Overview of Forming Process for Sheet Metal Bracket, Tool Analysis & Effect of Tool Wear

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ABSTRACT

Sheet metal forming process is a group of numerous methods to form a certain part. The main two groups of machining are 1) Shearing (cutting) and 2) Forming. Shearing process has further classification as punching, blanking, notching, etc; Forming processes include bending, flanging, and other processes with no metal cutting but to deform in desired shapes. In manufacturing of the bracket discussed below, processes include shearing, blanking, punching, bending and plating. The main components apart from the raw material that is to be formed are a power press tool attached to a power press. The tool is made to satisfy the geometric structure required on the part. The tool shape is made as per requirement and forms the part accordingly. The power press on the other hand is a machine made to release huge force onto the tool by means of mechanical, pneumatic or hydraulic mechanism. This paper is a brief overview of sheet metal forming process for a bracket along with the press tool calculations and effect of tool wear on the part and tool itself. A short analysis is also covered in this paper with help of Finite Element Analysis. AUTODESK INVENTOR 2017 is used for the FEA Analysis.

Keyword: - *Sheet metal, cold forming, process flow, Tool Wear, FEA Analysis.*

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1. INTRODUCTION

Sheet metal forming is one of the building blocks of almost every manufacturing industry. Automobile, aerospace, airplane, electric and various machineries are some major industries that need sheet metal formed parts. Various parts in automobile and aerospace industries are made of sheet metal as they are light weight and strong. In sheet metal forming there are numerous processes like stamping, blanking, punching, embossing, bending, shearing, notching, piercing, lancing, etc. in this paper, some processes are discussed which are used to manufacture a sheet metal bracket

1.1 Bracket

The bracket is intended to hold two parts and has two holes to bolt the parts together. The bracket is made of Cold Rolled Close Annealed (CRCA) Sheet of Grade – D as per IS: 513. The material properties are as follows:-

- Yield stress (MPa) = 240
- Tensile stress (MPa) = 370
- Chemical composition (%) are: Carbon = 0.12, Manganese = 0.50, Sulphur = 0.035, Phosphorus = 0.040

AutoCAD Drawing of the bracket is provided by “Panchashil Industries Pvt Ltd, Nashik”.

2. PROCESS FLOW

The process of sheet metal forming starts with the designing of power press tools to make the desired parts. Then the tools are manufactured and procurement of the raw material sheets is done. The materials for manufacturing tools are D2 for die plate and punch, MS for punch holder, stripper plate, punch back plate, top and bottom plate. The material for part is generally Cold Rolled Steel, Hot Rolled Steel, Copper, Brass, and Stainless Steel. The general size of these sheets is **2500*1250*2 mm**. After the material is available; it is cut into pieces with a shearing machine as per the strip layout. After this, the strips are cut into blanks on a power press with its own separate die tool. These blanks are then punched by another die tool on power press and thus the holes are punched. Bending of the bracket is done on a V-Block die in a right angle. At last the parts are plated with required material and the process is finished.

2.1 Incoming Sheets

The sheets come pre cut in standard size of **2500*1250*2 mm**. the sheet is **CRCA Sheet of Grade – D as per IS: 513**. The sheets are inspected upon arrival with micrometer gauge for thickness. To utilize the sheet completely and efficiently, it is sheared into smaller sections as per strip layout.

2.2 Shearing

A shearing machine is used to cut the sheets in smaller parts. For shearing, strip layout is a method to utilize the sheet completely and efficiently. Layout calculation is also done along with the images of the same. Strip is cut in size as **1250*52*2 mm**. the part size is 50 mm and some material is kept on both sides to ensure proper dimensions of blank.

Fig -1: Image of sheared strip

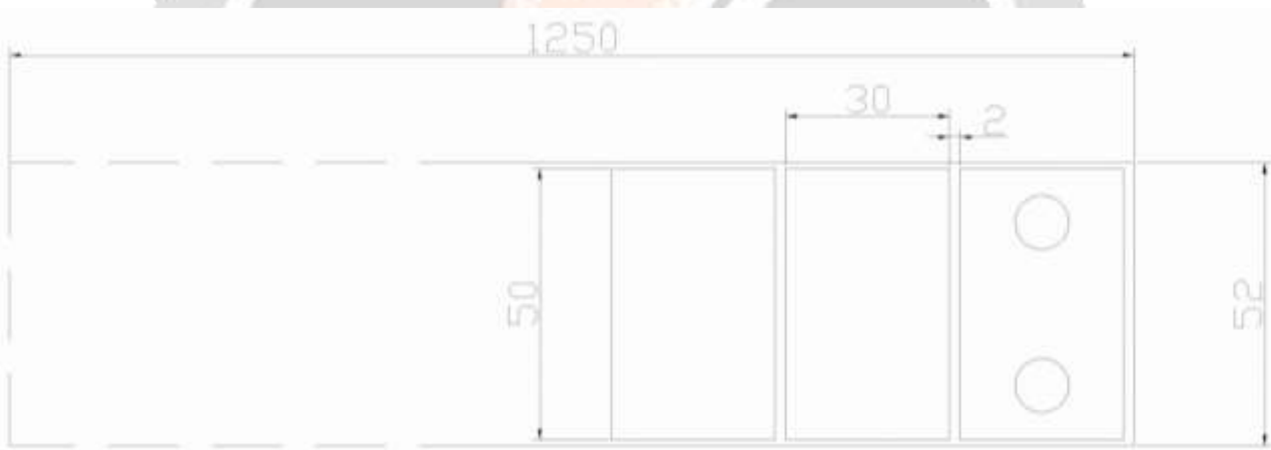

Fig -2: Strip layout

2.2.1 Strip layout calculations

1) Scrap bridge (B):- 1 to 1.25 * (T)

: - 1 * 2 = **<u>2mm</u>**

2) Margin (M): - 1 to 1.5 * (T)

: - 1 * 2 = **<u>2mm</u>**

3) Economy factor: - ((Area of blank * number of rows) / (width of strip * pitch)) * 100

: - ((1500 * 1) / (52 * 32)) * 100

= **<u>90.144%</u>**

2.3 Blanking

Blanking is a process of cutting useful part out of a strip of sheet metal. This is exactly similar to punching in a way, but here the piece coming in direct contact with punch head is the useful piece. For manufacturing the bracket, blank is first cut from strip using a specified press tool. For a simple rectangular shape like this can be cut by two ways, 1) By cutting the rectangle with shearing machine as it is the most simple way to do this , however, then the edges may be slightly out of shape and the burr may be more than usual. 2) By using a blanking die tool and cut it from rest of the sheet, this way the scrap may be more than the first method but the edges are in proper shape and the overall quality is optimum which required in this part. In blanking, blank size is taken slightly less than the requirement as in bending the metal tends to expand a bit. For sheets upto 3mm in thickness, the length is taken upto 3mm less. Here in bracket, the length is taken less than 50mm.

Fig -3: Image of Blanking Tool

Fig -4: Blank

2.3.1 Blanking force calculation

F = T * P * Sut

: - 2 * 160 * 370

= 118400 / 9810

= **12.069 Tons**

FOS = 25% or 0.25

: - 12.069 * 0.25

= **3.017 Tons**

TF = F + FOS

=12.069 + 3.017

=**15.08 Tons**

Thus, at least **20 Ton** capacity press should be used

Where, T = thickness of metal

P = perimeter of cut

Sut = ultimate tensile stress of metal

FOS = factor of safety

2.4 Punching

As mentioned earlier, punching and blanking are exactly similar processes just with a slight difference. In punching the part which comes in direct contact with the punch head is the waste, everything else is required part. There are two holes to be made in the blanked part. This is done by a small punching press tool with a punch diameter of 10mm and die diameter of 10.3mm considering clearance.

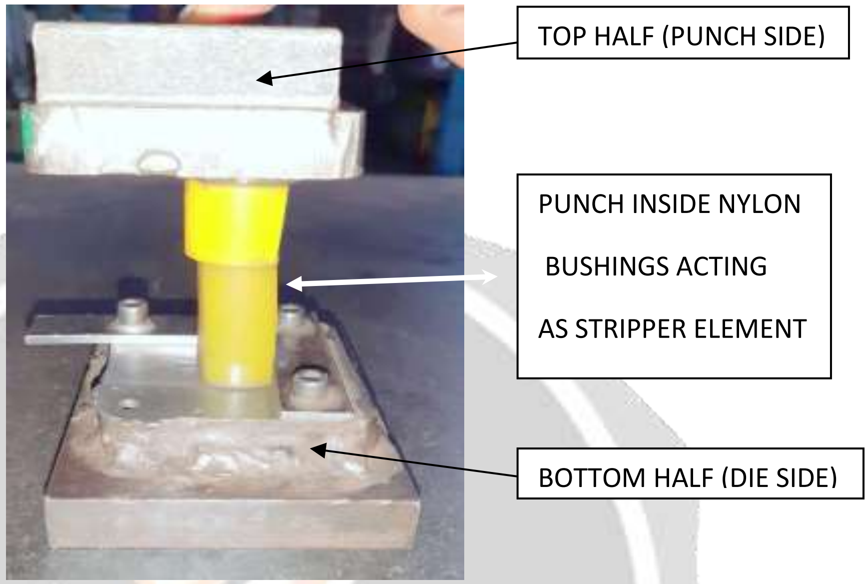

Fig -5: Punching Tool

Fig -6: Step wise procedure of blanking and punching

2.4.1 Punching force calculation

F = T * P * Sut

: - 2 * 31.415 * 370

= 23247.1 / 9810

= **<u>2.369 Tons</u>**

FOS = 25% or 0.25

: - 2.369 * 0.25

= **<u>0.592 Tons</u>**

TF = F + FOS

=2.369 + 0.592

=**<u>2.962 Tons</u>**

Thus, at least **5** Ton capacity press should be used

Where, T = thickness of metal

P = perimeter of cut

Sut = ultimate tensile stress of metal

FOS = factor of safety

2.5 Bending

Bending is a process to deform the sheet in such a way that at least two of its faces are making angularity with each other. This can be done in many ways, by using a progressive die that does all above processes in one stroke or by using a separate tool. Here a V-Block die tool is used that bends the part in a near perfect right angle. It can be done repeatedly for couple of times to get perfect angle.

Fig -7: Bracket after Bending

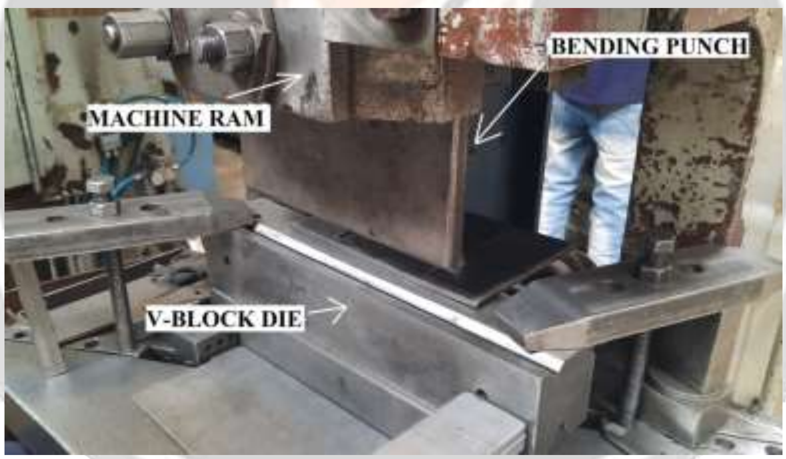

Fig -8: Bending Tool

2.5.1 Bending force calculation

BF = (Kv * Sut * W * T^2)/ (L * 9810)

= (1.33 * 370 * 30 * (2^2))/ (20 * 9810)

= **<u>0.300 Tons</u>**

Thus at least **0.5 Ton** capacity press should be used

Where, Kv = V die opening factor

Sut = ultimate tensile strength

W = width of metal at bend

T = thickness of metal

L = width of die opening

2.6 Plating

Plating is done to improve surface rust resistance and to give the surface a polished look. It is done by applying a layer of alloy by electrolysis process. The bracket is also plated with an alloy and to give a better appearance.

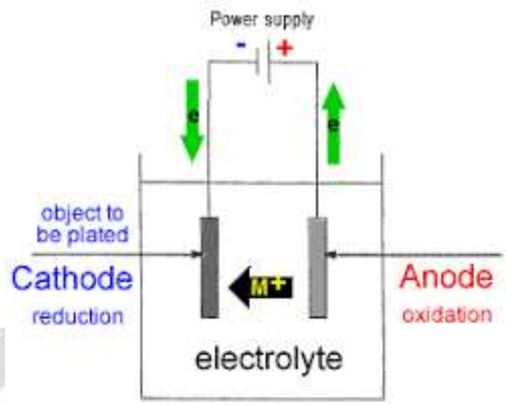

Fig -9: Electrolytic Plating Process [1]

3. ANALYSIS OF PUNCHING TOOL

Analysis is done to predetermine any failure which could cause during actual application. If the tool fails in the analysis, there are necessary precautions that can be made. Effects like tool breakage, tool wear, and deformation can be eliminated or at least minimized. This analysis is done using AUTODESK INVENTOR 2017 software with stress analysis method. Three main parameters were considered in the analysis, Von Mises Stress, 3rd Principle stress and Displacement.

Result Summary [2]

Name	**Minimum**	**Maximum**
Volume	434495 mm^3	
Mass	3.41079 kg	
Von Mises Stress	0 MPa	303.295 MPa
1st Principal Stress	-67.704 MPa	29.6519 MPa
3rd Principal Stress	-332.653 MPa	3.83606 MPa
Displacement	0 mm	0.0723998 mm
Safety Factor	1.15399 ul	15 ul
Stress XX	-102.51 MPa	19.8509 MPa
Stress XY	-78.8217 MPa	91.3288 MPa
Stress XZ	-16.9219 MPa	18.6422 MPa
Stress YY	-325.94 MPa	18.243 MPa
Stress YZ	-76.464 MPa	71.955 MPa
Stress ZZ	-100.522 MPa	20.6407 MPa
X Displacement	-0.00180156 mm	0.00182863 mm
Y Displacement	-0.0000235937 mm	0.0723694 mm
Z Displacement	-0.00216485 mm	0.00173656 mm
Equivalent Strain	0 ul	0.00136075 ul

1st Principal Strain	0 ul	0.00048468 ul
3rd Principal Strain	-0.00157687 ul	0 ul
Strain XX	-0.000143441 ul	0.00043392 ul
Strain XY	-0.0005084 ul	0.000589071 ul
Strain XZ	-0.000109146 ul	0.000120242 ul
Strain YY	-0.00153357 ul	0.000113018 ul
Strain YZ	-0.000493193 ul	0.00046411 ul
Strain ZZ	-0.0000990622 ul	0.000439289 ul
Contact Pressure	0 MPa	130.32 MPa
Contact Pressure X	-73.7142 MPa	74.8389 MPa
Contact Pressure Y	-44.0842 MPa	106.072 MPa
Contact Pressure Z	-63.9346 MPa	63.3916 MPa

4. EFFECT OF TOOL WEAR

Even if the tool is perfectly safe in analysis, the tool can still wear out by frequent use. This not only affects the tool, but also the part being formed. Main reason for tool wear is friction of tool with punch, inappropriate positioning of tool, or incorrect forming force.

4.1. On bracket

BURR

Burr is the excessive, leftover material on forming edges of part. It is highly undesirable as it reduces the quality of part. Burr can form with influence of following factors:-

- Inappropriate clearance between punch and die
- Wear on tool edge
- Inappropriate forming force

On bracket, following defects were found.

Fig -10: Heavy Burr on Bracket after Punching

ROLL OVER EDGE

Roll over edge is the phenomenon of stretching of metal at shearing edges if the metal is ductile or the force is too much. Clearance is the main factor behind the roll over edge and which is influenced by tool wear. Thus indirectly tool wear is the reason of roll over edges in shearing, blanking, punching and other processes where metal is sheared. Following figure shows the stages of punching. Here it can be seen that during the fracture, the metal is stretched and breaks in an angle. This causes the upper layers to move down and cause a roll over. The lower layers also move down along with punch. This causes burr at the other side of sheet.

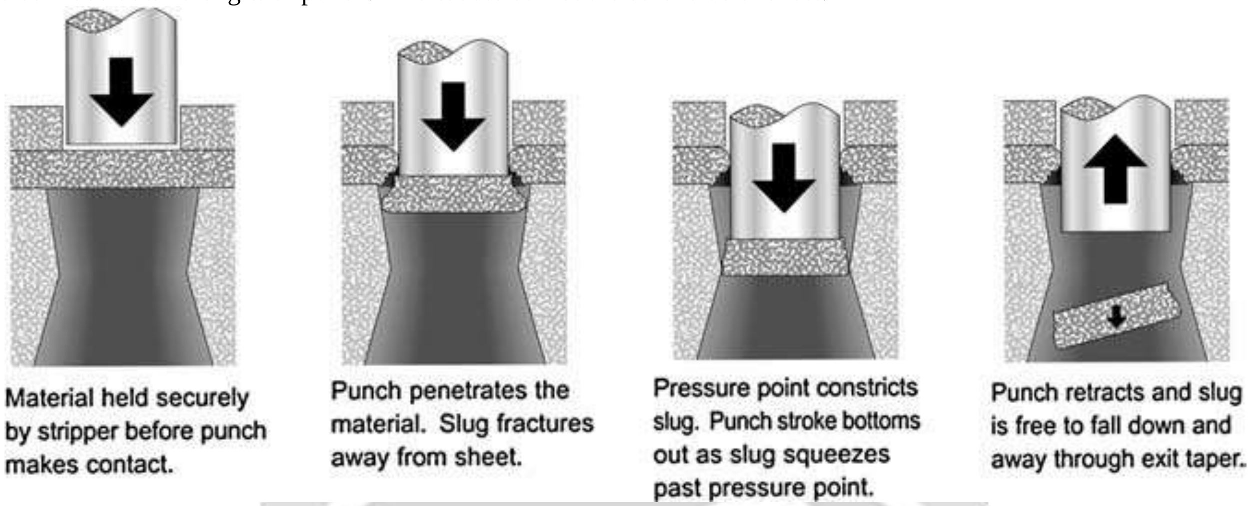

Fig -11: Step wise procedure of punching [3]

Roll over edge was also found in bracket. Following image shows the edge of the punched hole.

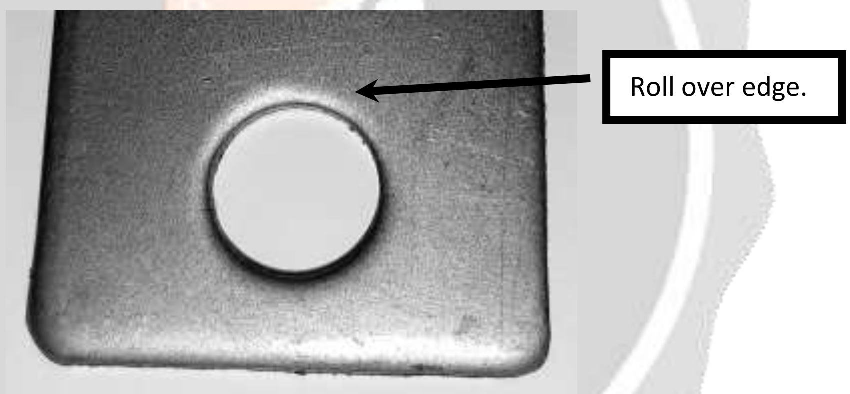

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Fig -12: Roll over edge on Bracket

DISHING AND DOMING

This phenomenon is the effect of roll over edge. The punched part (usually circular parts with small diameter) is deformed into a dish like shape. The overall shape is concave on one side and convex on the other. To eliminate this, the tonnage should be reduced and clearance should be reduced. The material from holes in the bracket shows this phenomenon more accurately.

Fig -13: Dishing and Doming

4.2. On die tool

Tool wear affects the tool edge dramatically. Chipping, breakage, deformation can occur to the tool reducing its life. Tool wear was significantly observed on the punching tool of bracket. Edge was damaged and the only way was to resharpen it. This can be done by grinding the face of punch. Die also gets affected as well. The diameter of die at opening was increased. This leads to increase in clearance. The actual diameter of punch was 10.00mm and after wear it was 9.80mm. Similarly, the diameter of die was 10.3mm which increased to 10.45mm. Thus the clearance increased by 0.65mm instead of 0.3mm.

Fig -14: Wear on Punching Tool

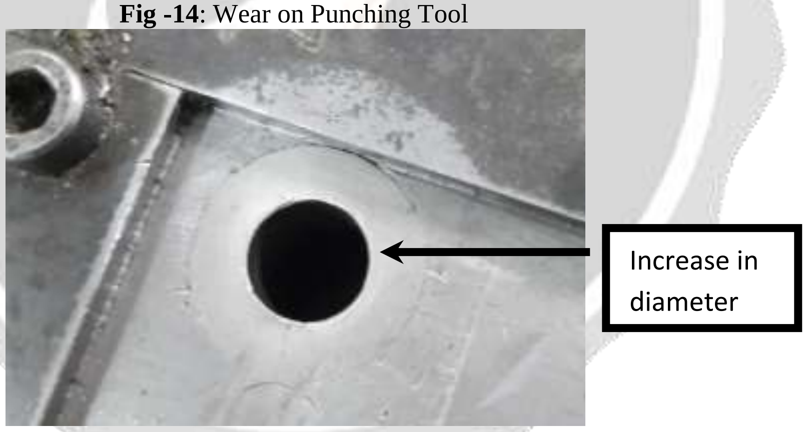

Fig -15: Wear on Punching Die

5. SOLUTION FOR TOOL WEAR

SANDING

Fig -16: Bracket after Sanding

Sanding is the process of smoothing the surface. Sanding disc is used with a sander and the burr is removed. Here, the bracket is sanded before bending and burr is removed.

SHARPENING

The tool is sharpened to regain its ability of smooth cutting operation. The punch and die are subjected to tremendous load and friction which leads to flaking of tool. Tiny microscopic irregularities are the start point for flakes to come off. These flakes mark on the part as well as the tool which leads to more flaking. This reduces the sharpness of the tool and makes it cause more friction. This way the tool gets dull and reduces the part quality. Tool should be grinded properly to sharpen it.

DESIGN CHANGES

This is the final option to counteract against tool wear. If wear is occurring frequently, this means the design is improper and new tool should be made. This can be done also if the tool is beyond repair. Optimum design should be considered to eliminate the wear.

6. CONCLUSION

Above points put a light on general sheet metal forming process flow, analysis of punching tool and also effect of tool wear on part and solutions for it. Considering above solutions can help solve the problem of tool wear.

7. REFERENCES

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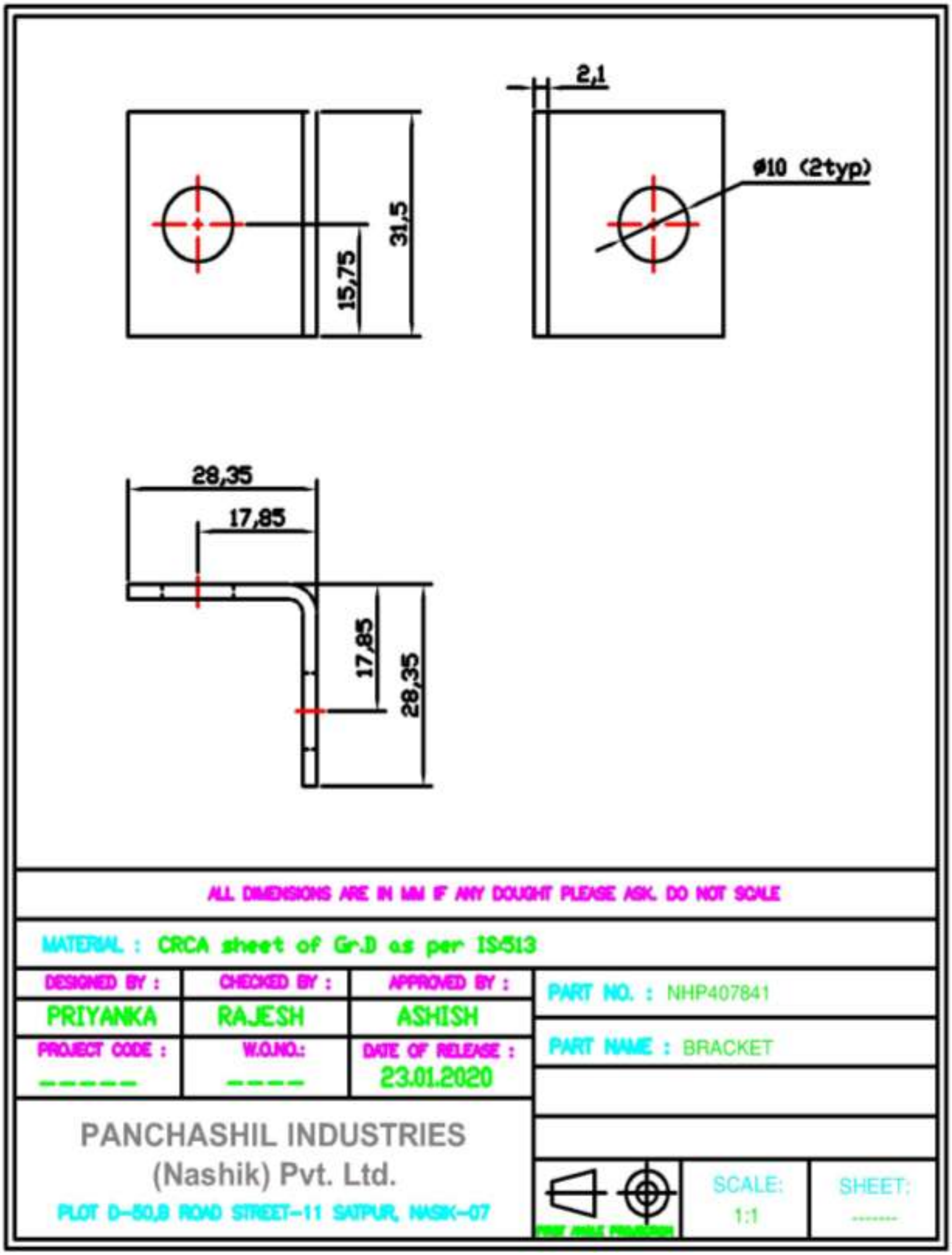

Fig -17: AutoCAD Drawing of Bracket [4]

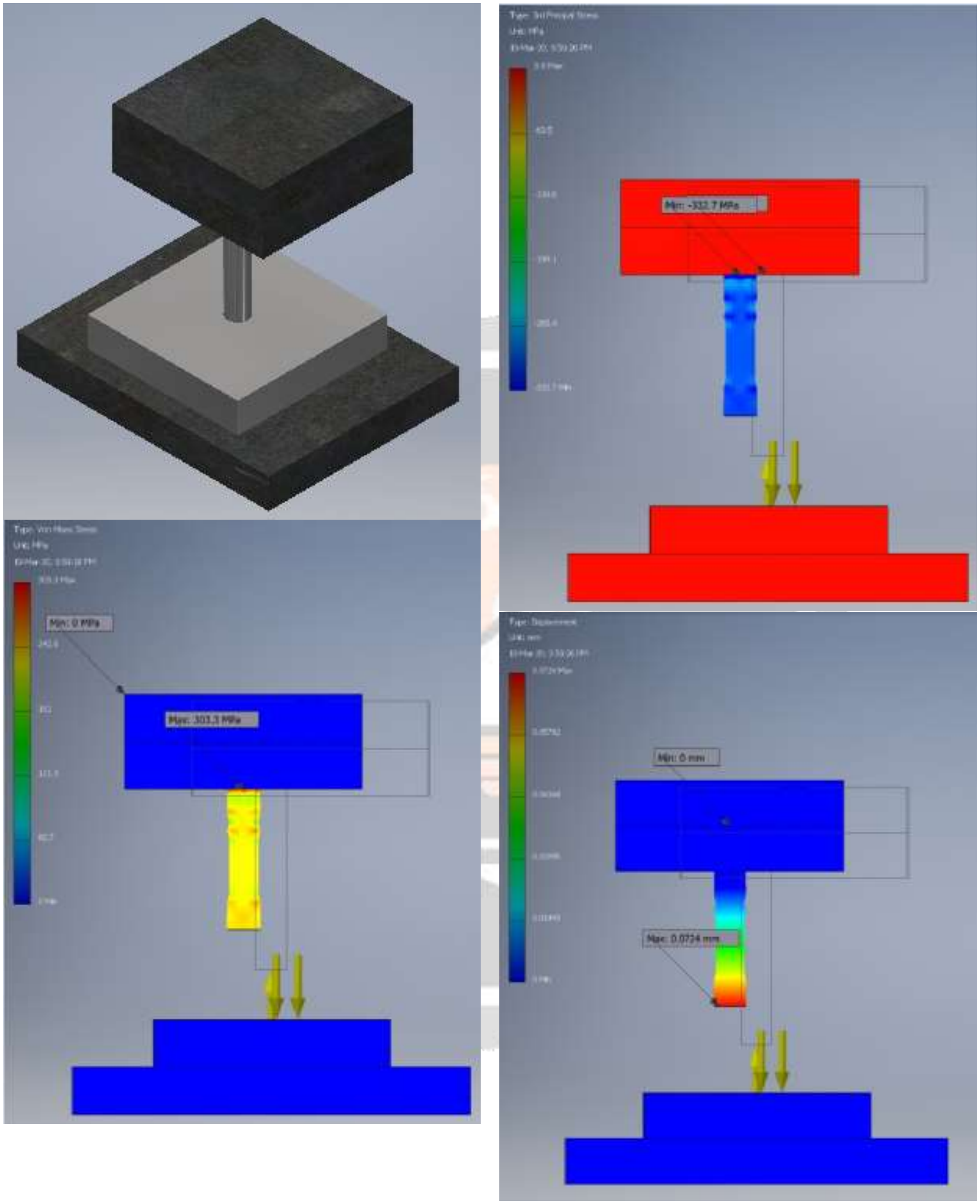

Fig -18: Stress analysis Results [5]