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Design of a Combination Tool

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Abstract: ***The undertaken project work involves design, analysis and manufacture of a COMBINATION TOOL to produce TABLE TOP NAME CARD HOLDER. The main advantage of this combination tool is it can be accommodated with different operations in one single stage. This will reduce the complexity of the design of the tool. As the number of stages increases the design complexity also increases. Therefore usage of this tool will reduces the manufacturing and the design complexity and make the things easy. The combination tool performs both cutting and non-cutting operations. It can be done in the following way- The piercing, notching, lancing & bending operations are performed in the first stage, and then the blank is kept in the inverted position in the second stage where another bending is carried out. The relative positions with the previously pierced holes are maintained during the bending operation, with locating pins.***

Keywords**:** ***combination tool, piercing, bending, notching, lancing***

I. INTRODUCTION

PROJECT BACKGROUND

The project mainly involves the design and manufacturing of Combination tool. The main contribution of the work is to achieve dimensional accuracy of the component with robust design and optimum production. The combination tool performs both cutting and non-cutting operations in a single stroke

OBJECTIVE OF PROJECT WORK

• To provide an organized, disciplined approach for product and process design, verification, validation and change maintenance.

• To provide simple, easy to operate tool for improve efficiency and also to produce parts consistently with the required precision.

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SCOPE OF THE PROJECT:

Scope of this project focuses on manufacturing of **COMBINATION TOOL FOR TABLE TOP NAME CARD HOLDER**.

- Carry out the literature survey related to combination tool.
- Exposure to modern techniques of manufacturing.
- Methods comprising of precision machining like tolerances.
- To study about the property of the component material.
- surface grinding, cylindrical grinding, wire EDM, etc.
- Knowing the various methods of the inspection tool parts and components.
- Developing the knowledge about the various fits and
- Exposure to tryout of tools and suggesting necessary correction of tools.

Methodology of the Work:

Methodology adapted in the work is briefly explained in the following steps,

• The first step is to decide the component to be made by the tool, once the concept of component design is over based on which the concept of tool design is made, make sure that the tool design concept should be functional, manufacturable, maintainable & the tool should be consistently produce the required target without fail.

• Design of the tool, the design work which mainly involves the detailed part drawings of the Tool as per the required dimensional accuracy and tolerances. The design has been done with the help of design software AutoCAD.

• The tool is modelled by using solid works software and parts of the tool are analysed by using ANSYS analysis software.

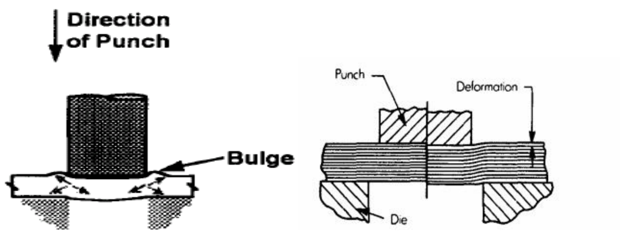
• The Tool manufacturing involves all the practical applications such as machining of the raw materials to the required size and shape as per the design dimensional accuracy and tolerances. The manufactured components will be assembled and subjected to inspection.

• Once the assembly is verified, tryout will be done. The manufactured component will be verified for dimensional accuracy. If the dimensions are not up to the required accuracy then the rework or modification of the Tool has to be done which involves the secondary operations and again the tryout will be carried out. If the tryout component achieves the required dimensional accuracy and tolerances the Tool will be set for mass production and the required maintenance work will be done frequently.

II. SHEARING THEORY

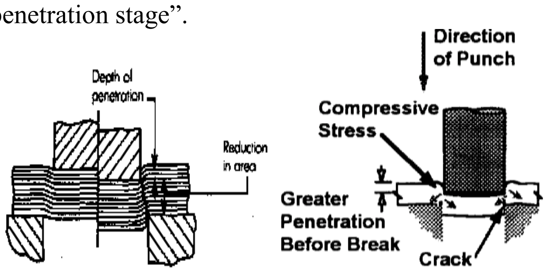
Critical stages in shearing
1. Plastic deformation.
2. Penetration.
3. Fracture.

1. Plastic deformation: The pressure applied by the punch on the stock material tends to deform it into the die opening when the elastic limit is exceeded by further loading, a portion of the material will be forced into the die opening in the form of an embossed on the bottom surface of the workpiece and it will result in a corresponding deformation on its top surface. This stage will induce a radius on the bottom edge of the work piece which is punched. This is called the stage of "plastic deformation". The force exerted by the punch on the stock material tends to deform it into the die opening when the elastic limit is exceeded by further loading, a portion of the material will be forced into the die opening in the form of a die on the bottom face of the workpiece and will lead to a corresponding depression on its top surface. This stage implies a radius of certain angle on the bottom edge of the punched out stock material. This is called the stage of "plastic deformation".



2. Penetration stage:

As the load is further increased, the punch will penetrate the material to a certain depth and force an equally thick portion of metal into the die. This stage imparts a bright polished finish on both the strip and the blank or slug. This is "penetration stage".



3. Fracture stage: In this stage, fracture will starts from both upper and lower cutting edges. As the punch travels further, these fractures will extend towards each other and eventually meet, causing complete separation. This will be resulted in a fractured edge. This is the "fracture stage".

4. Bending

Bending is a forming operation in which the sheet metal is stressed above yield stress and below ultimate stress so that material gets permanent deformation, especially in bending a secondary plane is created at an angle to the original plane by straining the material in a straight line.

When the bending forces cause the elastic limit of the material to be exceeded, the neutral plane moves towards the inner surface at a distance of 1/3 to 1/2 the thickness of the material. This is because the material under compression resists bulging much more than the material under tension resists stretching, and therefore the greatest amount of plastic flow takes place on the tension side of the bend.

III. PARTS OF A COMBINATION TOOL

1. Top plate: It is a soft plate, made out of **MS (St-42),** which will be more in overall size compared to all other plates except bottom plate. This plate is clamped to top unit of the press tool for the purpose of loading on the press. It should be thick enough to prevent bending; Tool shank is screwed into this plate.

2. Backup plate or Thrust plate It is made up of case hardened steel or **OHNS** material, hardened and tempered to **55-58 HRc**. If it is made of case hardening steel the depth of case carburizing must be between **0.8 to 1.3 mm**. While performing the cutting operation the punch exerts upward thrust, tries to make an indentation in the top plate, resulting in the punches level variation.

Hence punch should be backed by a hardened plate to prevent it from digging in the top plate. This plate is also called punch retainer plate for the reason that it retains the punch in the position during the operation.

3. Punch holder plate It is made up of **MS (St-42)** and will be in soft condition. The punch is usually inserted with a light key fit **(H7/k6).** Some times to prevent the profiled punches from rotating, a key or a dowel are to be provided in the punch holder.

4. Stripper plate It is made with **MS (St-42)** material. Usually it is kept in soft condition, but in certain tools made with **OHNS** hardened and tempered to **55-58 HRc**. The actual objective of this plate is to strip out the material from the punches during each stroke. In addition, the stripper will also be used to guide the punches and also hold the strip to a horizontal position and tight, while the strip gone under some work. It may also guide the stock strip some times. Strippers can be classified into 2 groups:

- Fixed strippers
- Traveling strippers

5. Die plate Die plate is a female part in a tool, made up of **HCHCr** material for cutting operation, hardened and tempered to **60-62 HRc**. For non-cutting operation **OHNS** material is used, hardened and tempered to **55-58 HRc**. It provides external shape to the component.

6. Bottom plate it is also called as Die shoe or Bolster plate. It is made out of either MS or Cast iron and is kept in soft condition. The bottom plate gives a temporary gain in lift to the dies and also provides sufficient room for the tool to be held to the press bed. There may be openings in the bottom plate which allows the blank to fall off from the tool.

7. Punches Punch is a male member of press tool made with HCHCr material. It is hardened and tempered to **60-62 HRc**. For non-cutting operation **OHNS** material is used, hardened and tempered to **55-58 HRc**. These punches are either fixed directly to the top plate or inserted in the punch holder with a light tap or force fit **(H7/m6).**

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It provides internal shape to the component innon-cutting operations like Bending, Forming, Drawing etc.,
These Punches can be differentiated into three types.

• Cutting punches
• Non cutting punches
• Hybrid punches

Cutting punches shears the material and the material strained beyond Ultimate tensile stress so that material get physically separated from the parent material. These punches will be reflect the hole size and shape of the component.

punches Non cutting strains the material beyond yield stress and less than ultimate stress so the material gets desired size and shape without rupture.

Hybrid punches performs both cutting and non-cutting operations in a sigle stroke of operation. For example in a lancing operation the lancing punch makes three sides cutting and one side is bending.

8. Guide pins or Guide pillars These are made of **17 Mn1Cr95** material and case hardened up to **58-60 HRc.**

- Guide pins are precision-ground pins which are slide fitted **(H7/h6)** into accurately reamed holes in the die plate.
- They align punch & die components with the high degree of accuracy.
- Guide pins are chromium plated to provide high degree of accuracy of resistance to wearing.
- The addition of chromium reduces wearing up to 50%.
- The guide pins are key fitted into the punch holder plate.

9. Sleeve The sleeve is a cylindrical tube, the limit bolts are positioned inside of the sleeves and the top half plates slides over on its external cylindrical surface. The length of the sleeve determines the gap between the stripper plate and punch holder plate in open condition. The length of the sleeve should be selected such a way that the punches should be inside the stripper plate 4 to 5mm.The sleeve is made up of wear resistant material.

10. Die springs Die spring are made up of alloy steels, which are used in conjunction with the travelling stripper. The compression force of the spring utilized to hold and strip the blank during the operation.

11. Shank It is made up of **MS**. The tool is located and clamped to the press ram by holding the shank firmly in the ram bore. Shank for a particular tool depends on the diameter of the bore in the press ram on which it is intended to mount. Shanks are standardized to suit different types of presses.

12. Dowels Dowels are case hardened and cylindrical ground standard pins used to align different parts of the press tool. These are readily available in standard diameter and length.

13. Screws Screws are used to hold the tool parts together firmly and temporarily. The socket head cap screw is the most popular fastener used in tools. This hardened tool steel screw, often referred to as an Allen head screw, offers superior holding power and strength.

14. Washers Washers will exert uniform pressure over the sleeves while tightening of the limiting bolts during the assembly of the tool.

OPERATIONS INVOLVED

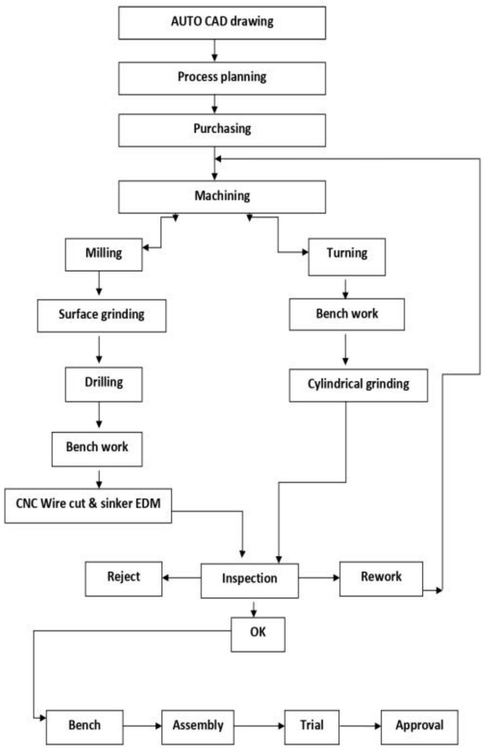
Piercing This operation involves the punching on the workpiece

Lancing Lancing is the process of shearing an interior portion of the blank so that three sides are cutting and the other side bending.

Notching Notching is a shearing process, removes a portion of metal from the side of a strip.

Bending Bending is a forming operation where a secondary plane is created at an angle to the original plane by straining the material in a straight line.

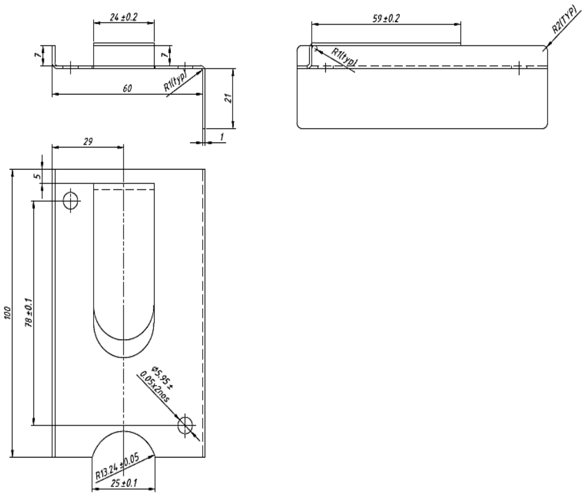
IV. FLOW CHART:



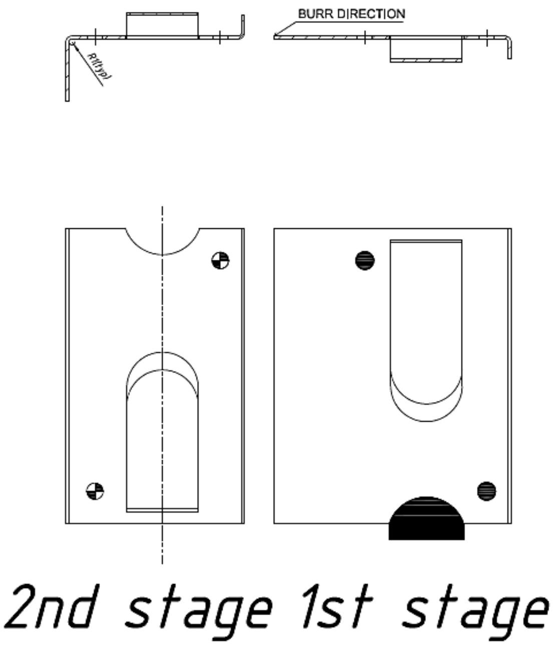
V. COMPONENT AND TOOL DESIGN

COMPONENT DETAILS:

name : Table top name card holder
material : Aluminum
thickeness : 1mm
tensile strength :15.6Kgf/mm^2
shear strength : 13Kgf/mm^2
type of tool : Combination tool



STRIP LAYOUT



VI. SEQUENCE OF OPERATIONS

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- **STEP 1** : The blank is located at the first stage by the Dowel pins which are inserted at the top of the die plate.
- **STEP 2** : In the Strip lay out shown the finished piece part is produced when the Blank passes through two stages
- **STEP 3** : During the first stroke of the press ram two holes are pierced by the two piercing punches, one notching, one lancing, one bending operation is performed by the corresponding punches. After starting of the cutting operations only bending operation starts, the cutting punches will prevent the dragging of the blank during bending operation.
- **STEP 4** : Before starting of the second stage operation the blank is removed from the first stage and locate the blank in inverted position in second stage, by using dowel pins, the two pierced holes will be used to locate the blank at the second stage of operation.
- **STEP 5** : To accommodate the bending portion of the blank due to the first bending operation in the first stage and the cut out projected portion because of lancing operation in the first stage, cut out reliefs are provided in the stripper plate.
- **STEP 6** : In the second stage the second bending operation is carried out.

VII. DESIGN CALCULATIONS

Design is a key for manufacturing of a mold or tool. Without design a mold or tool cannot be manufactured. So, I made key first.

CUTTING CLEARANCE PER SIDE

Cutting clearance is the intentional gap provided between the sides of a punch and Die.

Cutting clearance (c_c) = C x S x $\sqrt{}$ (T_{MAX} / 10)

where

C = Constant = 0.01

S = Sheet Thickness = 1mm

T_{MAX} = Shear Strength = 130N/mm^2

$C_c = 0.01 \times 1 \times \sqrt{\frac{280}{10}}$

= 0.03mm/side

Cutting force

Cutting force is which has to act on the stock material in order to cut the blank or slug. This determines the capacity of the press to be used for particular tool.

Cutting Force (Fc) = L x S x T_{MAX}

where,

L = Total Cut Length = 207.31mm

S = Sheet Thickness =1mm

T_{MAX} = Shear Strength

F_c = 207.31x 1 x 130

= 26950.3N;

Bending force

It is the force required to bend the edges of the blank, and also the bending associated in the lancing operation.

Bending Force $F_B = \frac{0.33\, Su\, W\, t^2}{L}$

Where, W = Width of Stock Material

L = Span = Die Radius + Punch Radius + C

C = Die Clearance

T = Sheet Thickness

Su = Ultimate Tensile Strength (Kg/mm^2)

Pad Force $F_P = 0.5\, F_B$

Total load required $F_N = F_B + F_P$= 1.5

Load required for one bending F_B=0.33×15.6×100×1^2/1+2 = 129.54 kgf

Load required for two bending operations = 2×129.54 = 259.08 kgf

Total Load required for two bending operations= 1.5x259.08 = 388.62kgf

Force required to one side bending in lancing operation

$F_B = 0.33 \times 15.6 \times 24 \times 1^2/1+2+1$
= 30.88 kgf
Total Bending load = 419.5 kgf or 4195N

Stripping force
Stripping force is the force required to strip the blank from the punches. It is the sum of the cutting force and the stripping force. It is normally expressed in tons.
Stripping force = 10-20% of cutting force
Consider 20% of cutting force

$$\text{Stripping force} = \frac{20 \times 26950.3}{100}$$
= 5390.06 N

Press force
It is the sum of the cutting force, Bending force and the stripping force.
Press Force = Cutting Force+ bending force+ Stripping Force
= 26950.3 + 4195 + 5390.06
= 36535.36 N

Press tonnage
Press tonnage = 1.3 x press force
= 1.3 x 36535.36
= 47495.96 N
Press tonnage ~ 5 tons

Thickness of die plate (Td)

$$\text{Thickness of die plate} = \sqrt[3]{Press\ force}$$
$$= \sqrt[3]{3653.536}$$
$$\approx 16\ mm$$

But based upon the width of bend required the thickness can be taken as 28 mm

∴ Thickness of die plate = 28 mm

Thickness of bottom plate
Thickness of bottom plate = $2xT_d$
= 2x16
=32mm

Thickness of top plate
Thickness of top plate= $1.5xT_d$
= 1.5x16
= 24 mm.
But based upon the stroke length and thickness of washer the thickness of Top plate
Can be taken as 32 mm

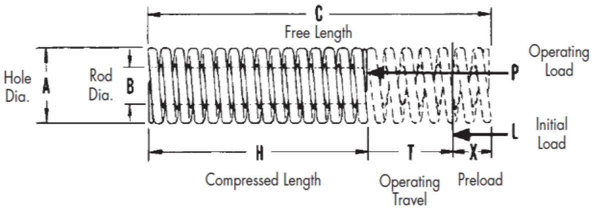
∴ Thickness of top plate = 28 mm

) Thickness of thrust plate
Thickness of thrust plate = 8 mm

Thickness of punch holder plate
Thickness of punch holder plate= 0.75x16
= 12 mm

Thickness of stripper plate
Thickness of stripper plate = 0.75x16
= 12 mm

Spring selection



Stripping and blank holding force = 6.685 KN
Pre compression= 1 mm
Stripper stroke= 8 mm
Number of springs selected = 4
Force per spring= 6685/4
= 1671.25 N/spring
Using the above data, selected a Compression Spring
20 mm = Hole diameter of spring, D_h
14 mm = Rod diameter of spring, D_d
3 mm = coil diameter of spring D
30 mm = Free length of spring, L_o
The actual force from the spring is more than the required stripping and blank holding force, so the springs are used in design.
Die sprigs are specified by using Hole diameter, Rod diameter and free length of Spring

Spring Back
Over bending is the simplest way to correct spring back. So instead of making straight bending vertical surface on die plate, 1^0 slope is provided.

Tool shut height
The tool shut height is the distance between the top surfaces of the top plate to the bottom surface of the bottom plate when tool is in closed condition.
Shut height of tool = 154 mm

Press shut height
It is the distance between the surfaces of the bolster (bed surface) to the top die mounting surface.
Minimum shut height of tool = 230mm

Center of Pressure
Center of pressure is the position, where all the forces related to the operations are concentrated. This is the exact position where shank is to be fixed.
Resultant force of all partial cutting force can found out applying the MOMENT'S method
Centre point for shank on 'X' & 'Y' coordinates

$$X = \frac{(X1 \times L1) + (X2 \times L2) + (X3 \times L3) + \cdots\ldots}{L1 + L2 + L3 + \cdots\ldots}$$

$$Y = \frac{(Y1 \times L1) + (Y2 \times L2) + (Y3 \times L3) + \cdots\ldots}{L1 + L2 + L3 + \cdots\ldots}$$

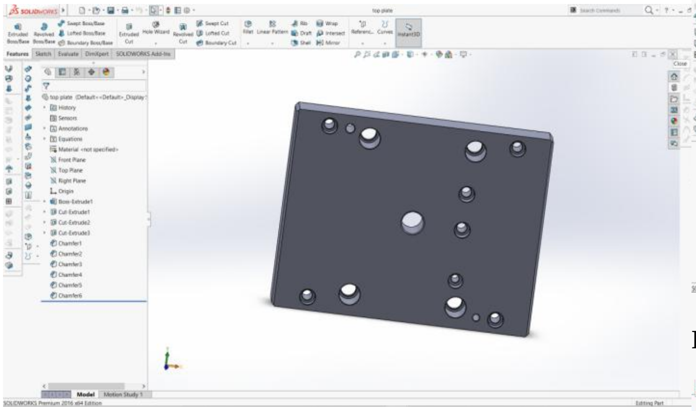
$$X = \frac{(18.84 \times 101) + (60 \times 121) + (33.04 \times 121) + (37.69 \times 121) + (96 \times 121) + (18.84 \times 142)}{18.84 + 60 + 33.04 + 37.69 + 196 + 18.84}$$
= 87.84 mm

$$Y = \frac{(18.84 \times 126) + (60 \times 35) + (33.04 \times 42) + (37.69 \times 78) + (96 \times 108) + (18.84 \times 48)}{364.41}$$
= 55.08 mm
Center of Pressure (X, Y) = (87.84, 55.08)

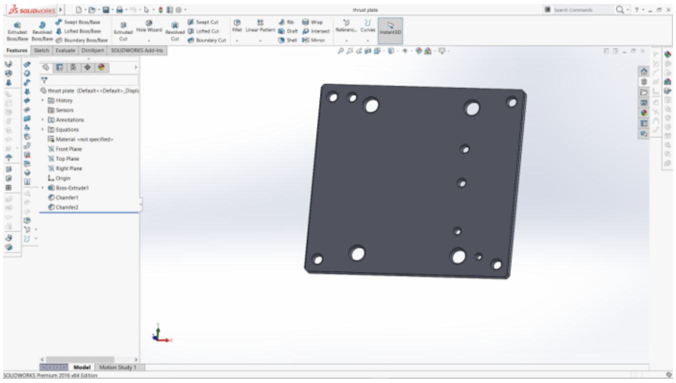
VIII. DESIGN AND ANALYSIS

MODELING OF PARTS:

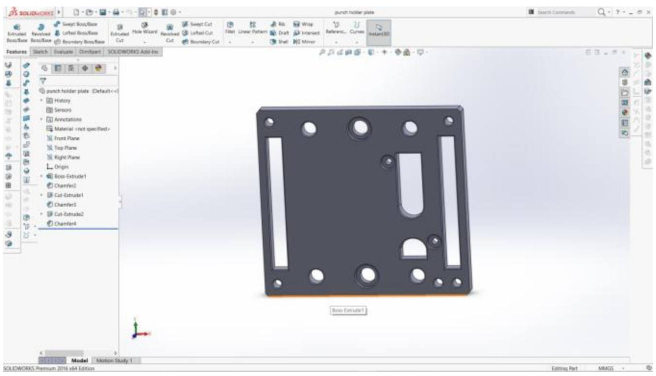
1.Top plate



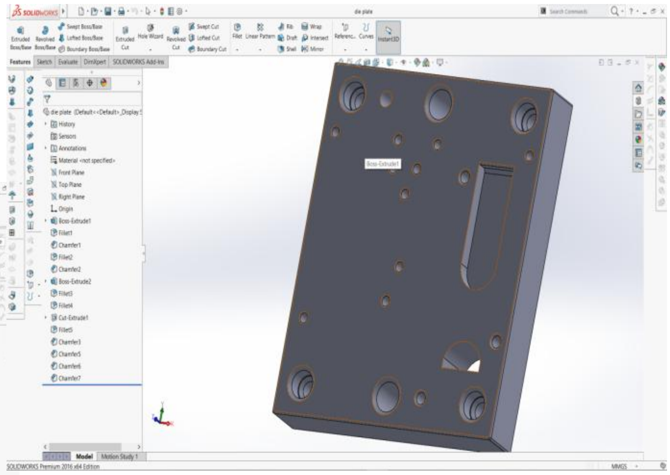
Thrust plate:



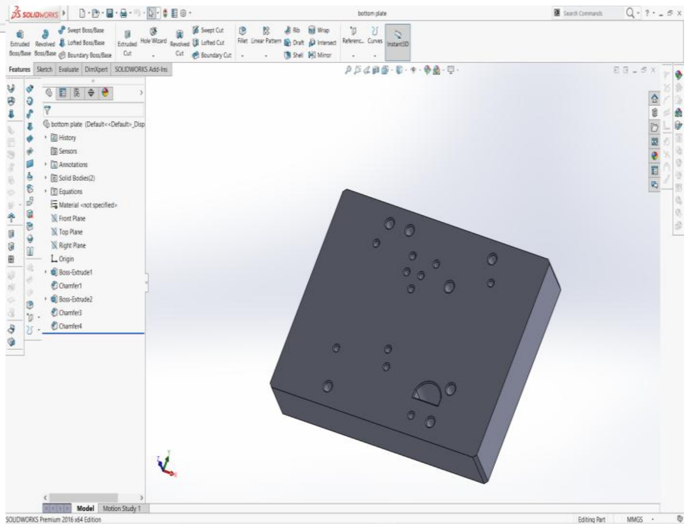
Punch holder Plate



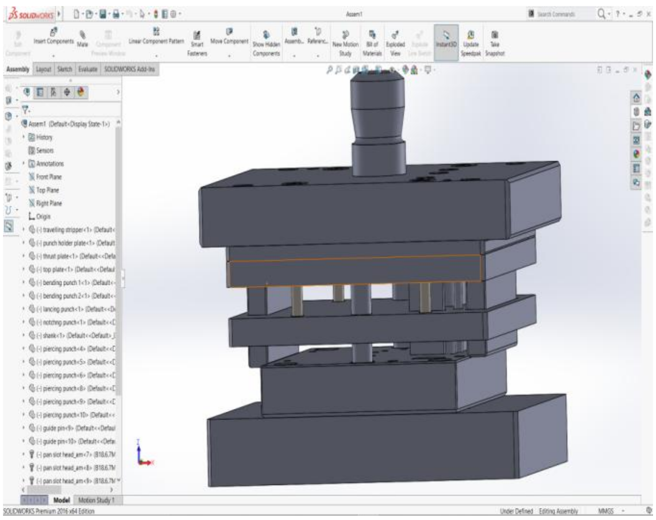
Travelling Stripper Plate



Bottom Plate:



Assemble Model of Compound Tool



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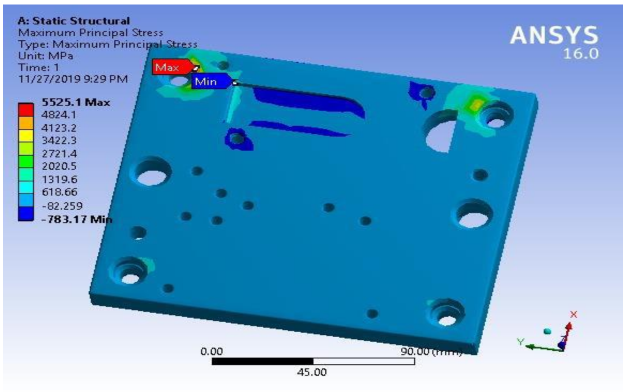
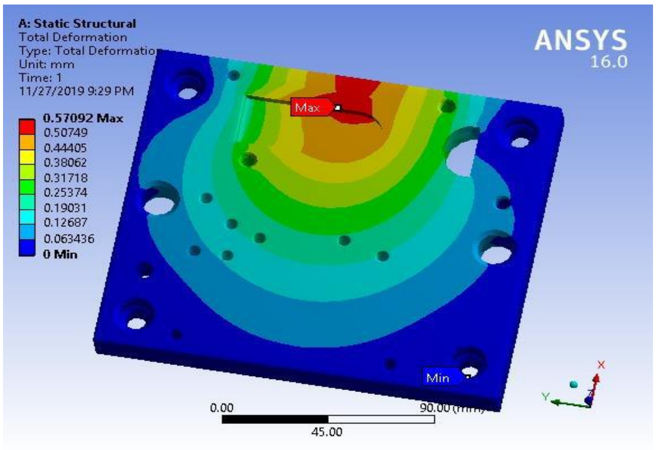
ANALYSIS ON DIE PLATE:





COMPONENT AND TOOL IMAGES

IX. CONCLUSION

Hence the designed combination tool can be able to perform different operation required for producing the component in one single stage.The design and analysis of a combination tool for a designed component has validated by using software tool ANSYS. The tool was manufactured and tryout was done and trail run production was made, the quality of the component inspected which is within specified limits, now the Tool is ready for mass production of the given component.

RESULTS WITH EXPLINATION

S.No	Parameter	Formulae	Result	Explanation
1	Cutting Clearance	Cutting clearance (c_c) = C x S x √ (T_{MAX} / 10)	0.03mm/Side	Optimum cutting clearance with smoothly blended top edge with one third cut band and low burr
2	Cutting force	Cutting Force (Fc) = L x S x T_{MAX}	26950.3N;	Force required for shearing operations on the sheet
3	Bending Force	Bending Force F_B $= \frac{0.33\, Su\, W\, t^2}{L}$	4195N	Force required for forming operations on the sheet metal blank.
4	Stripping force	Stripping force $= \frac{20 \times 26950.3}{100}$	5390.06 N	Stripping force is the force required to strip the blank from the punches. Stripping force = 10-20% of cutting force
5	Press force	Press Force = Cutting Force+ bending force+ Stripping Force	36535.36 N	It is the sum of the cutting force, Bending force and the stripping force.
3	Press Tonnage	Press tonnage = 1.3 x press force	47495.96 N	The tonnage of force required to perform the operations on the sheet metal by the Ram of Press.
4	Thickness of Die plate	Thickness of die plate = $\sqrt[3]{Press\ force}$	$\approx 16\ mm$	Die plate is a female part in a tool, It provides external shape to the component. But based upon the width of bend required the thickness can be taken as 28 mm ∴ Thickness of die plate = 28 mm
5	Thickness of bottom plate	Thickness of bottom plate = 2xT_d	32mm	The bottom plate gives cushioning effect to the dies as well as provides enough room for the tool to be clamped to the press bed. There may be openings in the bottom plate which allows the blank or slug to clear off from the tool.
6	Thickness of top plate	Thickness of top plate= 1.5xT_d	24 mm	This plate is clamped to top unit of the press tool for the purpose of loading on the press. It should be thick enough to prevent bending; Tool shank is screwed into this plate.
7	Thickness of thrust plate	Thickness of thrust plate = 8 mm	8 mm	It is made up of case hardened steel, While performing the cutting operation the punch exerts upward thrust, tries to make an indentation in the top plate, resulting in the punches level variation.
8	Thickness of punch holder plate	Thickness of punch holder plate= 0.75xT_d	12 mm	It is made up of **MS (St-42)** and will be in soft condition. The punch is usually inserted with a light key fit **(H7/k6).**

9	Thickness of stripper plate	Thickness of stripper plate=$0.75 \times T_s$	12 mm	function of the stripper plate is to strip the stock material from the punches after each stroke, the stripper may act as a guide for the punches and also hold the strip flat and tight, while the strip is being worked on
10	Selection of Spring	Stripping and blank holding force = 6.685 KN Pre compression= 1 mm Stripper stroke= 8 mm Number of springs selected = 4 Force per spring= 6685/4 = 1671.25 N/spring 	Using the above data, selected a Compression Spring 20 mm = Hole diameter of spring, D_h 14 mm = Rod diameter of spring, D_d 3 mm = coil diameter of spring D 30 mm = Free length of spring, L_o	The actual force from the spring is more than the required stripping and blank holding force, so the springs are used in design.
11	Spring back	Over bending the component than required	1^0	Over bending is the simplest way to correct spring back. So instead of making straight bending vertical surface on die plate
12	Tool shut height	The distance between top plate to bottom plate when tool is in closed condition.	154 mm	The tool shut height is the distance between the top surfaces of the top plate to the bottom surface of the bottom plate when tool is in closed condition.
13	Press shut height	It is the distance between the surfaces of the bolster (bed surface) to the top die mounting surface	230mm	
14	Centre of pressure	$X = \frac{(X1 \times L1)+(X2 \times L2)+(X3 \times L3)}{L1+L2+L3+\cdots}$ $Y = \frac{(Y1 \times L1)+(Y2 \times L2)+(Y3 \times L3)}{L1+L2+L3+\cdots}$	X= 87.84 mm Y= 55.08 mm	Center of pressure is the position, where all the forces related to the operations are concentrated. This is the exact position where shank is to be fixed
15	Analysis on Die plate	Total applied load is 5,490.4 KN	Total deformation: 0.57092 mm (max) Max shear stress: 3953 Mpa Max principle stress: 5525.1 Mpa	Hence the induced stresses are in a permissible limit and the design is also safe.

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