DESIGN, DEVELOPMENT AND ANALYSIS OF FORMING TOOL FOR SIDE PANEL OF AN AUTOMOBILE

[1]ULHAS K ANNIGERI, [2]Y P DEEPTHI, [3]RAGHAVENDRA RAVI KIRAN K

[1,2,3]Asst. Professor (Sr.Gr), Amrita Vishwa Vidyapeetham, Bengaluru.
E-mail: uk_annegeri@blr.amrita.edu, p_deepthi@blr.amrita.edu, kr_ravikiran@blr.amrita.edu.

Abstract- The design, development and structural analysis of forming tool for a side panel of an automobile is carried out in this endeavor. The design protocol is on conventional lines, based on tried and tested norms developed through expertise and experience reported in literature and design chapters. Solid works 2003, Auto CAD R2004 software has been used for modeling and detailing. Finite Element Analysis package Ansys5.4 has been used to determine the stresses that are induced in the Forming tool. This paper gives a brief overview of fabrication of tool, tool cost estimation and finally an insight into the stresses induced in the forming tool.

Keywords- Forming tool, Finite element analysis

I. INTRODUCTION

For large-scale production from sheet metal, press working is fast and relatively easiest method to generate the components. A press tool combines maximum production and least maintenance with lowest feasible life cost. It helps to serve maximum utilization of least expensive stamping material available.

The profile of the component that has to be formed, is machined on the die and punch with the help of CAD data and Computer Numerical Controlled machines through programming, based on a suitable reference datum or tooling holes. With the advent of such high technologies in the field of Computer-Aided Manufacturing, production of complex profiled three dimensional sheet metal components for automobile industry has become easier than it was a decade ago. Press components are widely used in automobile, aerospace, electrical, telecommunication & domestic appliance industries.

II. FORMING TOOL

Press forming is a process in which sheet metal is confined to the contours of die and punch. The operation of forming is similar to bending except that the line of bend is curved instead of straight and plastic deformation in the material is more severe. The sheet metal to be formed is kept on the die which has the negative profile of the component machined on it within the nesting provided. The punch with positive profile then descends and hits the sheet metal to form it to the required profile.

III. COMPONENT STUDY

Data for developing the component are obtained from customer. The component is a rear side L.H (left hand side) exterior side panel of an automobile.

3.1 Design Requirements

Maximum forming depth: 15.7 mm.
Eight embossing features of height: 1.5mm.
Pierced holes of Diameter: 10.2mm, 15.2mm, 7mm, 8.7mm.
oblong hole : 8.2mm x 11.2mm.
Up flange : 27 degrees with a bend radii of 3mm to a depth of 16mm.
Down flange : 95 degrees of bend radius 25mm with 16mm depth.

3.2 Component details

Material : Cold rolled steel 7C4 to IS: 1570
Thickness: 0.7mm.
Length: 400mm.
Width: 323mm.
Maximum forming depth: 15.7mm.
Grade of sheet: Drawable quality in soft Condition.

Table 1 Chemical Properties of Work Piece

Chemical composition wt %—	min	max
Carbon	0.08	0.12
Manganese	0.3	0.5
Sulphur	-	0.05
Phosphorus	-	0.04

Table 2 Mechanical properties

Ultimate tensile strength: 410 N/mm^2
Yield strength: 250 N/mm^2
Shear strength: 350 N/mm^2
Density: 7.82×10^{-3} g/mm^3
Young's modulus: 2.05×10^5 N/mm^2

3.3 Press data

Capacity of the press : 2486400N
Type of press: Mechanical ,Single crank
Model: SN1-250(S),C- frame
Shut height of the press : 370 mm
Stroke: 250 mm
Slide adjustment : 120 mm
Ejection system: Die cushion arrangement
Bed size: 900mm x 1500 mm
Bolster plate thickness: 180 mm

IV. METHODOLOGY

4.1 Blank Development

Component CAD data given by the customer is utilized to develop the blank size and the size so developed based on the Program zero value is 0.7x366x445. (Refer Fig 1)

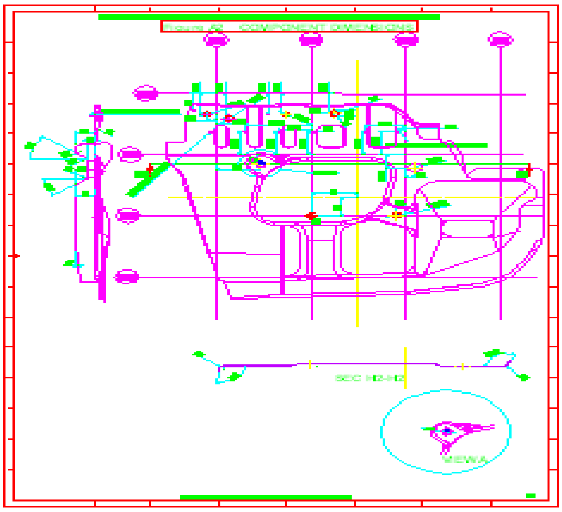

Figure 1: Orthographic views of LH side panel

In the first stage tool, formed part and embossing features are developed. In the second stage tool trimmed profile with two pierced holes of diameter 10.2mm are developed. In the third stage tool the up flanging of 27degrees and down flanging of 95 degrees are developed. In the fourth stage tool the holes of diameter 7.2mm, 8.7mm, 15.2mm, oblong hole of 8.2mmx11.2mm are developed. In this paper only the first stage, forming tool development has been discussed.

4.2 Design of Forming Tool

Forming force =P*T*UTS [4]
= (445mm *2+366mm *2) * 0.7mm*410
= 465514 N
Embossing force = H*T*UTS [4]
= 1.5mm*0.7mm*410
= 430.5 N
Where P=Perimeter in mm
H= Emboss height in mm
T= Thickness in mm
UTS =Ultimate tensile strength in N/mm^2
Total force required = 465944.5 ~ 470000N

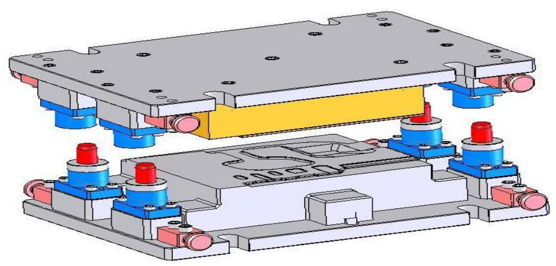

Figure 2 3D model of forming tool developed in solid Works 2003

4.3 Selection of Press

Based on practical experience, the press should be capable of delivering approximately 30-40% greater force than total forming force required by tool Therefore, 1.3 x 470000 = 620000 N This is well within the permissible limit of the 2486400N press, which is to be used.

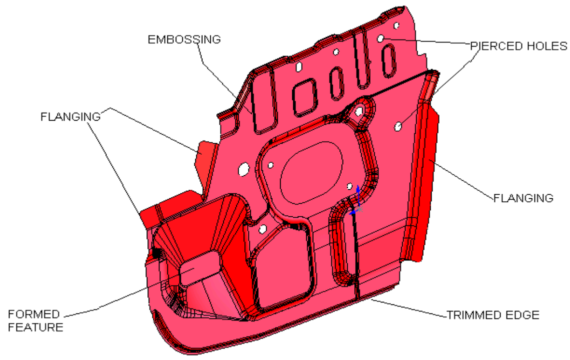

Figure 3 Final formed component details

V. STRUCTURAL ANALYSIS

In this dissertation work, structural static analysis of forming die and punch is carried out to find maximum deflection and stresses so as to ascertain that they are within the permissible value of 0.05mm. The forming force is applied on forming die and punch as surface load in on the forming area. The applied load is in the Y-direction of the Cartesian coordinate system with stepped input with no intermediate sub steps. The time of application of stepped load is one second. In the present analysis the effect of steady loading conditions are calculated ignoring the steady inertia loads such as gravity and also inertia, damping effects caused by the time varying loads. The solution to the problem is solved using frontal solver available with Ansys version 5.4. The program calculates nodal degree of freedom solution by back substitution and uses the individual element matrices to calculate element solution. In the present work nodal solutions are displayed in the power graphics display mode since display is at a much faster rate than the alternate full display method.

5.1 Modeling and Meshing

Solid modeling of the punch and die is carried out using Solid Works 2003 by importing Auto CAD drawings in the DXF format. Solid model is imported from Solid Works software in IGES format into Ansys5.4 package. The discontinuity and extra lines in the imported model are repaired to eliminate these errors. The model is free meshed using isoparametric SOLID92 3-D 10node tetrahedral structural solid. Due to curved areas at the area of application of load the mesh has become much finer at these regions as can be seen from the figure m1 and m5.SOLID92 has a quadratic displacement behavior and is well suited to model irregular meshes as in this particular case. The element also has plasticity, creep, swelling, stress stiffening, large deflection and large strain capabilities. The size of the element is chosen based on the RAM capacity of the computer being used to solve the problem. In the present analysis smart size "6" is used to define the mesh density. After meshing the die nearly 6000 elements were generated and the time duration to solve the problem was 15 minutes. The mesh density was chosen purely on iterative basis after finding the results with a much finer and coarser mesh. The element is defined by ten nodes having three structural degrees of freedom at each node. The mesh is refined using h-convergence method to get converged solution.

5.2 Boundary conditions

The boundary conditions specify the constraints that are imposed on the component at various regions. All the nodes of the bottom faces of forming die and punch are fixed in all three directions.
i.e $U_x = U_y = U_z = 0$[1]

5.3 Loads

For static structural analysis loading is considered during closed condition of the press tool. During this condition the punch exerts a pressure equal to applied load of twice the forming force over the top surface area of the punch and die.
The applied load is taken as twice the forming load considering the dynamic factor.

P_a = L/A where, L= 2x470000=940000N.

Area = 162870 mm^2

Therefore, P_a = 940000/162870

= 5.78 = 6 N/mm^2

5.4 Material properties

Gray Cast Iron: FG 300

$E = 1.17 \times 10^5$ N/mm^2

μ = 0.26

5.5 Results

The figure numbers 4 to 11 show the meshed model, boundary conditions applied, deflection and von Mises stresses induced.

5.6 Analysis Results

Table 3 FEM Results

Parameters	Punch	Die
Max deflection	0.016mm	0.012mm
von Mises stresses	57.4N/mm²	51.11N/mm²

The material FG300 has an ultimate compressive strength of 960N/mm^2. From this we conclude that stresses are well within the permissible value and also the deflection is well within the permissible value of 0.05mm.

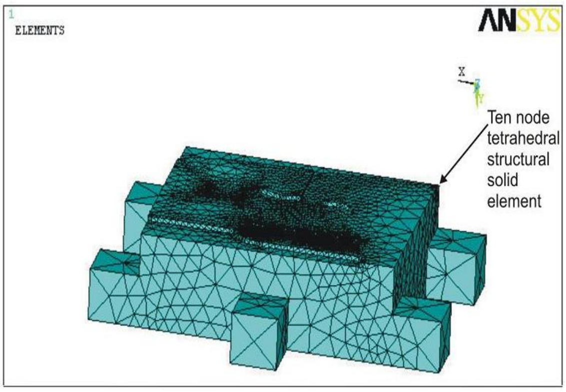

Figure 4 Meshed Die

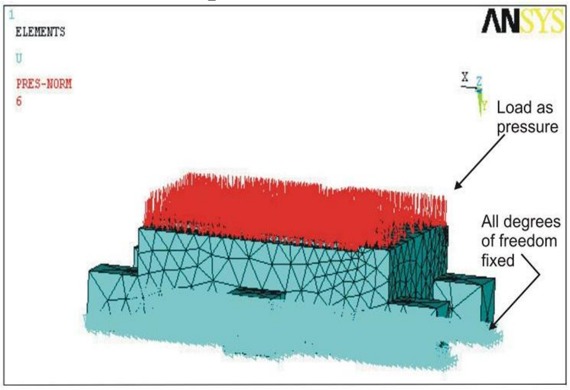

Figure 5 Die with boundary conditions applied

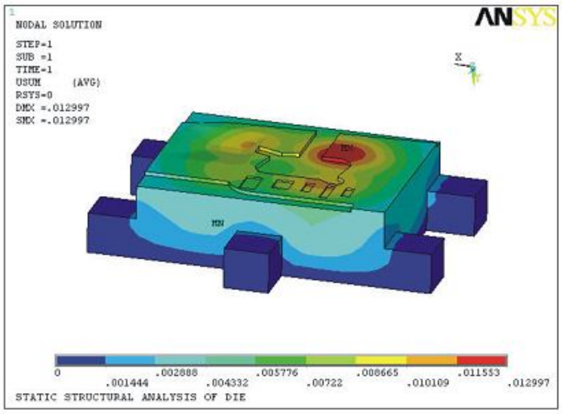

Figure m3-Deflections in die in mm

Figure 6 Deflections in die in mm

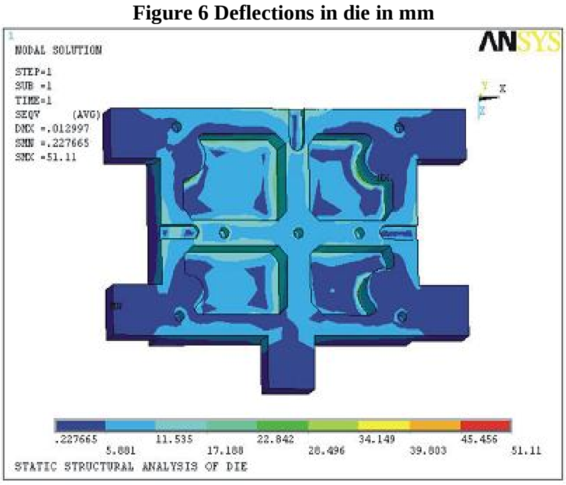

Figure m4-von Mises stresses in MPa

Figure 7 Vonmises stresses in die in MPa

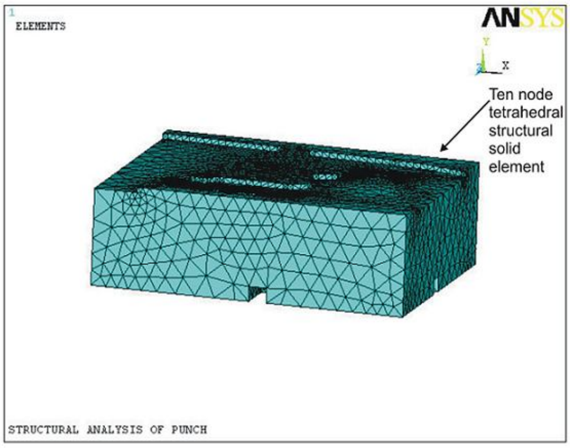

Figure 8 Meshed Punch

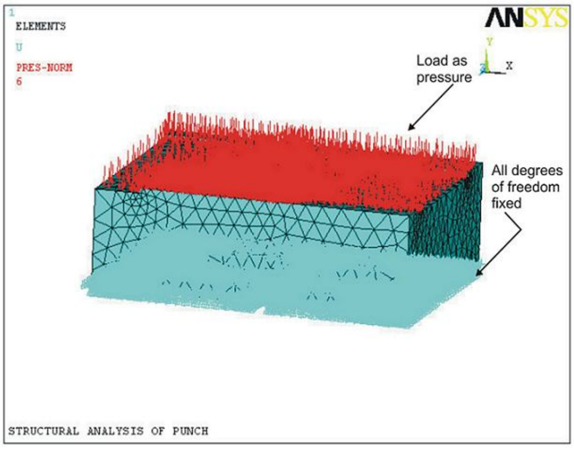

Figure 9 Punch with boundary conditions applied

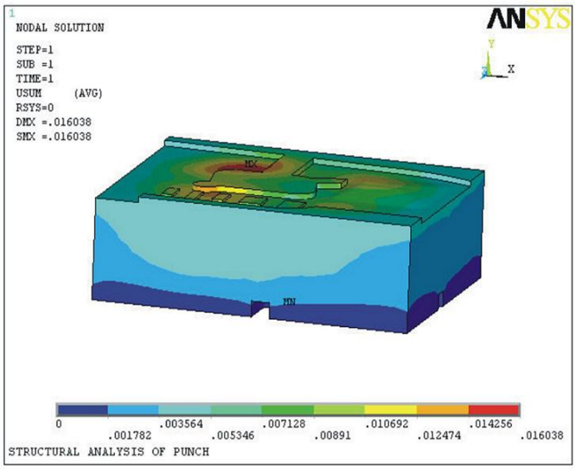

Figure 10 Deflections in punch in mm

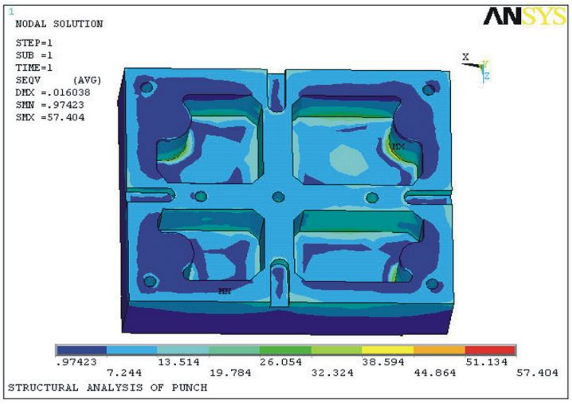

Figure 11 Vonmisses stresses in punch in MPa

CONCLUSION

It is observed that the design of forming tool is safe as the von mises stress is well within the compressive strength of the material for both punch and die.
The deflection of both punch and die are well within the allowable deflection of 0.05 mm and hence we conclude that the design of both forming punch and die is safe.
The reduction in web thickness of punch and die by 30% didn't interfere with the allowable stress and deflection values of punch and die. This has made us conclude that weight reduction of 4.2 kg is possible.

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