadari Ramesh, Dr.G.Chandra Mohan Reddy, Analysis of Optimization of Blank Holding Force In Deep Drawing By Using LS DYNA, Gyadari Ramesh, Dr.G.Chandra Mohan Reddy / International Journal Of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 3, Issue 4, Jul-Aug 2013, pp.1975- 1995.

[4] Fuh-Kuo Chen, Analysis of draw-wall wrinkling in the stamping of a motorcycle oil tank, Journal of Materials Processing Technology ,192–193 (2007),pp. 200–203

[5] C. Loganathan, Wrinkling behaviour of different grades of annealed commercially pure aluminium sheets when drawing through a conical die, Available online at www.sciencedirect.com, Materials and Design 29 (2008),pp. 662–700

[6] H. Zein, Effect of Die Design Parameters on Thinning of Sheet Metal in the Deep Drawing Process, American Journal of Mechanical Engineering, 2013, Vol. 1, No. 2,pp. 20-29

[7] R. Venkat Reddy, Effect of Various Parameters on the Wrinkling In Deep Drawing Cylindrical Cups, International Journal of Engineering Trends and Technology- Volume3Issue1- 2012,

[8] Y. N. Dhulugade, P. N. Gore, Design and Development of Sheet Metal Draw Component Using CAE Technology, International Journal of Emerging Technology and Advanced Engineering.

