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Forming Process Parameter Optimization through CAE & Experimentation to Reduce Development cycle time of Solar Panel

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ABSTRACT

During the development of the Die, a reduction in the number of trials would directly influence the cycle time for development. A shorter cycle time can be planned with due utilization of software tools (Hyperform) in Design Stage that would predict the trial results without actually conducting the same. The simulation offered by the software during the process of stamping lends important insights into the modifications needed in the die and/or the component to effect a simplified and productive die. Normally, a Forming die (including Draw die) calls for refined design parameters like Blank Holding Force(BHF) for ensuring a smooth passage through the trial phase of the developed Die normally accompanied by crucial review inputs over the design of the component too. The study of the papers offers enough inputs to take up the project work in identifying a `process-oriented' solution that could be used as a reference for academicians and the corporate entities while faced with the challenges associated with the elusive process of `Forming'.The forming operation for panel used in Solar Cooker needs to be undertaken for development. This forming process poses challenges for processing the component using conventional design practices. The time required for development through this iterative process is high. Consequently, the development time is longer for realizing a defect-free component matching the design specifications.

Keywords -**Forming, HyperForm, Sheet-metal, Solar Cooker Panel, BHF, Thinning**

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I. Introduction

A large variety of metallic parts of automobiles, aircrafts, building products and domestic appliances are produced by deformation processing. This comprises manufacturing methods that are used to create the primary shape of products by plastically deforming the material. Well-known examples are forging, rolling, extrusion, sheet metal forming and hydro forming. Sheet metal forming is a special class of deformation processes in which blanks, with the thickness being much smaller than the other dimensions, are formed into the desired shape. Sheet metal forming is one of the most widely used manufacturing processes for the fabrication of a wide range of products in many industries. The reason behind sheet metal forming gaining a lot of attention in modern technology is due to the ease with which metal may be formed into useful shapes by plastic deformation processes in which the volume and mass of the metal are conserved and metal is displaced from one location to another.

Sheet metal forming operations consists of simple bending, ironing, wheeling, press brake forming, stretch forming, roll forming, rubber-pad forming, stamping, flanging, spinning, embossing, bulging, hyper plastic forming, peen forming, Explosive forming, magnetic-pulse forming and deep drawing of complex parts indeed, the sheet metal products have become current also due to low price, accuracy of dimensions, durability and favorable physical properties. In today's industry, where the cost play very important role, the sheet metal products have replaced many products made by forming process. They have replaced also many complex composed products. Forming 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. Forming 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.

Items often made by forming include cupped baking pans, like muffin pans, and aluminum can cylinders. However, irregular items, like fire extinguishers and enclosure covers for oil filters in trucks are also made this way - as is your kitchen sink! Products made by forming are deep and seamless. The finished shape produced by a forming press depends on the position in which the blanks are pushed down. Only malleable Industries where forming is often used include the dairy industry, pharmaceuticals, plastic manufacture, and the auto industry, aerospace and lighting. Companies making parts by forming need expensive presses and operations put together by trained engineers, as well as plates, molds, and other accessories. Unlike metal stamping, forming uses a single piece blank, not a continuous stream of blanks. The productivity of the stamping process in the industry yields better quality product at a economic price. The dissertation work is relevant in the context of developing a cost effective die with a lower lead time through the phase of Design, Development, Trials and Testing, Pilot lot production & Regular supply. The forming process being critical to evaluate offers higher scope for study and research while addressing the most suitable design for the forming Die.

II. Literature Review

Sagar Bajaj et al. in, In an era of exceptional digital computation and immense indulgence in the theoretical behaviour of sheet metal during its manufacturing process, the simulation of sheet metal forming becomes the most feasible and viable option for every OEM to consider this prior to its manufacturing. This paper contains a methodology for using an optimizing tool like Hyper Study to get the best formed part by incorporating forming benchmarked parameters like FLD (forming limit diagram), percentage thinning and plastic strains as responses by building up expressions among various variables and thus optimizing the forming process parameters like blank holding pressure, sliding friction, and Draw bead restraining force effectively to meet the formability requirements. This would reduce the time and effort of a forming engineer to reiterate among these parameters to get the desired result effortlessly.[1]

Ling Zhanget al. in The Forming limit diagram (FLD) is a powerful tool for describing the formability of sheet materials in the automobile industry, which provides fundamental data for die design and Finite Element (FE) simulation. However, traditional FLD testing is typically conducted at quasi-static strain rates from 0.001/s to 0.01/s, which are much lower than the industrial stamping process with strain rates about 1-10/s. In this research, FLDs at various punch speeds (from 1mm/s to 100mm/s or 120mm/s) were obtained for three kinds of AHSS, Quenched and Partitioned steel, Dual Phase 980 and Dual Phase590 and three kinds of conventional steels, Low Alloy High Strength steel, Bake Hardening steel and IF steel. The results show that FLDs at a typical industrial stamping speed (100mm/s or 120mm/s) are considerably lower than the quasi-static test speed for the Advanced High Strength Steels (AHSS).[2]

K.Y.Choi al. in Due to environmental concerns and safety regulations in the automotive industry, the development of strong and lightweight cars has been a hot issue in the last decade. One solution for this purpose would be to use high-strength steel (HSS) and advanced high-strength steel (AHSS). These materials can make the car lighter while maintaining the crash resistance of the vehicle. HSS and AHSS have more resistance force in the die structure compared with conventional steel due to their higher yield and tensile strength and thus, these materials have a greater effect on die deformation during the sheet metal forming process. As a result, die deformation can affect the blank sheet drawn pattern, strain, and stress as well as springback. This study presents a sheet metal forming simulation that considers die deformation. The simulation process was compared with conventional simulation methods. Our results indicate that the sheet metal forming simulation with die deformation consideration provides useful information on the die structure as well as formability and springback.[3]

M.Tisza, et al studied on the Integrated Process Simulation and Die –Design in Sheet Metal Forming. In this paper, the integration of various CAE techniques as Knowledge and simulation Based System (KSBS) will be described through the examples of sheet metal forming practices. The forming simulation in sheet metal forming technology and it's industrial applications have greatly impacted the automotive sheet metal product design die developments, die construction and tryout, and production stamping in the past decades. In today's die stamping industry, the simulation for virtual validations of die developments before production trials is a critical business for lead –time reduction, cost reduction and quality improvement. The global competitions driver higher quality requirement, lower cost, and shorter lead-time. All these new trends create new challenge for stamping simulation and production application.[4]

Fig.No.1 Work flows in simulation based process planning and die design

III. PROBLEM STATEMENT & OBJECTIVE

Sheet metal forming is one of the most commonly used processes in industry. Throughout the years, the sheet metal forming industry experienced technological advances that allowed the production of complex parts. However, the advances in die design progressed at a much slower rate, and they still depend heavily on trial-and-error and the experiences of skilled workers. During the development of the Die, a reduction in the number of trials would directly influence the cycle time for development. A shorter cycle time can be planned with due utilization of software tools that would predict the trial results without actually conducting the same.

Fig.No.2 Comparison of Conventional and New Proposed process.

The simulation offered by the software during the process of stamping lends important insights into the modifications needed in the die and/or the component to effect a simplified and productive die. Normally, a Forming die (including Draw die) calls for refined design parameters for ensuring a smooth passage through the trial phase of the developed Die normally accompanied by crucial review inputs over the design of the component too. The study of the papers offers enough inputs to take up the project work in identifying a `process-oriented' solution that could be used as a reference for academicians and the corporate entities while faced with the challenges associated with the elusive process of Forming Operation for the panel used for the Solar Cooker need to be undertaken for development. This forming process poses challenges for processing the component using conventional design practices. The time required for development through this iterative process is high. Consequently, the development time is longer for realizing a defect-free component matching the design specifications. The current component design features a formed shape with flanges along the side and a large curvature over its central region. Ribs are required to be formed in a single stage along-with the forming operation. The component is expected to be accomplished in a single stroke of the press. Also the direct material cost is one the important factor. Challenges are to the problems anticipated during the development process are as below:

1) Wrinkling
2) Tearing
3) Thinning
4) Spring back

Objective is to done forming analysis to optimize the forming process parameter in design stage to reduce iteration based on trial and error. However, the advances in die design progressed at a much slower rate, and they still depend heavily on trial-and-error and the experiences of skilled workers. During the development of the Die, a reduction in the number of trials would directly influence the cycle time for development. A shorter cycle time can be planned with due utilization of software tools. The software during the process of stamping gives important input to the modifications needed in the die and/or the component to affect a simplified and productive die. This leads to reduction in process time.

IV. THEORETICAL ANALYSIS

The Component was assign is Solar panel support. The part has complexity due to curvature and draw height.

a. Material- CRCA Steel D5315 grade.

Thichness-0.5 mm

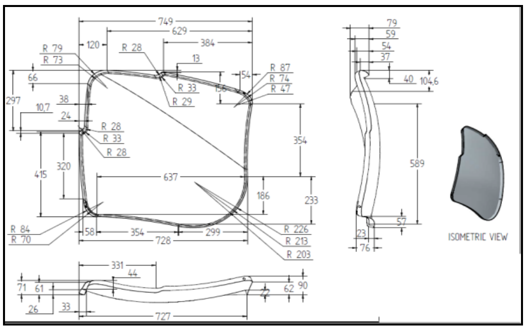

Fig.No.3 Solar Panel support Plate drawing

b. No. of draws can be calculated by relation below

$$\text{Limiting Draw ratio (LDR)} = \frac{\text{Height of the part}}{\text{Dia (Opening)}}$$

$$= 90/749 = 0.12$$

0.12 is less than the 0.75, so the part can be produced in one step.

c. Draw Force can be calculated by empirical relation,

P =[2(Li+Bi)*t x S{(Lo+bo/Li+Bi)-C}]

Where,

P =Draw force in kg; Li = Final part length, mm

Bi = Final part width, mm; t = Part thickness, mm

S = Shear strength, 40 Kg/mm$^{2;}$ L0 = Blank Length, mm

B0 = Blank Width, mm;

C = Constant based on friction (0.6~0.7)

Draw Force=2(Li+Bi) x t x S x [(L0+B0)/ (Li+Bi)-C]

We have, L_1= 727; B1= 749; t= 0.5; L0=727+20 =747

B0= 749+20=769

Therefore,

Draw Force = P

= 2(727+749) x0.5x40x [(747+769)/(727+749)-0.6)

= 25387.2 Kg ~ 25 Ton

Factor of safety should be taken as 15%

Therefore, Draw Force (P) = 25*1.15=28.75 ≈ 30ton

d. Blank Holding Force (BHF)-

It is used to suppress the formation of wrinkles that can appear n the flange of the drawn part.

Blank Holding Force (B.H.F.) is always 25 % of Draw Force

Therefore B.H.F. can be calculated as,

Blank Holding Force (B.H.F.) = 25 % x 25 = 6.25 Ton

Material for Blank Holder should be use EN-353 or 20MnCr5 Hardness – Blank Holder should be harden up to 30 to 35 HRC

e. Press Tonnage or Press Capacity-

Maximum force that ram exert on the work piece, this is expressed in tones and called tonnage. Press Tonnage can be calculated by using following formula,

Press Tonnage = Draw Force + Blank Holding Force (B.H.F.)

= 30 + 6.25 = 38.25 ≈ 40 Ton

Therefore, Press Capacity of 40 Ton shall be suitable.

V. FINITE ELEMENT ANALYSIS

As per Customer requirement and by taking in account the basic sheet metal design rules like the bend radius, flange length and draft etc. part was designed. For designing the part the Design Tool used is Catia V5R22.

a. Iteration I

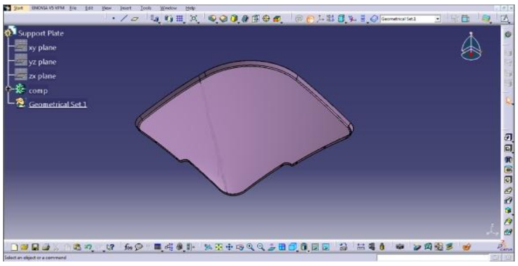

Fig.No.4 Solid Model of Solar Panel support Plate conceptual Stage.

After the modelling the Forming analysis run through the Hyperform and the current conceptual part we get result where the input BHF 6.25 Ton as calculated above and the thickness 0.5 mm the result observed below.

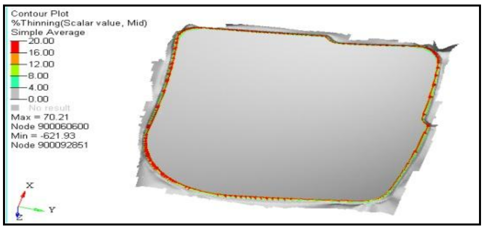

Fig.No.5 Percentage thinning at BHF 6.25 Ton

Maximum Thinning observed 70 % that was beyond the acceptable limit of 20 % therefore it is unacceptable. The failure observed in FLD diagram as

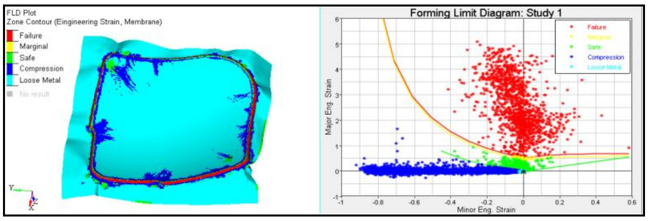

Fig.No.6 Forming Limit Diagram at BHF 6.25 Ton

From the above diagram maximum point found to be in failure region.

b. Iteration II

Uniform flow of the sheet metal during stamping is required. Rib was added on the part to control the flow of the material. The analysis result of the same part is as below.

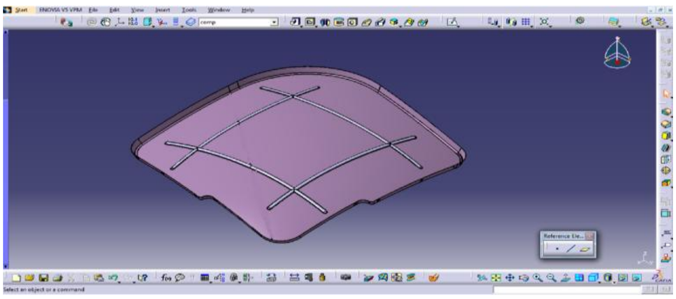

Fig.No.7 Solid Model of Solar Panel support Plate. with Rib

The analysis run on modified part with the ribs .BHF was taken 6.75 Ton.

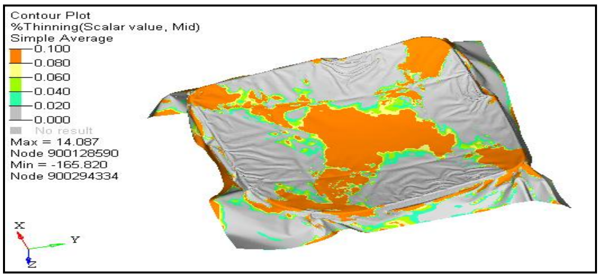

Fig.No.8 Percentage thinning at BHF 6.75 Ton

Maximum Thinning observed 14.087 % that was below the acceptable limit of 20% therefore it is acceptable. The failure observed in FLD diagram as

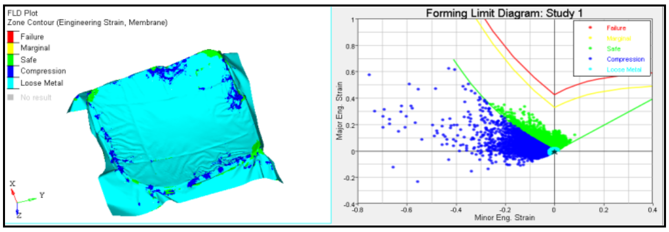

Fig.No.9 Forming Limit Diagram at BHF 6.75 Ton

Here the maximum compression find out at the corner it might be leads to the unnecessary wrinkle at the corner .so the next iteration was done at 6.2 Ton.

c. Iteration III

For current iteration same part to be used in earlier stage.

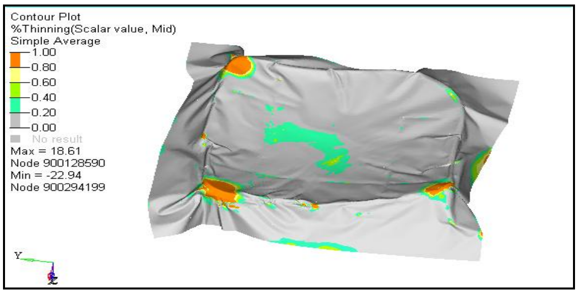

Fig.No.10 Percentage thinning at BHF 6.2 Ton

Here we found the thinning percentages below the acceptable limit and wrinkle is less prominent at the corner.

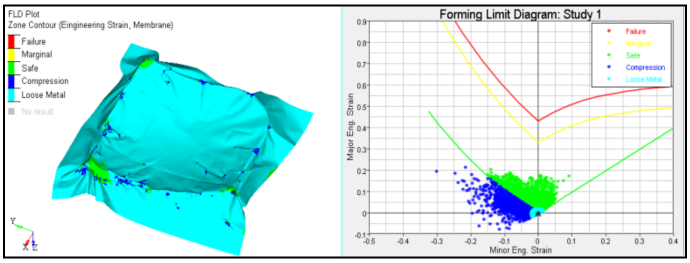

Fig.No.11 Forming Limit Diagram at BHF 6.2 Ton

As compared with above result in iteration 2 & 3 wrinkles are minor at the corner in iteration 3.. Analysis result obtained with the help of Hyperform software shows following relation of thickness and BHF as below.

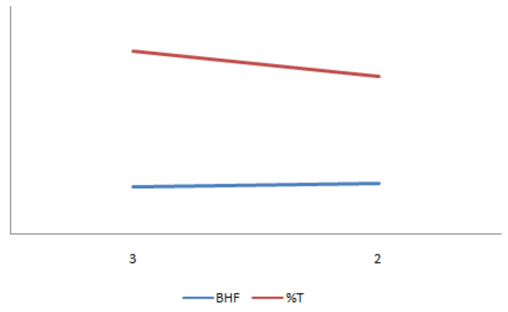

Fig. No. 12 Relation BHF Vs %T

Here the BHF increase the thinning decrease due to the the flow of sheet metal gets control. It is used to suppress the formation of wrinkles that can appear n the flange of the drawn part.

VI. EXPERIMENTAL ANALYSIS

Experimental Analysis done with selection the Hydraulic Press of 40 tonnage. Minimum Bed size of 1000mm x1000mm and shut height 300mm

VII. CONCLUSION

Forming limit diagram and result like thinning percentage has given the behaviour of the various parameters like BHF, Draw force in early stage to overcome the problem in earlier stage.

Thus the parameter of forming process can be optimized and leads to the defect free parts. This reduces the trial and error

From the graph Fig No.12 it is observed the thinning decrease as the BHF value increases. In the iteration II by applying the BHF value 6.75 ton the thinning percentage reduced drastically but the wrinkles are prominent at the corner. But with BHF values 6.2 Ton got the thinning percentage below the 20% and the wrinkles are minor at corner and less as compare to the earlier. Therefore the correlation between the calculated value and analysis adequately establish. Here

By introducing the forming analysis process in earlier stage as shown in Fig 2. Product design will be manufacturable and defects will be eliminated in concept stage. This decreases trial error and ultimately the product development cycle time reduced.In order to expand the range of application of developed method, parts with more complex geometries can be considered for future.

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