International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review Paper on 'Forming Analysis' of A Sheet-Metal Automotive Component by Finite Element Analysis with Physical Experimentation.

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ABSTRACT

Operations like cutting and non-cutting manufactures Sheet metal parts. The large amount of sheet metal parts are manufactured by mostly frequently used non-cutting operation like forming . The forming operations can be dealt with CAE solvers. The behavior of the material during this operation depends upon the material properties and is manifested by the Forming Limit Diagram Curve. The feature like radius on the die-block, velocity of ram, use of lubricant, blank holding pressure, etc plays a key role in delivering a defect free component. Mathematical tools and Hyper Form shall be deployed for the practical problems . Validation shall be realized using physical experimentation during trials or testing.

Keyword- Forming, Hyper Form, Tonnage, CAE, Finite Element Analysis

1. INTRODUCTION

1.1 Relevance

Most Automotive parts are made of sheet metal . The automotive parts are subjected to stresses (like compression, friction, shearing or combined stress) for giving the desired geometry.

Sheet metal forming processes are special manufacturing processes that uses considerable stresses (like compression, friction, shearing or combined stress) for plastic deformation of the materials to form the desired geometry. The desired shape is obtained by plastic deformation without undergoing any kind of milling. During the manufacturing process there are some defects will be associated with the forming operations. The common defects are Spring back, tearing, thinning. These defects will result in Material loss of productivity etc. To avoid these losses analysis of forming processes is important. The feature like radius on the die-block, velocity of ram, use of lubricant, blank holding pressure are playing a key role in delivering a defect-free component.

Sheet metal forming processes :

Sheet metal processes are broadly classified by method and application as per following types.

- Shearing processes- in this process the forces used to for cutting, fracture or separating of the sheet metal.
- Shaping processes- in this process the desired shape given to sheet metal changes without loss, change in thickness or shearing. It achieved by bending and stretching.
- Finishing processes – in this process the quality of surfaces improved after operation of shearing or shaping.

Forming Processes :

- Roll forming: It is a process in which the sheet metal strip got the desired Shape.
- Bending: in this process the desired shape is achieved by bending .

- Stretching: this process categories as forming process which allows the part to undergo the desired change in form by stretching with no loss.
- Drawing: where a sheet metal blank is shaped into a desired form using a die.

1.2 Application of sheet metal forming :

It is used in almost all industrial sector for production:

- Food industry (e.g. pots, canned containers)
- Aircraft industry (e.g. wings, body)
- Automotive industry (e.g. hoods, doors, chassis, cabin)
- Home appliance industry (e.g. washing machine, cooker, freezers)

Fig1.1. Application of sheet metal forming

1.3 Defects in sheet metal forming process :

Most common defects observed in forming process are as follows,

Galling: This is due the friction between the object and Die. It damages area of the die where rubbing is happened.. The defect can be avoided by making sure the surface of the die in good condition with frequent maintenance and by ensuring proper lubricant during operation.

Ironing: Iron is primarily used to reduce the thickness of the wall of the draw part by reducing the clearance between the die and the punch by less than the blank thickness.

Earing: This defect is outcome of planar anisotropy, it is caused by a difference in the mechanical action of the sheet from its plane to some other direction, bent or perpendicular to it, which is usually in number 2 / 4 / 6. The poor number is 8 when the brass is empty. It emerge on the top of the drawn cup and are handled with trimming.

Orange peeling: Happens on the exterior of the draw part when the grain size of the substance is high and can be stopped by decreasing the grain size before drawing by heat application or by applying grain processing to the crop by adding the required refiners.

Wrinkling: It begins in the lip area of the draw part and moves into the central region. It caused due to radial tensile forces and tangential compressive forces. Maintaining proper clearances and blank holding force to control the flow of material may avoid this defect

Tearing: This defect observed in the inside region of the circular part of the lip near the die area if the keeping down pressure is high, which avoids the tearing of the lip area. draw part from slipping and bending at die radius, or it may occur in the maximum thinning area in the clearance area near the punch shape, which is likely to bending and stretching.

The most common defects are presented in figure 1.2 and the notations are:

1. The flange waviness;
2. The lip waviness;
3. The flange wrinkle;
4. The annular patches;
5. The scrub marks;
6. The orange peel;
7. The luders strips;
8. The cracks at flange or at bottom;
9. The corner cracks;

10. The misalignment;
11. The Contour misalignment;
12. The wave loop;
13. de-laminations;
14. The corner wave loop

Few of the defects shown above are product of dies (5, 9, 10, 14), some are appeared due to friction (1, 4, 13), others are due to the structure of the material (6, 13) and few are due to material properties mainly mechanical(1, 2, 3, 6 , 7, 8, 11) and rest are due to the shape of the part (12, 14). The deep draw by extending just the defect of form 3, 6 and 8 of them are popular.

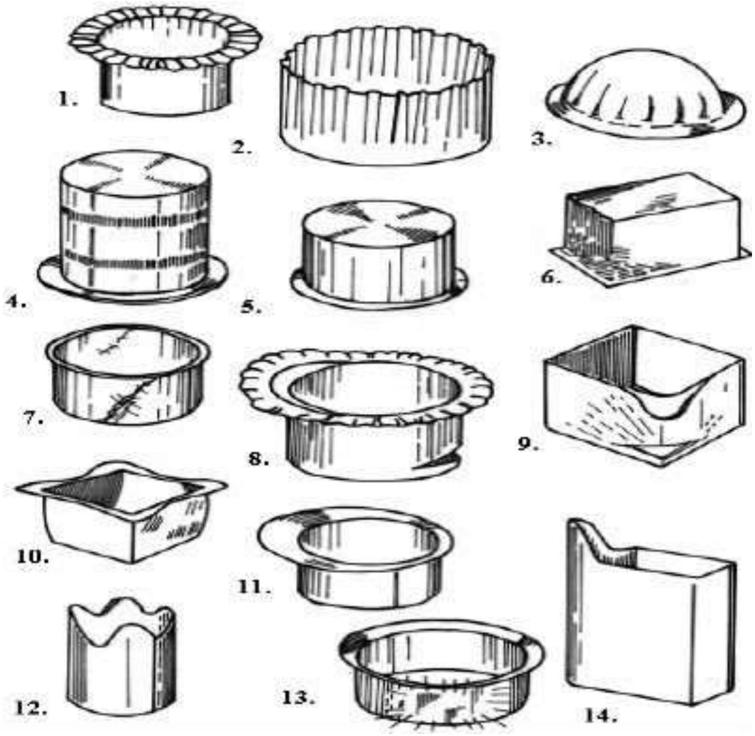

Fig.1.2 Types of defects in deep drawing

1.4 Sheet metal forming analysis techniques

Optical measurement device is used to measure the deformation . For example, the machine analyses, analyses and records deformations of sheet metal pieces. It gives the co-ordinates of the surface of the part also it gives variation of stress over the object (Major and Minor) and the reduction of material thickness. The calculated deformations are related to the material properties in the Forming Limit Diagram. The framework facilitates optimization processes in the formation of sheet metal by way of;

- Quick identification of critical areas of deformation
- Solving complex formation questions
- Verification of numerical simulations;
- Review of the FE model
- Formation of the Shaping Limit Curve, FLC
- Forming Limit Diagram uses the properties of the material and the measured

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- Formation of the Shaping Limit Curve, FLC
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1.5 Objectives :

1. Study the sheet metal forming process and calculate the tonnage and estimate the blank holding force for the given component.
2. Deploy CAE to analyze stresses involve in forming process and optimize thinning and other defects by iterating suitable parameters out of blank holding force, clearances, material properties, punch velocity, lubrications and many.

1.6 Research methodology :

1. Blank development using CAD Software such as CATIA V5, UG-NX and Creo-3.
2. Pre-processing or die-punch setup using Hyper Mesh Interface
3. Applying loads and boundary conditions
4. Solving using Hyper Form as a Solver
5. Post-processing using Hyper View interface
6. Generating alternative/s while altering processing parameters
7. Repeat step no. 4 & 5
8. Recommend the best alternative

1. Numerical Method -

In numerical method, we shall attempt to conduct preliminary investigation for the problem through calculation of the required tonnage for forming the component. Using industrial practices for assigning blank holding force, selection of spring, bush, guide-pillar and press selection as shall be suitable for the component and the operation.

2. Experimentation-

Experiments shall be carried out on a press tool of the required kind and capacity. The die would be placed on the press plate and the parameter of press ram would be set on the basis of the empirical calculation data as well as the data gather from outcome of forming simulation. Simulation data result of ram speed and force help to confirm the press requirement which was selected from empirical calculation of performed for die design.

Formation issues can be forecast before tool manufacture by the use of tools that can be implemented into development routes that increasingly depend on digital technology.

Predicting the shape problems at the design level of the part means that the structure selected is consistent with the formability of steel. Formation has become a highly technological operation, and the construction of a steel formation route no longer requires easy checking and error methods. Close cooperation between model makers, developing engineers and steel producers ensures the industrial viability of new products with very limited production times associated with the experimentation / test.

The parameters influencing the `form' operation during the trials could be listed as:

- Type of material (influencing the Limiting Draw Ratio)
- Thickness of the component
- Blank holding pressure

1.7 Phases of Work :

Literature survey on 'Deploying CAE for 'Forming Analysis' of a sheet- metal automotive component'. This information helps to understand the present research status in the field. Further, the need for the research is identified.

a) Study the forming Die Design practices in industries.

b) Will do the numerical calculation for the required tonnage and die design.

c) Shall be used of Hypermesh for meshing the components and quality checks

e) Doing the Finite element analysis of components

f) Shall be Worked with Experimentation of component with dies and parameters.

g) Finding the Results and Discussion.

h) Presents the Conclusion and Scope for Future Work.

2. LITERATURE REVIEW

In the literature study different sheet metal forming processes and approach to minimize defects are discussed. In the past, some results on theoretical and experimental research on sheet metal forming are reported in the literature. Finally approach of deploying CAE in forming process from literature are investigated and discussed.

2.1 Introduction

Sheet metal forming processes are uses forces and stresses which cause plastic deformation of the sheet metal to produce required geometry. The stresses involved in this process are mainly tensile, compression, shear and sometime combined. Like other processes sheet metal forming need to deal with defects associated with it. There are many defects could arise in forming process, but major and most common defects related to automotive sheet metal parts are: Spring-back, wrinkles, tearing, thinning, draw lines. From pas many decades industry evolving through best practices though experimentation and minimize these defects but it needs large amount of experience with money and time in hand. But with time the new technologies of digital computing help to reduce this hassle and gives predictive results from FEA simulations. Let's review the recent development happens in industry in of deploying CAE in forming analysis of sheet metal components.

2.2 Review of literature

The first paper has a research on thick plate construction using a fluid construction technique which is applied to a purely shaped plate in prototyping. Before prototype development the numerical calculations are carried out performed the simulation of forming process on thick plate, in this simulation the study the effect of spring back to predict the forming effectiveness. Experiments carried out in a compact forming process. Flexible shaping and spring-back analyses are carried out in the simulation and the structure of the results is contrasted with the prototype in relation to the curvature radii. It is verified that the modular formation mechanism and its formation system have been properly built.

Second paper explains the CAE (Computer Aided Engineering) method of sheet metal forming and identifies the spring back consistency feature for a robust construction process. For advanced high strength steels, a springback reduction is required. Approximate formula for calculating the springback field after stamping into a phase analysis of the finite element. This can be calculated the residual nodal forces after stamping creates a springback structure which can be referred to as a combination of number of modes of vibration of the nominal structure of the component. At the early stage of component design, the accepted finite element code is typically based on one step inverse approach. A quick assessment of the stamping force spectrum and an analysis of the general formability of the part are possible with this type of FEA. This helps to identify the next die design, to control the correct set-up of the punch and die shape or to restore the most important specifics to the component.

Third paper explain the use of FEA approach for the study of industrial forming processes. There is a vast variety of production processes in the industry that include the presence of extremely deformable continuous processes, it involves semi solid fluids and solids that undergo significant deformations. Lagrangian formulation is used for the study of industrial formation processes involving thermally coupled interactions between deformable continuous processes. The governing equations for deformable bodies was written in a single way that keeps all fluids and solids together. Mass conservation equation's residual expression obtained using the FIC approach, it provides the stability for quasi-incompressible condition. The equations for the generalized continuum are discretized with the Finite Element Method using basic elements of the same linear interpolation for velocity, pressure and temperature.

Fourth paper estimates the life of press forming with heat application by using the interface of coefficient of heat transfer calculated from the inverse analysis. In this sheet metal forming process, the die undergone cyclic mechanical and thermal loads due to proximity to hot metal work part. These repetitive thermal loads reduces the life of die due to damage to the die from hot workpiece from fatigue failure. The inverse FEM analysis of the high heat press moulding mechanism was carried out to evaluate the coefficient of heat transfer of the device. The FEM analysis applied to determine values of the temperature distribution, interface heat transfer coefficient and the die stress. The damage from cyclic stresses and fatigue failure determine from stress-length process. The difference between the magnitudes die forces in hot and cold conditions has estimate that die life can be substantially decreased in hot press forming. It concludes that precise data on the interface coefficient of heat transfer is invaluable for the good prediction of dietary life.

The fifth paper is on research and test Shape Error Correction in a compact formation solution using a surface overbending tool. The construction of a scalable shaping solution taking into account Compensation of the die form using an iterative overbending technique based on a numerical approximation shall be carried out. It includes the spring- back shape got from the final stage of the first shaping simulation is compared with the ideal target shape and the error is calculated as a vector norm with 3D coordinates. Conversely, the error vector is added to the target surface to compensate for both the upper and lower adjustable die conditions. The configuration of the prototype obtained from the experiment is associated with the computational simulation output, taking into account the spring-back compensation.

The sixth paper is a Research and analysis Technical and injury analysis on a flat- rolled cold wire shaping timeline. Numerical modelling is used to research proprietary high-carbon steel flat rolled cold rolled wire forming processes. In the Forge2005 ® Finite Element (FEM) kit, an elasto plastic power law, defined from mechanical testing, is used to define the material action during wire drawing followed by cold rolling. In experimental analyses it is seen that the damage is started at the wire-drawing level and is completely formed during rolling. The result is a multitude of tiny cavities all over the wire, but more clustered in the central region.

The Seveth paper has the Finite Element dimensional numerical analysis of the deep draw method using the different software. By using of FEA and statistical methods helps to determine the punch force, the blank holder force, the thinning of part and the lubrication need. It can be cost effective as potentially it can reduce the production costs, it cut down the production time and cost as well as provides agility to engineers to timely respond to changing market needs. In for validation the FEM results are compared with experimental trial's results. The outcomes of the FEM are compared with the physical trial's outcomes for confirmation. The developed method will forecast the thinning of the blank with the geometry parameter of the die. Additionally, with numerical modelling, operating parameters can be optimized without investing much time and efforts compare to experimental trails.

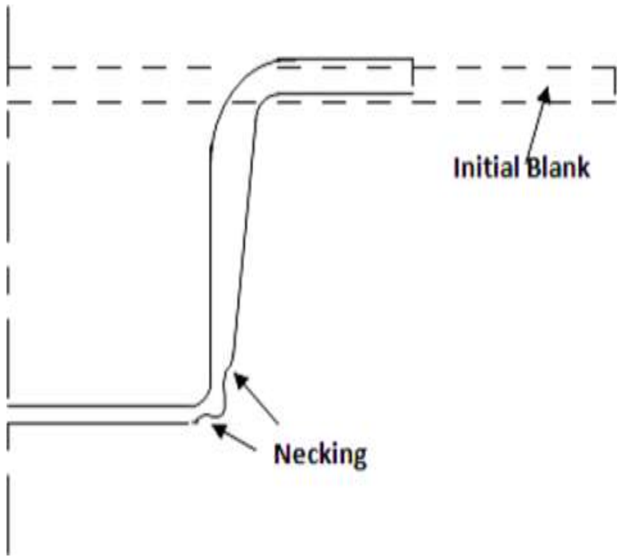

Fig.2.1 Deformation and necking of work piece

The eight research paper deals with selection of the blank holding force for cup shape part draw forming process. Here finite element package is used to predict the required holding force. In deep draw forming process one of major defect is wrinkling, it is significant when holding force is sufficient, but increase in holding force is also not advisable as it increases friction which demand high energy from press and invites other sheet metal defects like excessive straining and thinning results into tearing of cup. So, the holding force has to be designed such a that it will avoid wrinkles and tearing defect. A certain example of deep draw cup from blank is consider with certain diameter and thickness. Initially the holding force is determined by empirical formula. Later it is computed from simulation of forming analysis through FEA package or numerical calculation. The max. blank holding force is obtained and presented by the iterative method. Blank holding force is an important parameter to be calculated optimally in order to prevent the formation of wrinkles. It is therefore important to decide the force in the drawing process and the failure of the cup. Here, the optimal force was calculated by testing the state of non-formation of at various friction points, at various die radia. The force values were reordered where no defects were observed.

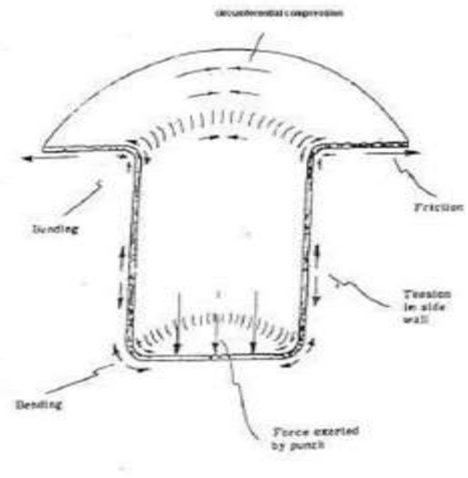

Fig.2.2 Forces during Cupping

The ninth paper is innovative approach has been introduced that incorporates two approaches for forecasting and maximizing thinning of automotive component. Taguchi's DOE (Design of Experiments) and study of variation was used to analyses the parameters of the process which responsible for defect like thinning. A model for the correlation of input process inputs and variation in thickness has established. The optimization problem was developed for reduction in thickness and the common formula was used to get optimum results. The findings of physical experiment shows the use of the newly formulated method. And the final part is reported to be healthy when processed, no thinning or fracturing is detected.

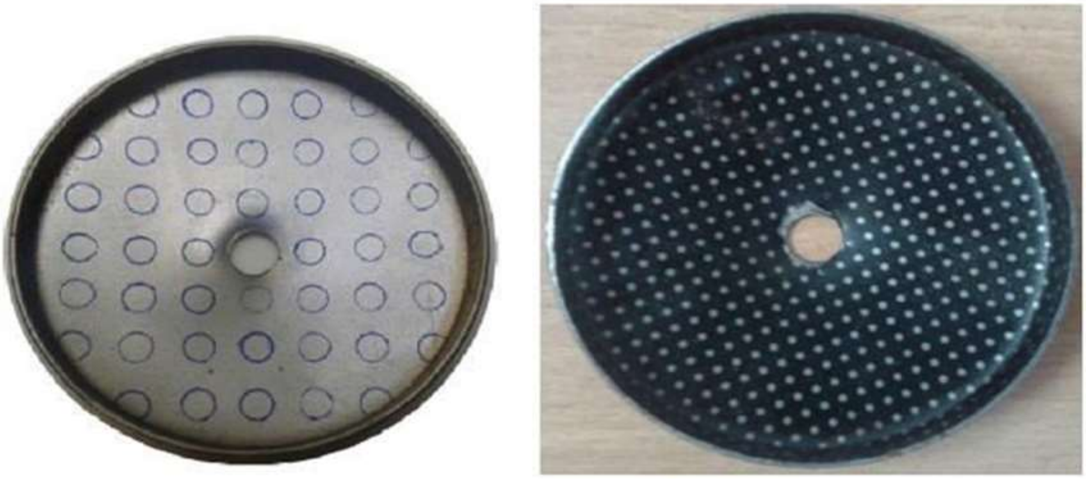

Fig 2.3 Circle grid analysis is of manufactured components

2.3 Problem Definition

The researcher are interested in forming of material in plastic zone and how the stresses are developing in the elasto-plastic zone. And to study the theories related to spring back, blank development and minimizing thinning. and here deploying CAE to analyze the stresses and the behavior of material flow in die to predict the thinning and spring back effects. Then this result should be verifiable with experimental results.

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