Design and Analysis of Progressive Tool

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ABSTRACT

Design and development of Progressive tools for the sheet metal component is one important phase in sheet metal manufacturing. Sheet metal press working process by progressive tools is a highly complex process that is vulnerable to various uncertainties such as variation in progressive tools geometry, strip layout, die shear, material properties, component and press working equipment position error and process parameters related to its manufacturer. These uncertainties in combinations can induce heavy manufacturing losses through premature die failure, final part geometric distortion and production risk.

Identification of these uncertainties and quantifying them will facilitate a risk free manufacturing environment, which goes a long way to minimize the overall cost of production. FEM based modelling of press working process is a very effective tool to overcome the above uncertainties.

1. INTRODUCTION

The progressive die performs a series of fundamental sheet metal working at two or more stages during the press running to produce a production part as the strip stock moving through the die surface. Press working from the optimum dies design and its making has been the purpose of mass production in the manufacturing field.

The design and manufacture of press tools, or punches and dies, is a branch of production technology that has extended into many lines of engineering manufacture over the past seventy years. There is no doubt that the accuracy achieved by new ideas in design and construction applied by the press tool designer, coupled with increased speed and rigidity of the presses etc, used have all contributed towards maintaining this form of metal tooling well to the force as a means of obtaining pleasing, yet strong, durable articles that can withstand severe day-to-day usage.

Four factors are essential contributions to first-class press work.

1. Good operation planning
2. Excellent tool design
3. Accurate tool making
4. Knowledgeable press setting

According to upper factors, this paper is aimed at the optimum die design through the FE analysis, Pro-E. Furthermore the aim of least defects could be obtained mostly by revision through the tryout.

2. PROGRESSIVE TOOL

Progressive tool performs two or more operations at different stages in each stroke. The stock strip is advanced through a series of stations that form one or more distinct press working operations on the strip to get the component.

3. COMPONENT ANALYSIS

Material	: Mild Steel (St-42)
Thickness	: 2 mm
Shear strength	: 35kg/mm^2
Temper grade	: Hard
Supply condition	: Strips
Geometry tolerance	: IS2102

PROPERTIES

- It has a bright and fine finish.
- It can withstand heavy loads, as it is tough.
- Welding of this material does not change its chemical structure.
- It has a scale free material.
- Fine or bright for electroplating.

4. DESIGN CALCULATION

4.1 COMPONENT DATA

Material: mild steel (St-42)
Supply conditions: strips
Temper grade: hard
Shear stress: 35 kg/mm^2
Geometry tolerance: IS2120

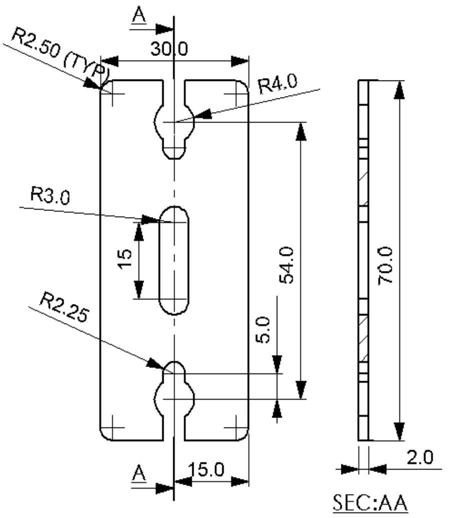


Fig: 4.1 Component Diagram

4.2PROGRESSIVE TOOLS DETAILED DRAWING

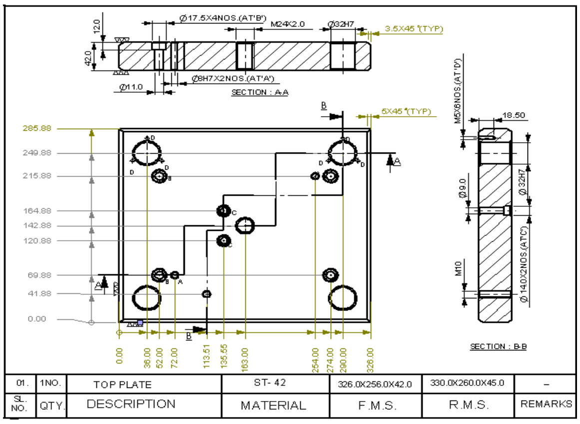


Fig: 4.2a Detailed Drawing of Top Plate

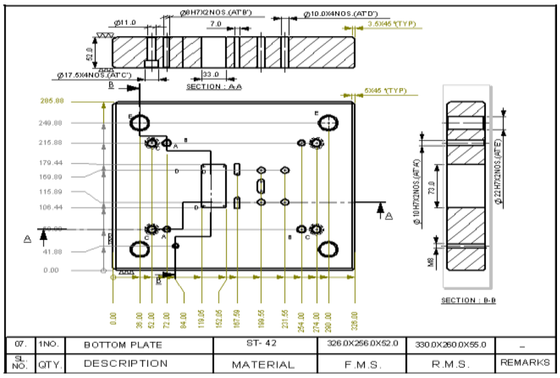
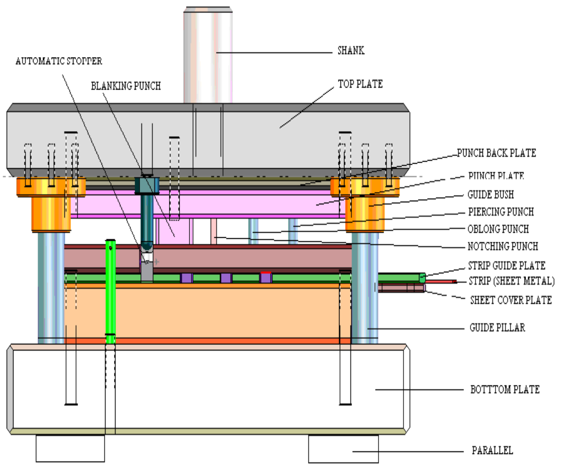


Fig: 4.2b Detailed Drawing ofBottom Plate

4.3 ASSEMBLED VIEW OF PROGRESSIVE TOOLS



TOOL SPECFICATION	
PRESS CAPACITY	40 TONES
TYPE OF PRESS	MECHANICAL
PITCH	32.00 MM
STRIP WIDTH	74.00 MM
CLEARANCE	0.06 MM/SIDE
SHUT HEIGHT OF THE TOOL	190.00 MM
DAYLIGHT OF THE TOOL	96.00 MM
TYPE OF DIE SET	REAR AND FRONT PILLER
TYPE OF STRIPPER	SOLID TYPE
METHOD OF FEEDING	MANUAL
TYPE OF STROKE	FIXED
NO. OF SLIDE	SINGLE ACTION

5. THEORETICAL DEFLECTION AND STRESS CALCULATION

5.1 DIE BLOCK

Assuming that the die block (die plate) is considered to be as fixed beam. The shoe deflection is calculated using the strength of material formula for fixed supported beam,

Deflection, $\delta = FL^3/192EI$

Where, F = 80% of cutting force = 0.8 x 26177.41 kgf = 209419.3 N

L = 222 mm, E = 2.1×10^5 N/mm^2

I =$bh^3/12$=6.29×10^6 mm^4

Where, b = 176 mm, h =35 mm

$\delta=(209419.3 \times 222^3)/(192 \times 2.1\times10^5 \times 6.29 \times 10^6)$

=13.49µm

Stress, p = F/A

p = 209419.3 / (176 x 35) = **5.98×10^7 N/m^2**

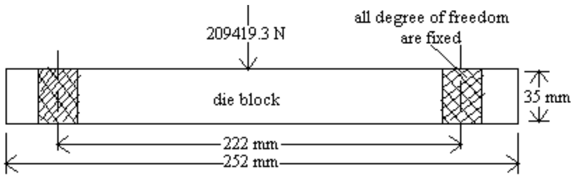


Fig : 2D Diagram of Die Block for Theoretical Calculation

5.2 TOP HALF

Top half includes as for calculation and analysis purpose as top plate, punch back plate and punch plate. Assuming that the Top plate is considered to be on parallels. The shoe deflection is calculated using the strength of material formula,

deflection,$\delta=FL^3/48EI$

Where,F = 80% of cutting force

= 209419.3 N

L = 254 mm,E = 2.1×10^5 N/mm^2

I=bh^3/= 6.85×10^6 mm^4

Where, b= 286 mm,h= 66 mm

$\delta=(209419.3\times254^3)/(48\times2.1\times10^5\times6.85 \times 10^6)$

= **4.97 µm**

Stress, p=F/A

=9.73×10^6 N/m^2

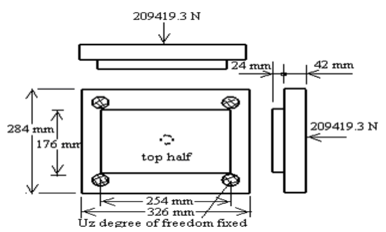


Fig : 2D Diagram of Top Plate for Theoretical Calculation

5.3 BOTTOM PLATE

Assuming that the bottom plate is considered to be on parallels. The shoe deflection is calculated using the strength of material formula for parallels supported beam,

Deflection, $\delta = FL^3/354EI$

Where, F=80% of cutting force = 209419.3 N

$E = 2.1 \times 10^5$ N/mm^2

$I = bh^3/12 = 3.35 \times 10^6$ mm^4

Where, b = 286 mm, h = 52 mm

δ = **5.26µm**

Stress, p = F/A

p = 209419.3 / (326 x 52)= **4.37 x 10^7 N/m^2**

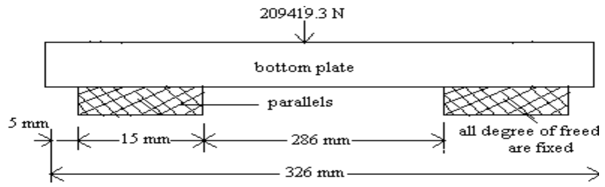


Fig : 2D Diagram Bottom Plate for Theoretical Calculation

5.4 STRIPPER PLATE

Assuming fixed stripper to be considered as a fixed beam support.The fixed stripper plate deflection and stress is calculated using the strength of material formula, Deflection, $\delta = FL^3/192EI$

F = 10% to 20% of cutting force = 52354.8 N

L = 222 mm, $E = 2.1 \times 10^5$ N/mm^2

$I = bh^3/12 = 1.17 \times 10^5$ mm^4

Where, b= 176 mm, h= 20 mm

δ= **9.26µm**

Stress, p = F/A

p = 52354.8 / (176 x 20)

= **1.487 x 10^7 N/m^2**

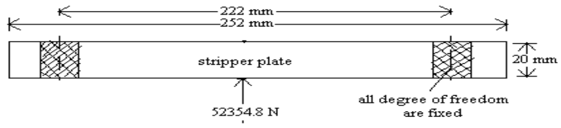


Fig :2D Diagram Stripper Plate for Theoretical Calculation

5.5 GUIDE PILLAR

The diameter of guide pillar is = 1.1 to 1.3 x thickness of die plate = 1.1 x 35 = 38.5 mm > 22 mm. Hence the guide pillar diameter is safe dimension.

Assuming that the guide pillar as a cantilever beam vertical load. So guide pillar is as consider as a one side is fixed and other end is free column construction,

From strength of material for column construction of one end is fixed and other end is free type, crippling load as $P = \pi^2 E I / 4 l^2$

Where $E = 2.1 \times 10^5$ N / mm^2

$I = \pi d^4 / 64$

d = 22 mm, l = 142 mm

P = 73872.53 N > 10000 N

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The applying load is also within crippling load. Hence the applied load is safe for design.

Deflection, $\delta = P\,l / A\,E$ = **8.022 μm**

Stress, $p = P / A$ = **2.63e8 N/m²**

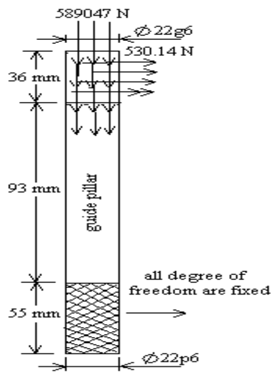

Fig : 2D Diagram Guide Pillar for Theoretical Calculation

5.6 PUNCHES

5.6a Piercing punch

Assuming that the piercing punch as consider as one end is fixed and compressive force is acting on other end. Here for cutting operation (piercing operation) 80% of cutting force is acting on punch as compressive nature.

We know that the compressive force on the punch is equal to the shear force on sheet metal.

Cutting force on piercing punch

S_{cp} =cutting force/cross sectional area of punch

$S_{cp} = 4\,\pi\,d\,t\,S_s / \pi\,d^2 = 4\,t\,S_s / d$

Where, t = 2mm,S_s = 35 kgf/mm²

d = Ø8 mm , S_{cp} = $\mathbf{3.50 \times 10^8}$ **N/m²**

Deflection of piercing punch, $\delta_p = P_p\,L / A_p\,E$

Pp = Compressive force for piercing operation = 14074.32 N

L =55 mm,A_p= 50.27 mm2,E = 2.1×10^5 N/mm²

δ_p = **3.15 μm**

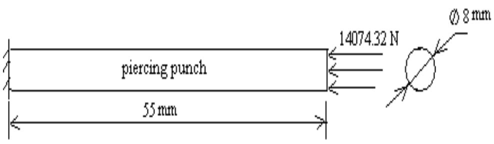

Fig : 2D Diagram Piercing Punch for Theoretical Calculation

5.6b Oblong piercing punch

Assuming that the oblong piercing punch as consider as one end is fixed and compressive force is acting on other end. Here for cutting operation (oblong piercing operation) 80% of cutting force is acting on punch as compressive nature.

We know that the compressive force on the punch is equal to the shear force on sheet metal.

Cutting force on oblong piercing punch,

S_{co}=cuttingforce/Cross sectional area of punch

, P_o = 27559.81 N

A_o = 118.27 mm²,E = 2.1×10^5 N/mm²

L =55 mm

S_{cp} = $\mathbf{2.89 \times 10^8}$ **N/mm²**

$\delta_o = P_o\,L / A_o\,E$ = **7.57 μm**

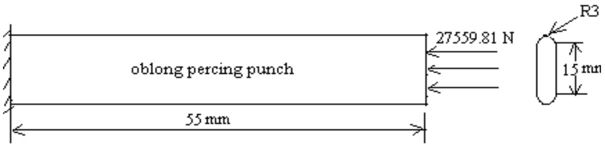

Fig : 2D Diagram Oblong Piercing Punch for Theoretical Calculation

5.6c Blanking punch

Assuming that the blanking punch as consider as one end is fixed and compressive force is acting on other end. Here for cutting operation (blanking operation) 80% of cutting force is acting on punch as compressive nature.

Cutting force on blanking punch,

S_{cn}=cuttingforce/Cross sectional area of punch

P_b = 109599.84 N

$A_b = 2094.64\ mm^2$, $E = 2.1 \times 10^5\ N/mm^2$

L=55mm

S_{cb} = **$6.54 \times 10^7\ {}^N/mm^2$**

Deflection of blanking punch, δ_b = **1.75 μm**

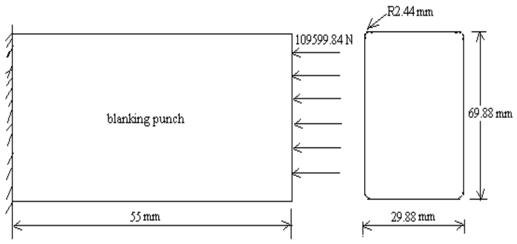

Fig : 2D Diagram Blanking Punch for Theoretical Calculation

6 ANALYSIS

The objective of the analysis of the functional elements like die set (top plate and bottom plate), die plate, punches (piercing punch, oblong punch, notching punch and blanking punch), stripper plate, guide pillar and guide bush are include structural analysis to estimate the deflection and stresses.

To carry out the analysis, 3D-Solid model of the all functional elements are modeled in PRO-E 4.0 software. The types of elements chosen for analyses are given below.The element shown below is used for steady state structural analysis

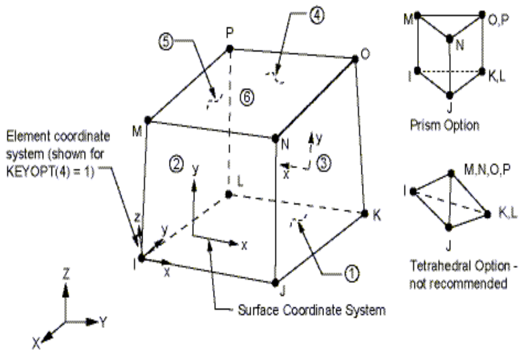

Fig: 6.1 Solid 45 3-D 8 Nodded Hexahedral Structural Solid Element

The element shown above is used for steady state structural analysis. SOLID 45 have a quadrilateral displacement behavior and are well suited to model irregular meshes. Eight nodes having three degrees of freedom at each node define the element: Translations in the nodal x, y and z directions. The element also has plasticity, creep, large deflection and large strain capabilities.

Material Properties

Material properties such as modulus of elasticity, poison's ratio are taken as

Modulus of elasticity, $E = 2.1\times10^{11}$ N/ m^2

Poisson's ratio, $\nu = 0.3$ to 0.5

Boundary Conditions

Here $U_X = U_Y = U_Z = 0$. Thus all the functional elements like top half, die plate, stripper plate, guide pillar, guide bush, punches (piercing punch, oblong piercing punch, notching punch and blanking punch) and bottom plate are fully restricted to move in any of X, Y, Z directions at specified place or nodes.

Loads

Load for some function elements like top half, bottom plate and die plate are applied on F_z positive direction of magnitude as 80% of cutting force as vertical. And for punches like piercing punch, oblong piercing punch, notching punch and blanking punch are applied on F_z positive direction of magnitude as calculated cutting force of that operation as compressive load on surface. And also for guide pillar load applied is on F_x positive direction of magnitude as 10 to 20% of cutting force as thrust load and F_z positive direction of magnitude of 80 to 90% of cutting force as vertical load. Element type: structural solid brick 8node 45. Application : structural analysis.

6.2 MESHED MODELS

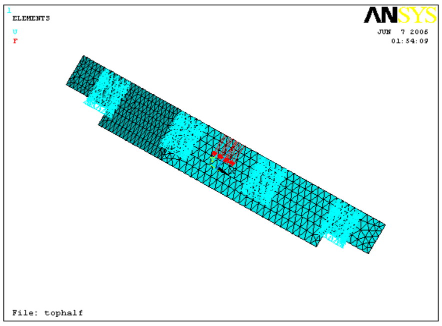

Fig: Top Half Meshed with Load and Boundary Conditioned FE Model

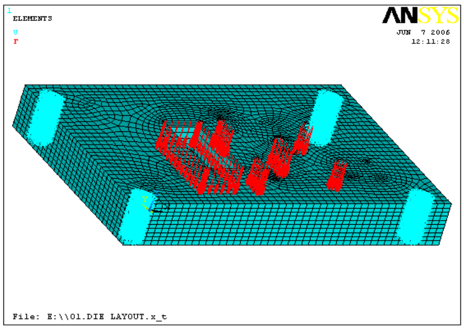

Fig: Die Plate Meshed with Load and Boundary Conditioned FE Model

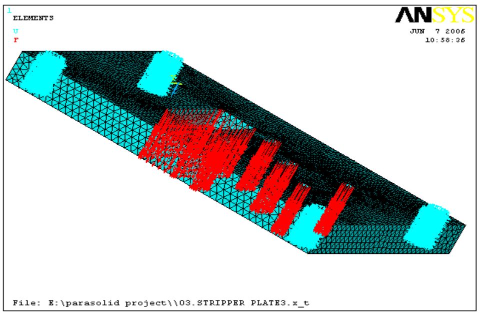

Fig: Stripper Plate Meshed with Load and Boundary Conditioned FE Model

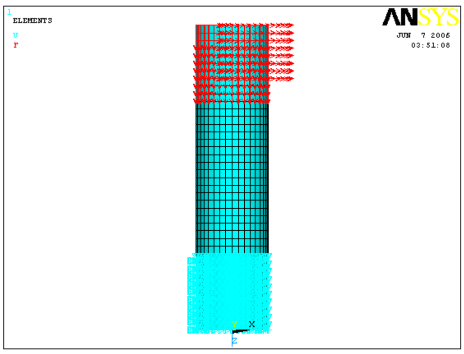

Fig: Guide Pillar Meshed with Load and Boundary Conditioned FE Model

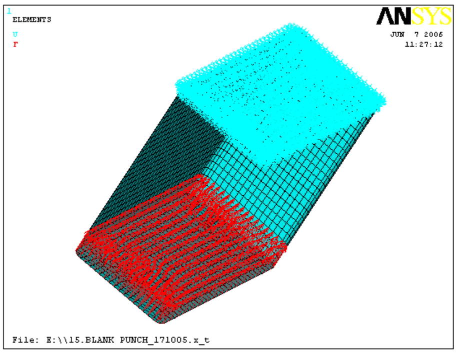

Fig: Blanking Punch Meshed with Load and Boundary Conditioned FE Model

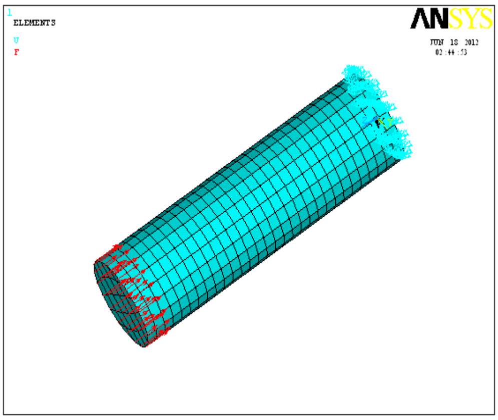

Fig: Piercing Punch Meshed with Load and Boundary Conditioned FE Model

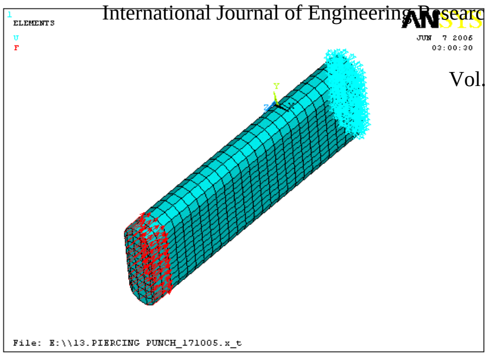

Fig: Oblong Piercing Punch Meshed with Load and Boundary Conditioned FE Model

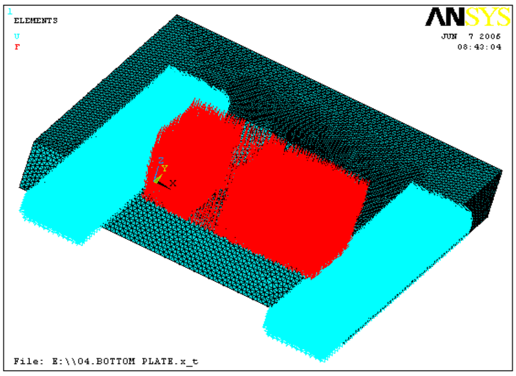

Fig: Bottom Plate Meshed with Load and Boundary Conditioned FE Model

7. RESULTS

Sl.No	Description	Thickness mm	Analysis result		Calculated value	
			Deflection µm	Stress N/m^2	Deflection µm	Stress N/m^2
1	Top half	42+8+16	5.41	8.91e7	4.97	9.73e6
2	Die plate	35 (80%)	13.6	3.44e8	13.49	5.98e7
3	Stripper plate	20	11.4	1.96e8	9.26	1.48e7
4	Guide pillar	Ø 22 X 184	7.68	3.17e6	8.02	2.63e8
5	Blanking punch	69.88 X 55 X 29.88	2.51	4.69e8	1.75	6.54e7
6	Oblong punch	55 X 21 X 6	8.43	1.37e9	7.57	2.89e8
7	Piercing punch	Ø 8 X 55	2.98	4.87e8	3.15	3.50e8
8	Bottom plate	326 X 256 X 52	4.06	3.13e8	5.26	4.37e7

8. CONCLUSION

The individual components of progressive tool were modelled in Pro-Engineer 4.0. Each individual file was imported to Ansys12.0 software through Initial Graphics Exchange Specification (IGES) format. The following conclusions were made.

1. The results obtained through analysis are approximately nearer to the theoretical values. This demonstrates that the analysis carried out was correct.

2. It is also observed that the design of progressive tool is safe as all the stress values were less than the allowable stress of the material.

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