Determining Manufacturing Solutions For Sheet-Metal Forming Using Computational Methodology For Analysis

Abstract

This dissertation work shall focus on deployment of computational tools and techniques to evolve manufacturing solutions. The challenge posed by the ‘Form’ and/or the ‘Draw’ operation in terms of wrinkling, tearing, thinning and/or spring back has a pronounced effect on the development cycle time and the quality of the part or the product. It could have adverse consequences relating to the function of the part and/or the aesthetic aspect for visual appeal to the customer. Hyperworks suite from ‘Altair’ could be utilized in analyzing the problem. This would help the Engineer in arriving at alternative solutions for the problems at hand. Mathematical treatment shall be offered for finding the tonnage required to carry out the operation, while the analysis shall be conducted using ‘HyperForm’ to predict the nature of effects to be addressed in the tryout phase. Experimentation at the press shop shall be done to validate the solution determined during the research work.
1. **INTRODUCTION**

In stamping, drawing, or pressing, a sheet is clamped around the edge and formed into a cavity by a punch. The metal is stretched by membrane forces so that it conforms to the shape of the tools. The membrane stresses in the sheet far exceed the contact stresses between the tools and the sheet, and the through-thickness stresses may be neglected except at small tool radii. Figure 1 shows a stamping die with a lower counter-punch or bottoming die, but contact with the sheet at the bottom of the stroke will be on one side only, between the sheet and the punch or between the die and the sheet. The edge or flange is not usually held rigidly, but is allowed to move inward in a controlled fashion. The tension must be sufficient to prevent wrinkling, but not enough to cause splitting.

![Figure 1: A schematic section of a typical stamping die](image)

The limits of deformation, or the window for stamping, are shown in Figure 2. It is assumed that the failure limits are a property of the sheet. This assumption is reasonable if through-thickness stresses are negligible, and if each element follows a simple, linear path represented by a straight line radiating from the origin.

![Figure 2: A schematic plot of the window of safe straining for simple paths the FLD](image)

The path in stampings is described by the ratio of the membrane strains $b=e_2/e_1$ which vary from equal biaxial stretching ($b = 1$) to uniaxial compression ($b = -2$.) Figure 3 shows the strain paths along two lines in a rectangular pressing. Such diagrams are strain signatures of the part. Unequal biaxial stretching ($b \neq 1$) will occur in the middle, A. In the sidewall, C, plane strain is most likely. If the side of the stamping is long and straight, plane
strain will exist also at D. Over the rounded corner of the punch at F, the strain is biaxial. From H to J, strains are in the tension-compression quadrant. The concept of the forming limit curve is that all possible strain signatures are bounded by an envelope that is a characteristic only of the material. The origins of this failure map were reviewed earlier, and more recent developments are described here.

2. LITERATURE REVIEW

1. A particle finite element method for analysis of industrial forming Processes by, Eugenio Onate, Alessandro Franci, studied about Lagrangian formulation for analysis of industrial forming processes involving thermally coupled interactions between deformable continua. The governing equations for the deformable bodies are written in a unified manner that holds both for fluids and solids. The success of the formulation lays on a residual based expression of the mass conservation equation obtained using the finite calculus method that provides the necessary stability for quasi/fully incompressible situations. The governing equations are discretized with the FEM via a mixed formulation using simplified elements with equal linear interpolation for the velocities, the pressure and the temperature. The merits of the formulation are demonstrated in the solution of 2D and 3D thermally-coupled forming processes using the particle finite element method.

2. Seong-Chan Heo & Young-Ho Seo studied on thick plate forming using flexible forming process and its application to a simply curved plate. Flexible forming machine are carried out for the purpose of manufacturing a prototype of curved plate block for hull structure used in shipbuilding industry. Flexible forming dies which consist of numbers of punches in an array form for upper and lower sides are designed in view of thick plate forming. A punch has formation of male and female screws to adjust its length with regard to a given surface, and all punches are supported by each other in punch housing.

3. Giovanni B. Broggiato studied the Computer-aided engineering for sheet metal forming: definition of a spring back quality function. Computer-aided engineering methods are extensively applied to sheet metal forming integrated design. The adoption of a new class of materials, the advanced high strength steels, has increased the occurrence of springback, and consequently the request for tools oriented to spring back reduction and optimization. This paper presents an approximated formulation to compute the spring back field after stamping through the finite element analysis of the process. This can be found assuming that the residual field of nodal forces after stamping produces a spring back shape referable to a linear combination of n modes of vibration of the nominal shape of the component. The aim of this formulation is not that of substituting the finite element analysis of the spring back but rather to make use of the coefficients of the linear combination, so to define a global quality function for spring back. In this way, Robust Design methods or other current optimization procedures to improve the stamping process as for structural defects (such wrinkling, necking and flatness) can be applied also for the reduction of spring back. The meaning of these coefficients will be shown through three test cases and the consistency of
the formulation will be discussed according to the number of modes of vibration included in the computation.

4. D. Y. KIM et al studied the Life estimation of hot press forming die by using Interface heat transfer coefficient obtained from Inverse analysis. During the hot press forming process, the die experiences repeated thermal and mechanical loads owing to exposure to the heated workpiece. Such repeated thermal loads may cause deterioration in the mechanical properties of the die, leading to fatigue failure. Therefore, for the successful implementation of the hot press forming process in mass production, it is necessary to estimate the die life under hot press forming conditions. The fatigue life of a hot press forming die is estimated based on the stress history of the die during the forming process. Because accurate understanding of thermal behavior is essential for reliable analysis of fatigue life of the die at elevated temperatures, we characterized the thermal boundary condition, i.e., the heat transfer coefficient at the die–workpiece interface. For this purpose, die temperatures during a hot press forming process were measured as a function of time at select locations on the die. Inverse finite element method (FEM) analysis of the hot press forming process was performed to determine the interface heat transfer coefficient. The interface heat transfer coefficient was applied to the FEM simulation, and the temperature distribution and stress values for the die were determined. Considering the thermo-mechanical stress history, the fatigue life of the die was estimated based on the stress-life approach.

5. Seong-Chan Heo & Jae-Nam Kim studied the Shape error compensation in flexible forming process using over bending surface method. In this article, the design of the flexible forming process considering die shape compensation using an iterative over bending method based on numerical simulation is carried out. In this method, the spring back shape obtained from the final step of the first forming simulation is compared with the desired objective shape, and the shape error is calculated as a vector norm with three-dimensional coordinates. The error vector is inversely added to the objective surface to compensate both the upper and lower flexible die configuration. The flexible dies are made up of several punches that make a forming die that is equivalent to a solid die, thus the forming surface shape can be reconfigurable with regard to the compensated die shapes.

3. PROBLEM DEFINITION

The Tool-Die making ancillary industry need to cope up with unique problems during the Design as well as Process Engineering phase. The Engineer has to deal with quality related Design issues which finally have a bearing on the try-out and the Manufacturing phase of the development cycle. Anticipation during the Design and Development phase can reduce total development time and consequently save costs towards rejections. The typical problems encountered while dealing with the Forming or Draw operation can be listed as:

i. Presence of ‘Wrinkles’ around the periphery of the semi-finished or finished part

ii. ‘Tearing’ observed especially around sections subjected to non-uniform strain due to uneven material flow (usually restricted by relatively sharp edges).
iii. Thinning observed in local regions that may be unacceptable for ‘function’ or could lead to ‘tearing’ further.
iv. Springback- Tendency to regain original (unformed) dimensions causing distortions or deviations from the given size or the included angle.

4. SCOPE AND OBJECTIVE:
   i. Study the existing component function and its specifications.
   ii. calculate the tonnage calculation for the given component
   iii. Selection of other components in the die based on tonnage
   iv. Forming analysis and results interpretation using Altair Suite.
   v. Find out the alternatives to minimize the component defects.
   vi. Validation through experimentation

5. METHODOLOGY
   I. Mathematical calculations:
      In mathematical calculations, tonnage calculation for the component will be completed using standard formulae. Based on these calculations other part selection will be completed.
   II. Computational analysis
      In computational method, defects would be predicted using Hyperworks Suit. There are three main steps, pre-processing, processing, post-processing. Blank holding force calculated using mathematical method, would be used for analysis.
      ▪ Pre-processing: Die-punch setup would be prepared using Hyperform interface. Meshing, material property assigning, applying load and boundary condition are the steps in pre-processing.
      ▪ Processing: The input file exported to RADIOSS software.
      ▪ Post-processing: For post-processing, HyperView interface used for interpretation of results. Results would be studied in contour format. Thinning, wrinkles, FLD, these plots are studied.

6. EXPERIMENTATION
Experiments are to be conducted on a press of a suitable type and capacity. The die would be mounted on the bolster plate of the press and the speed of the ram would be set based on the historical data as well as the input received from the analysis data (simulation). Forming problems can be predicted before tool fabrication through the use of software that can be integrated into production routes which rely increasingly on computer technology. The prediction of forming difficulties at the component design stage ensures that the chosen geometry is compatible with the formability of steel. Forming has become a highly technical process, and the development of a steel forming route no longer involves simple trial and error methods. Close collaboration between component designers, forming engineers and
Steelmakers guarantees the industrial feasibility of new parts with very short development times.

The parameters influencing the form operation as evident during the trials are:

- Type of material
- Thickness of the component
- Mechanical properties, especially the Limiting Draw Ratio
- Use of lubricant
- Blank size and development
- Blank holding pressure
- Speed of the operation

For this work, the critical parameter/s (one or two) shall be identified and modified to realize a desired response.

7. VALIDATION

The appropriate capacity press can be selected by knowing the forming load. Working with the presses of higher capacities may lead to many types of defects such as cracks and tearing. Blank holder pressure needs to optimize over a given range for optimized geometry. The coefficient of friction needs to be optimized for the new geometry. The actual trials performed over the component would directly reflect over the ease of “Forming operation” realized for the said Die design.

8. CONCLUSION

The sheet metal forming operation poses challenges for defects including Tearing, Wrinkles, Spring-back, Thinning, etc. Use of Finite Element Modeling can help to reduce the development time for trials and the associated costs for the project. Use of Altair HyperForm as a CAE tool is predominant in the industry for simulating the process and predicting the defects. This work shall primarily include F.E.Modeling techniques for finding alternative solutions. Trials and testing shall be considered towards the concluding phase of the project work for validating the solution proposed during Analytical phase of the work.

9. REFERENCES

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