# A Review Paper on Design for a Sheet Metal Die by CAE for Forming Analysis With various Process parameters

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*Abstract*— Sheet metal forming is a mostly used and costly manufacturing process. decrease of response time and costs, increases of the efficiency and quality of the product are very important for survival in the competitive manufacturing industry. Using Finite element analysis as a simulation Technique we can evaluate the behavior of components, equipment's and structures for various loading conditions. Various components are required to be produced in a single stage along-with the forming operation. In Finite element process we can use The application of computer aided engineering, design and manufacturing CAE/CAD/CAM Tonnage calculation is also be needed for the Die design of different component. The components needs to be formed in a single stroke of the press with minimum amount of defects such as wrinkling, tearing, spring back.

***Key words:*** Hyper form, Forming, Die Design

## I. Introduction

### A. *Sheet Metal Forming Processes*

Sheet metals are widely used for industrial and consumer parts because of its capacity for being bent and formed into intricate shapes. Sheet metal parts comprise a large fraction of automotive, agricultural machinery, and aircraft components as well as consumer appliances. Successful sheet metal forming operation depends on the selection of a material with adequate formability, appropriate tooling and design of part, the surface condition of the sheet material, proper lubricants, and the process conditions such as the speed of the forming operation, forces to be applied, etc. A numbers of sheet metal forming processes such as shearing, bending, stretch forming, deep drawing, stretch drawing, press forming, hydro forming etc. are available till date. Each process is used for specific purpose and the requisite shape of the final product.

#### 1) *Shearing*

Irrespective of the size of the part to be produced, the first step involves cutting the sheet into appropriate shape by the process called shearing. Shearing is a generic term which includes stamping, blanking, punching etc. Figure 3.4.1 shows a schematic diagram of shearing. When a long strip is cut into narrower widths between rotary blades, it is called slitting. Blanking is the process where a contoured part is cut between a punch and die in a press. The same process is also used to remove the unwanted part of a sheet, but then the process is referred to punching. Similarly, nibbling, trimming are a few more examples of cutting process using the same principle of shearing process.

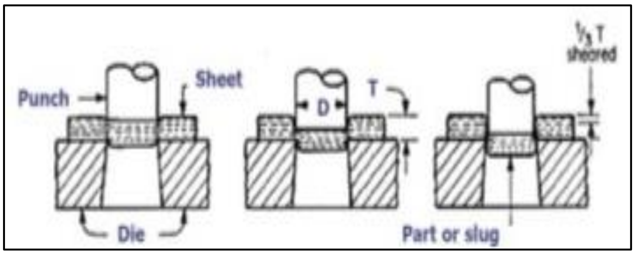


Fig. 1: Schematic set-up of shearing operation [1]

#### 2) *Bending*

Bending is the operation of deforming a flat sheet around a straight axis where the neutral plane lies. It is a very common forming process for changing the sheets and plates into channel, drums, tanks, etc. Two different scheme of bending are shown in the figure 3.4.2. Spring back is a major problem during bending of sheets that occurs due to elastic recovery by the material causing a decrease in the bend angle once the pressure is removed. The springback can be minimized by introducing excess amount of bending so that the finished bending angle is the same after the elastic recovery. However, a careful estimate of the elastic recovery based on the mechanical behavior of the sheet material is necessary to achieve the same.

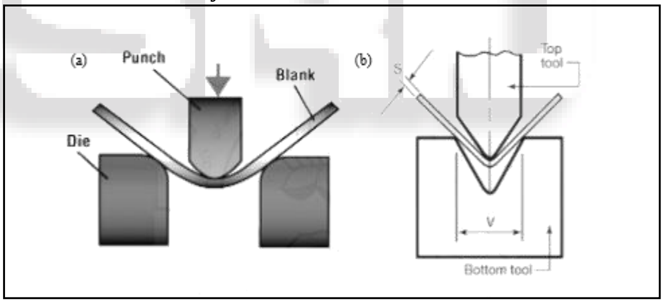


Fig. 2: Schematic set-up of (a) air vee bending, and (b) die bending [3]

#### 3) *Stretch Forming*

It is a method of producing contours in sheet metal. In a pure stretch forming process, the sheet is completely clamped on its circumference and the shape is developed entirely at the expense of the sheet thickness. Figure 3.4.3 presents a schematic set-up of stretch forming process. The die design for stretch forming is very crucial to avoid defects such as excessive thinning and tearing of the formed part. The stretch forming process is extensively used for producing complex contours in aircraft and automotive parts.

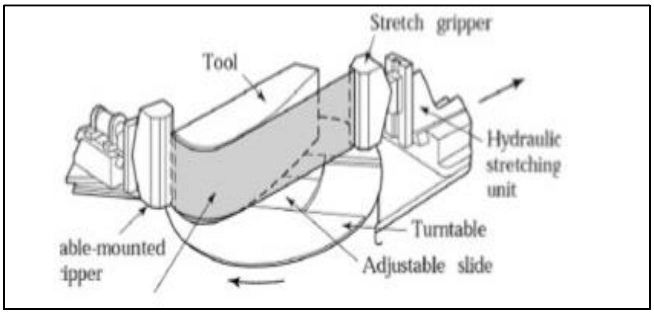


Fig. 3: Schematic illustration of typical stretch forming process [3]

*4) Deep Drawing*

Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch. It is thus a shape transformation process with material retention. The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. This can be achieved by redrawing the part through a series of dies.

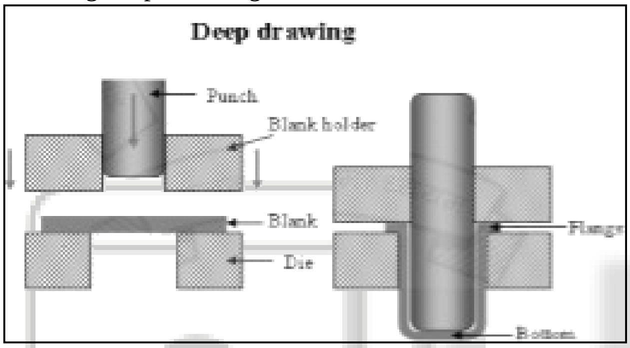


Fig. 4: Schematic outline of Deep Drawing Process [3]

The metal flow during deep drawing is extensive and hence, requires careful administration to avoid tearing or fracture and wrinkle. Following are a few key issues affecting metal flow during deep drawing process and each of them should be considered when designing or troubleshooting sheet metal deep drawing stamping tools.

a) Type of Material Used and Its Thickness

Slightly thicker materials can be gripped better during the deep drawing process. Also, thicker sheets have more volume and hence can be stretched to a greater extent. However, the drawing force will increase with the sheet thickness. The percentage elongation property or ductility of the material is an essential quality for materials to be used for deep drawing.

b) Tool Surface Finish and Use of Lubricant

Die surface finishes and lubricants are important to reduce the friction between the tool surfaces and metal being drawn, thus allowing materials to flow through tools more easily. Die temperatures can affect the viscosity of the lubricants. Slower deep drawing speed allows better metal flow.

Blank size and shape Blank that are too large can restrict metal flow. The geometry of parts can also affect the ability of metal to flow during deep drawing process.

c) Blank Holding Force

Control of the blank holding force (BHF) enables control of friction on the flange during deep drawing process and significantly influences the quality of drawn part. Greater blank holding force may lead to tearing of the flange while inadequate blank holding force may lead to wrinkling of the flanges.

d) Punching speed

Sufficient punching speed allows time for materials to flow through the tool. Corner cracking will always occur if press speed is tool fast in deep drawing process.

e) Draw radius

Radius on the draw die where the material flows through should be optimum. Too big a die or punch radius can result in wrinkling where as too small a die radius would create cracking at the bottom radius of drawn part.

f) Draw Bead Height and Shape

This should be selected properly to control metal flow and gripping pressure in deep drawing process. Draw bead height and shape can cause materials to bend and unbend to create restrictive forces going into a tool. Increasing pressure will exerts more force on a material, creating more restraint on material going into the tool.

g) Defects in Deep Drawing

Wrinkling is a major defect in drawing operation. The movement of the blank into the die cavity induces compressive stress in the flange causing wrinkle. This can be reduced by keeping a blank holder under the effect of a holding force. The magnitude of the force has to be controlled as a function of punch travel to minimize wrinkle. Rapture and excess thinning of the cup wall are also some pronounced defects in deep drawing process. Rapture is caused by incorrect draw ratio and improper die and punch design whereas too little die and punch clearance is responsible for the thinning of the cup wall. Failure generally occurs by thinning of the cup wall under high longitudinal stress.

*5) Hydro forming*

Hydro forming, as shown schematically in figure 3.4.5, is a specialized type of die forming that uses pressurized hydraulic fluid to form typical metallic sheets in to a desired shape with a die cavity. Hydro forming is a cost-effective way of shaping malleable metals such as aluminum or brass into lightweight, structurally stiff and strong pieces. Hydro forming allows complex shapes with concavities to be formed, which would be difficult or impossible with standard solid die stamping. Hydro formed parts can often be made with a higher stiffness-to weight ratio and at a lower per unit cost than traditional stamped or stamped and welded parts. Virtually all metals capable of cold forming can be hydro formed, including aluminum, brass, carbon and stainless steel, copper and high strength alloys.

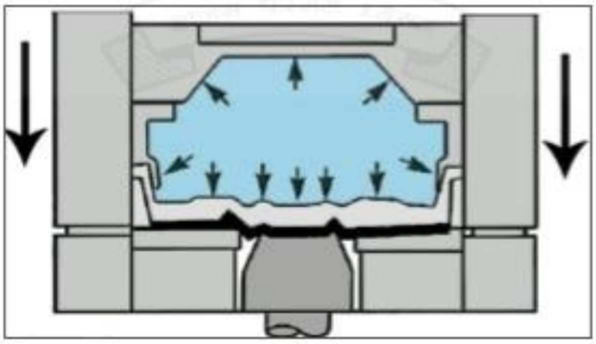

Fig. 5: Schematic set-up of Hydroforming process of sheet metal parts [3]

 

## II. LITERATURE REVIEW

Literature review is carried out in the following areas.

a) Effects of die design on various parameters.
b) Forming analysis of die
c) Die Design

### *A. Literature Review Regarding Effects of Die Design on Various Parameters.*

H. Zein, M. El-Sherbiny*, M. Abd-Rabou, M. El Shazly(2013)has analyzed that A Finite Element (FE) model is developed for the 3-D numerical simulation of deep drawing process (Parametric Analysis) by using ABAQUS/EXPLICIT FEA program with the proper material properties (anisotropic material) and simplified boundary conditions. for the 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. They compared The FE results with experimental results for validation. The developed model can predict the thickness distribution and thinning of the blank with the die design parameters (geometrical and physical parameters). Furthermore, with numerical simulation, working parameters can be optimized without expensive shop trials. They Found that The finite element analysis simulation (FEAS) is a powerful tool in the sheet metal die design, reducing time and trial and error efforts. A Finite Element Model is developed to reach the optimum solution without many costly trials of production which is a common practice in the traditional production approaches and came to conclusion that 1. The die shoulder radius is recommended to be about 8 times sheet thickness. 2. The punch nose radius is recommended to be greater than 3 times sheet thickness. 3. The thicker sheet metal is softer due to its increased volume which increases the thinning in sheet metal. 4. The radial clearance is recommended to be greater than the value of the sheet thickness [If the clearance is not large enough, ironing or thinning will occur]. 5. Blank holder force (BHF) is recommended to be less than 3 tons to avoid increased thinning. 6. The fluid lubricant with (µ p= 0 to 0.3), is more suitable to apply between punch and blank to reduce the thinning of the cup.

Wei-XueHu, Qing-Min Chen, Xue-Ping Yan (2015) They analyzed the roll gap distribution corresponds to the wrinkling zone by numerical simulation &established finite element analysis model to overcome from the wrinkling problem, wrinkling in the spherical surface and saddle surface are simulation and the experimental results of the wrinkling in saddle surface is presented. The results demonstrate that unreasonable distribution of the roll gap is the main reason for the generation of wave-shaped wrinkling. Continuous roll forming is a new sheet metal forming process for three-dimensional surface parts. In the process, the sheet metal is thinned non-uniformly in transverse direction by controlling the distribution of the gap between the upper and lower forming rolls, the longitudinal elongation is different, which makes the sheet metal generate a doubly curved surface parts. When sheet metal forming, the complex stress state produced in the sheet. Since the size in thickness is much smaller than in the transverse and longitudinal directions, the energy required for the deformation of the thin plate is small, it is easy to produce wrinkling problems. The simulation analysis of the causes of wrinkling defects are verified by experiment.

### *B. Literature Review Regarding Forming Analysis of Die.*

Prof. N. C. Mehta1, Viral V. Shiyani2, Jemish R. Nasit3 (2013)There are a wide range of physical defects which occur during metal forming processes. In this paper we will analysis the metal of forging and try to reduce metal defects in forging processes. Finite element analysis is used to predict residual stresses in forgings The objective of this paper is to obtain an optimal billet shape in the consideration of the metal flow deformation in closed die forging process. Finite element method in conjunction with optimization algorithm was used to analyze the effect of billet shape on forging load in axi symmetric closed for die forging process. ANSYS was used to simulate closed die forging process and then performing a series of optimization iteration in order to obtain the optimal shape of the billet based on forging load minimization. Defects in forging reduce its strength. They occur for a number of reasons including. Defects of forged product include exterior cracking, interior cracking, laps, cold shuts, warping of the part, improperly formed sections and dead zones. Cracking both interior and exterior is caused by excessive stress, or improper stress distribution as the part is being formed.

C.-C. Wang, J. Lee, L.-W. Chen and H.-Y. Lai (2000)This paper presents a new method that, in addition to achieving the desired property of orientation invariance, discards assumptions that conflict with real-world processes. The proposed method is implemented and tested using simulated and real- world data. Results are reported and compared with those obtained by the existing method. The existing method, by employing the computationally efficient routines of multiple linear regression, takes only a few seconds to achieve the LS solution. On the other hand, the proposed method typically takes tens of seconds. Nevertheless, the extra computation time of the new method does not appear to put any practical limitation to its potential applications in sheet metal forming tests.

Harshal A. Chavan1, D. D. Deshmukh2 (2014) Methods of sheet metal processes such as stretching, shearing, blanking, bending, deep drawing, redrawing are introduced. Variables in sheet forming process were discussed together with formability and test methods. Defects occurring during the forming process will be emphasized. The solutions to such defect problems will also be given. As lots of research is going in the field of material forming a systematic literature review based on the optimization technique and analysis is presented in the paper. The application of computer-aided engineering, design, and manufacturing, CAE/CAD/CAM, is essential in modern metal-forming technology with the application of traditional and nontraditional optimization techniques. Thus, process modeling for the investigation and understanding of deformation mechanics has become a major concern in research. The finiteelement method (FEM) and optimization techniques have assumed increased importance, particularly in the modeling and optimization of forming processes.

V. Sajn · B. Jurisevic · F. Kosel (2008) The main aim of this paper is to present the technologicalwindowforWJISMFandcharacterizetheattributesoftheWJusedasthemaintool.AFiniteElementAnalysis (FEA) simulation of axis-symmetrical, incompressible, turbulent, free surface flow was developed to simulate the impact of a WJ on the impingement rigid surface. Measuring the surface pressure distribution at the interface between the WJ and the impingement rigid surface experimentally validated the FEA simulation. Calculated pressure distributions along the surface are in good agreement with those obtained experimentally.

M. Firat *(2005) In order to make an utmost benefit of computer analysis in the tooling design for stamping processes, the stamping engineer should have the fundamental understanding of the computational concepts of the finite element analysis in the sheet metal process simulation. The finite elements, the deformation response of sheet metals, and the numerical procedures are key concepts for the stamping simulation engineer in this perspective. The finite element procedure sand the element formulations, along with their performance comparisons in an industrial stamping applications are the subjects in this part of the study. The sheet metal deformation modeling and the die-face design concepts are presented in Parts II and III, respectively, together with a set of industrial applications. The practical connotations of the computer aided analysis and design of the sheet metal stamping dies is given and conclusions are drawn.

### C. Literature Review Regarding Die Design

Dipak Sudam Patil, Prof. P. M. Solanki (2013)To develop a cost effective die with a lower lead time through the phase of Design, Development, Trials and Testing, Pilot lot production & Regular supply. The Deep draw process being critical to evaluate offers higher scope for study and research while addressing the most suitable design for the Draw Die. technology that helps exceed the engineering requirement of products. This research highlights the advantages of using Altair's Hyper Form using RADIOSS to design drawing tools like die and punch for one of the automobile components along with the procedure of required blank shape. Hyper form help reducing the complete product development cycle to almost less than 40% of what it usually took using conventional methods. Lesser effort and easy to model the complete set up important features with different design parameters, improved the product development without compromising quality. The challenge was to developed the wrinkle free component restricting percentage thinning to 20%. Different design iterations were carried out to get the best possible product in minimum time. Design changes where done in the existing die design to make it cost and time effective by saving workmanship involved in its development. Simulation revealed the need of optimizing the blank apart from die modification , to get rid off the wrinkles.

Y. N. Dhulugade1, P. N. Gore2 (2013) This paper highlights development of 'draw' component and the changes 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. Otherwise without these efforts the die design and the processing could end up as a costly and complicated assignment.

A. C. S. Reddy, S. Rajesham, P. R. Reddy , T. P. Kumar, J. Goverdhan (2015) The optimum process parameters were determined based on their influence on the thickness variation at different regions of the blank material. Three important process parameters i.e., punch nose radius, die shoulder radius and blankholder force were investigated in this study. Plan of experiments based on Taguchi's technique were used for acquiring the data. An orthogonal array, the signal to noise ratio and the analysis of variance was employed to investigate the deep drawability characteristics. Influence on thickness due to variation of these parameters was individually evaluated in terms of percentage. The results showed that the blank holder force (56.98%) was the most significant parameter followed by punch nose radius (30.12%) and the least influence (12.90%) was with die profile radius. The main conclusions obtained through this research are 1) Experiments designed based on the orthogonal array of the Taguchi method can be used to identify the most significant forming parameter affecting deep drawing.2) The greatest effect on thinning ratio in deep drawing is contributed from blank holder force. The second greatest effect is
from punch nose radius.

## III. PROPOSED FLOW OF WORK AND METHODOLOGY

Analytical/ Numerical Methodology shall be followed for arriving at the Design. Analysis to be performed using suitable software while determining the Design/ Process parameters and suitable levels for the same. The following steps shall represent the methodology for arriving at a feasible solution.

a) Literature Review or Data collection for Historical data of forming/ draw Dies
b) General layout for the Die Design for preliminary assessment
c) Analysis for Component (Forming Analysis) for evaluating effect of parameters on the performance characteristics
d) Final Die Design and Process recommendation
e) Trials/ Experimentation (upon development of Die)

## IV. CONCLUSION

From literature 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. The application of computer-aided engineering, design, and manufacturing, CAE/CAD/CAM, is essential in modern metal-forming technology to reduce the defects in the component. In this respect, the future research will focus on the application of an experimental design of in order to reduce the defect and improve the quality of the formed parts by an accurate control of the process parameters.

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