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TASK: **MANUAL SHEARING MACHINE PROJECT**

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Abstract

This report presents the design of a manual shearing machine which is designed to increase the thickness of material it can cut in such a manner that the shearing force is great enough to cut material of width greater than 20mm. The objective of this project was to come up with a shearing machine that improves productivity by reducing labour costs (easy to use), meets client needs for small businesses by providing a design that can be fabricated in a workshop and increases worker safety. This is done by modifying the existing shearing machine by increasing blade angles and also increasing the structural rigidity of the shearing machine. The parts are modelled in Autodesk Inventor and machined using the Inventor CAM plugin. We made considerations in dimension and materials used so that the assembly could be manufactured locally at the machine shop.

Introduction

A shearing machine is a machine that cuts a sheet of metal by reciprocating a linear motion with one blade moving relative to a fixed blade. Shearing is a general name for most sheet metal cutting, but in a specific sense, designates a cut in a straight line across a strip, sheet or bar. This procedure leaves a clean edge on the piece of the metal that is sheared or cut. Shearing machines are used to cut or shear metal sheets in many ways. The particular method chosen depends on several factors such as the size and shape of the parts required and the numbers needed. The moving cutting member of a shearing machine may be actuated by a hand lever in bench shearing machines, foot treadle in treadle guillotines or electric motor or hydraulic system in power guillotines.

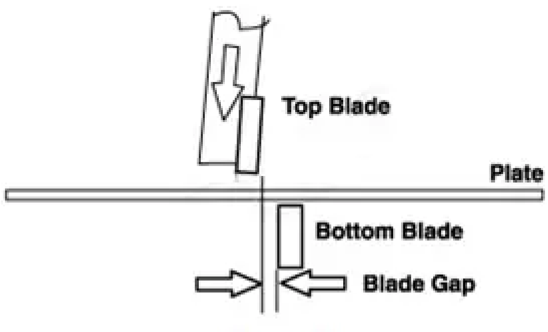

Figure 1: How shearing is done

Problem Definition

During our attachment at the welding shop, we were able to encounter the manual shearing machine. Currently, it is able to cut up to a maximum of 20mm. This seems large but we saw an opportunity. We set out to increase the thickness the manual shearing machine could cut up to 30mm. Also, the shearing machines in the market include hydraulic swing beam shear, hydraulic guillotine shear, and electric shear. These off the shelf designs are very expensive and only top manufacturing plants can afford them. To make shearing available for small businesses, our design introduces a simple manual shearing machine that can be fabricated in a workshop at a relatively low cost. Our design is an adaptive redesign of an already existing solution, which has become outdated. The design is as shown below:

Figure 2: Manual Shearing Machine at Welding shop

Design Requirements

The design shown in *Figure 1* cuts sheet metal of up to 20mm. To improve on this design, we designed our manual shearing machine to shear sheets of up to 30mm.

The following formula is used to calculate the force required to shear sheet metal:

$$F = L \bullet T \bullet S$$

Where: F is the force required (Newtons), L is the length of the sheet to be cut (millimetres), T is the sheet thickness (millimetres) and S is the shear strength (N/mm^2).

For a steel sheet metal with a thickness of 20mm, length is 20mm and shear strength of 300MPa, the force required to cut the shear metal will be:

$$F = L * T * S$$

$$F = 20 * 20 * 300$$

$$F = 120kN$$

Now, our design is supposed to do better, by generating enough force to cut up to 30mm thick of sheet metal.

$$F = 20 * 30 * 300$$

$$F = 180kN$$

This will be the requirement for our design. We also intend for our design to reduce labour costs, increase worker safety and increase the productivity of the process.

Design Description

The design selected is constructed using only nine main parts from material that can be found readily: a combination of mild steel and stainless steel. The manual shearing machine has an upper and lower blade from which a sheet of metal can be cut. The upper blade is part of a lever system together with the handle through which shearing force is applied. The lower blade is fixed to the body part of the shearing machine which has a large surface area to absorb the pressure due to the shearing force and increase the stability of the machine. During a shearing operation, a sheet of metal is placed on the lower fixed blade, and a cutting force is applied through the handle. When the two blades make contact, the sheet metal is broken and separated according to the desired dimensions. The design is as shown in *Figure 3*.

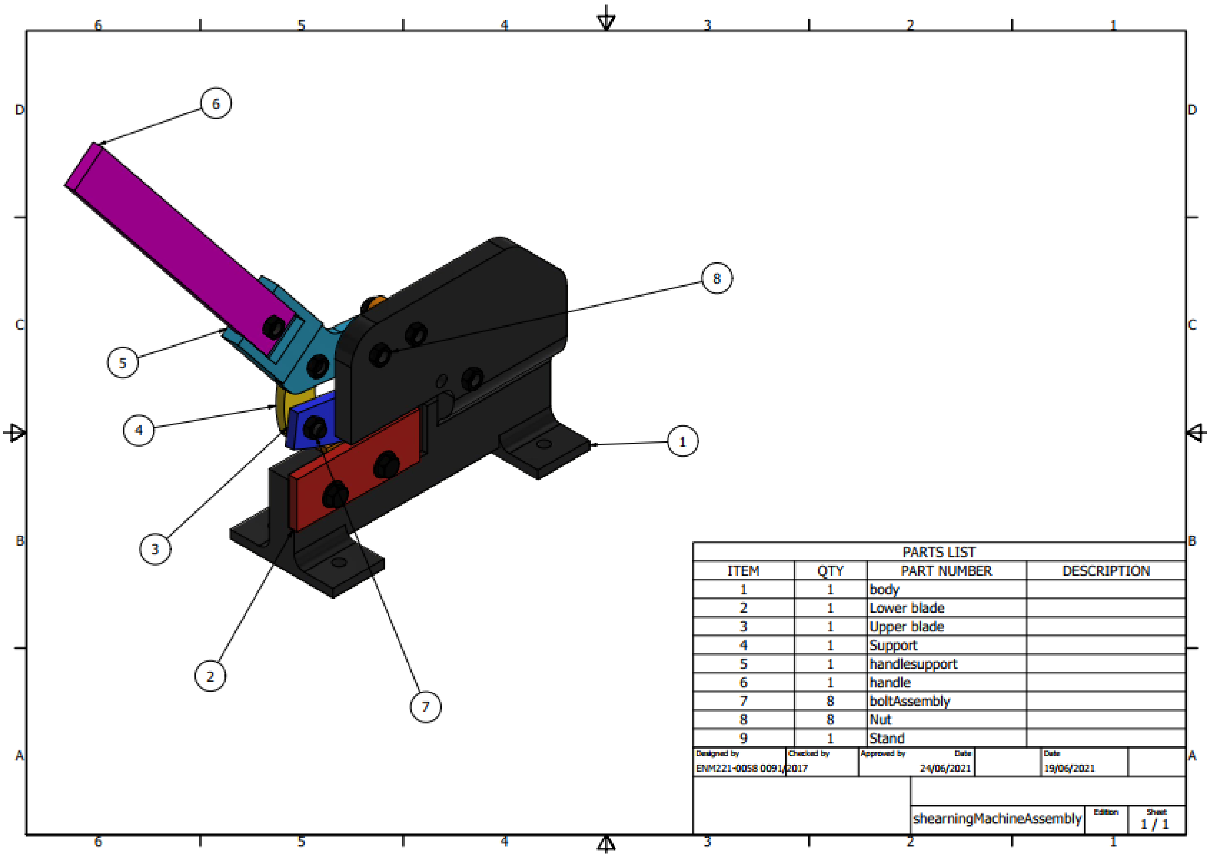

Figure 3. CAD Drawing of the Manual Shearing Machine

Design and Manufacturing Process

The manual shearing machine design is an assembly of various parts and to describe its production process, we need to discuss the manufacture of the individual parts. In coming up with the parts, various workshop processes are applied, including turning, milling, drilling, among others. Some parts such as the fasteners (nuts and bolts), the washer and the handle were bought off the shelf. The other parts were first developed using CAD software, and we used Autodesk Inventor.

Manufacturing processes applied include:

1. Machining

CNC Machining. This is the most important machining process as most of our parts will be produced in a CNC machine. We will initially buy the billet material then place it on the milling table and program the machine to cut the specific geometry we want. Some of the parts we mill include the body, lower blade, upper blade, support, handle support and stand. The CNC milling process has four distinct stages:

- CAD model design.
- CAD model design conversion to a CNC program
- CNC milling machine setup
- Milling operation execution

Now let us take a look at the various parts, their CAD model designs, and their CNC programs to be executed in a milling machine. A computer-aided manufacturing software will be used to generate the CNC program. We decided to use the Siemens 840D due to its similarity with the CNC machine at the machine shop. This will actually help us do the physical analysis of our design if we were to be given a go-ahead to machine one of the parts.

a. Body

To produce the body in *Figure 4*, we decided to use a modular approach since machining the whole body altogether is a difficult operation. We broke the body into 3 main pieces, the bottom part, the top part and the standoffs. These individual parts are now able to be machined using a milling operation. We set up an initial stock which is an extra 5 mm at the top and an extra 2mm on the sides. The first operation was facing the required height of the workpiece. This was done with even multiple depths of 2mm spacing. Then we followed up by adaptive milling which is a 3D milling technique. We finally finished up with drilling the holes onto the workpiece. This operation was the same for all the parts of the body. We used flooding when applying coolant since our tool could not be able to deliver coolant inside. We thought of using air suction by keeping in mind the CNC at the machine shop, so we decided flooding was the better approach. We then used two joining techniques; welding and the use of nuts and bolts. We joined the standoffs to the bottom part with welding after having placed the bottom part in a slot on the standoffs. Joining the top part and bottom part was done mainly using the nuts and bolts. We finally reinforced it using welding with a fillet shape. The weld bead report is in *Table 1.*

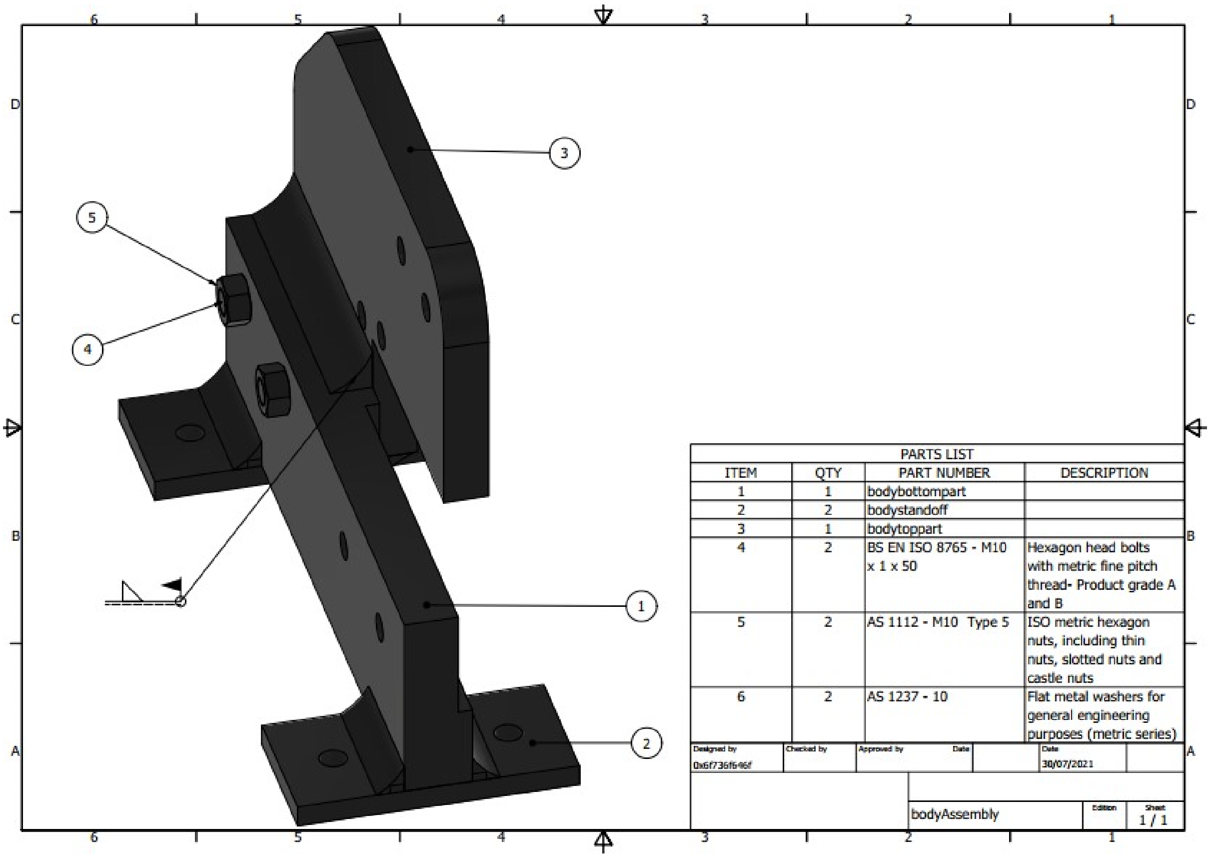

Figure 4. CAD Model of the Body

		Length	Mass	Area	Volume
Fillet Weld 1	Fillet	110 *mm*	0.023 *kg*	5872.448 mm^2	8443.037 mm^3
Fillet Weld 2	Fillet	110 *mm*	0.023 *kg*	5872.448 mm^2	8443.037 mm^3
Fillet Weld 3	Fillet	50 *mm*	0.005 *kg*	1797.566 mm^2	2026.715 mm^3
Fillet Weld 4	Fillet	50 *mm*	0.005 *kg*	1797.566 mm^2	2026.715 mm^3
Fillet Weld 5	Fillet	50 *mm*	0.005 *kg*	1797.566 mm^2	2026.715 mm^3
Fillet Weld 6	Fillet	50 *mm*	0.005 *kg*	1797.566 mm^2	2026.715 mm^3

Table 1: Weld bead report

b. Lower blade

To come up with the lower blade the first manufacturing operation was facing, using a face mill of diameter 50mm. This operation reduced the workpiece to the required height. One edge was turned at an angle as it would form the cutting edge of the blade. Since we have a sloping cutting edge we decided to place it in a Z-direction such that the slant was an incremental downwards slope. We used additive machining, a form of 3D machining, to be able to obtain the contours on the blade. Once the dimensions of the part were achieved, the two 10 mm diameter holes were created using a drill using the rapid out technique.

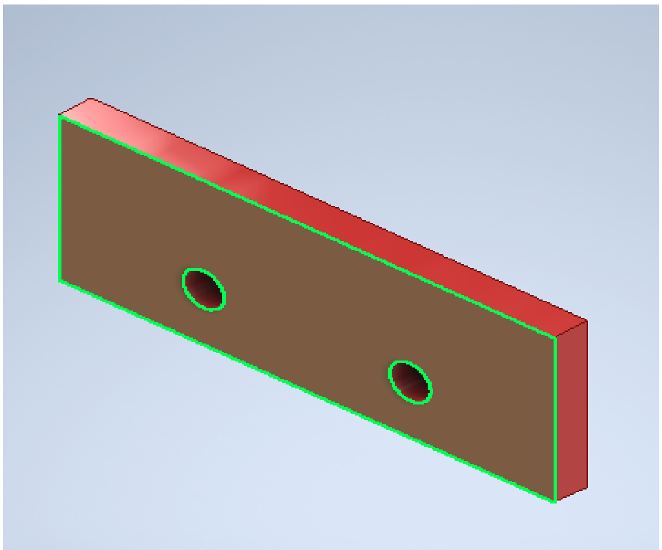

Figure 5. CAD Model of the Lower Blade

c. Upper blade

Face milling, end milling, and drilling are the operations carried out to come up with this part. We first reduced the workpiece to the required height using a face mill, which was followed by adaptive milling to establish the shape of the blade. In this operation, the milling tool axially follows the path with a predefined geometry. The two holes that would form the assembly were drilled into place.

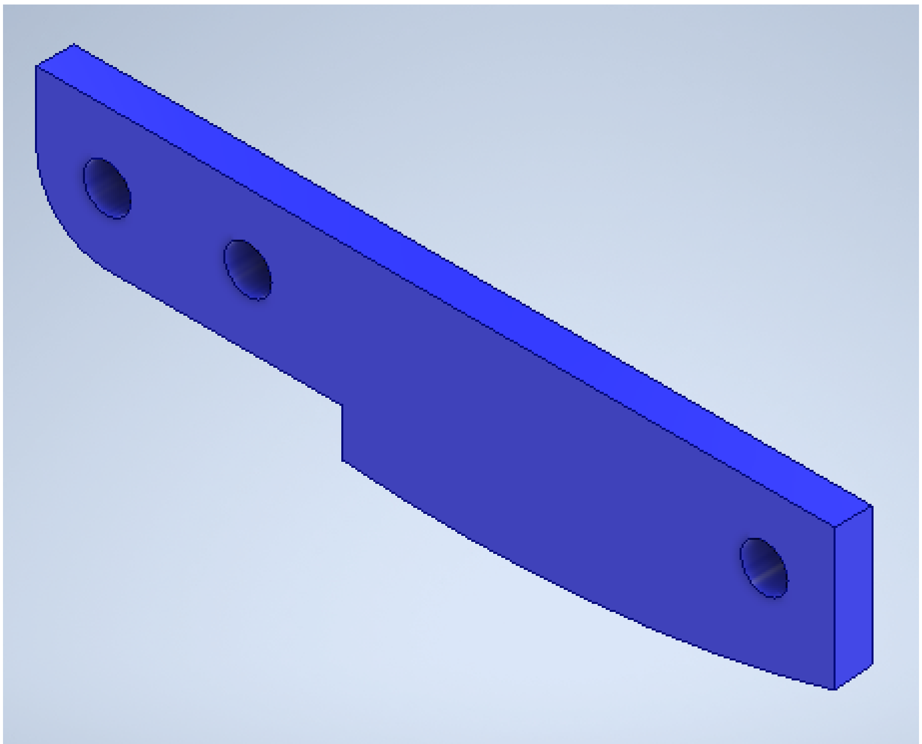

Figure 6. CAD Model of Upper Blade

d. Stand

Due to its design complexity, we decided to do a modular approach too. Here we split the stand into three different parts. The circular part was turning on a CNC lathe while the supporting beam together with the base was milled. For the circular part, we bought stock then we faced it off. This was done by a right-hand turning tool. We set the centre point at an offset of 1 mm from the true centre in order to get all of the material out during facing. We did multiple passes with 3 passes 2 mm apart. We continued to the turning where we defined it as profile roughing. We turned up to the end of the workpiece. We did multiple passes 1 mm apart. We then drilled the inside hole using the rapid out technique up to the end and finally parted off the workpiece from the stock using a grooving tool.

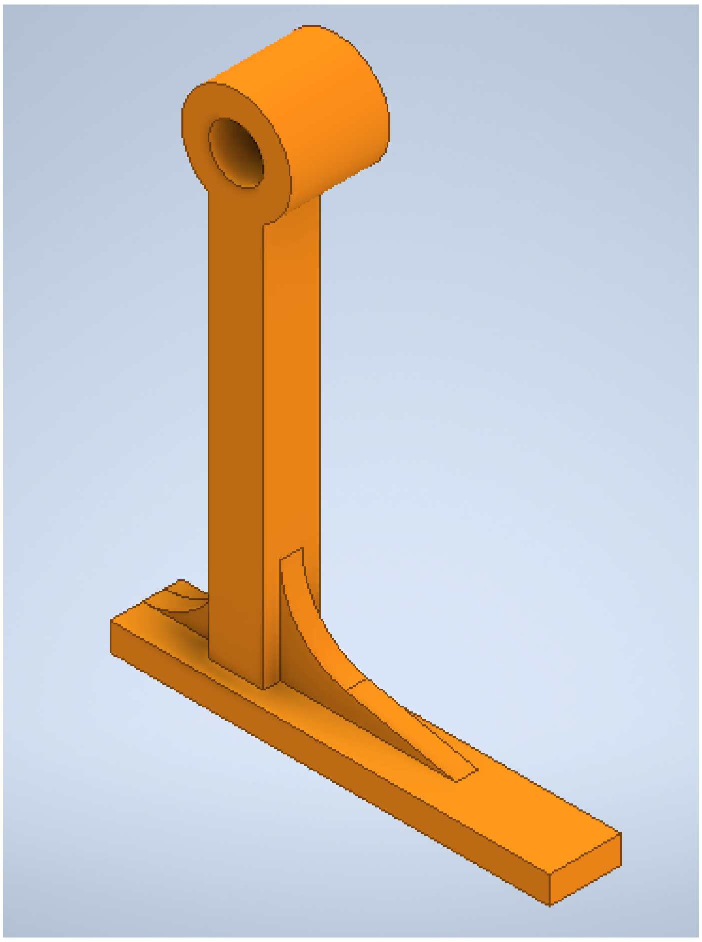

Figure 7. CAD Model of the Stand

e. Support

We first reduced the height of the workpiece using a facing operation. The two holes were drilled into place. We then machined the part using adaptive milling which maintains a consistent tool path and chip load which results in faster, smoother cutting.

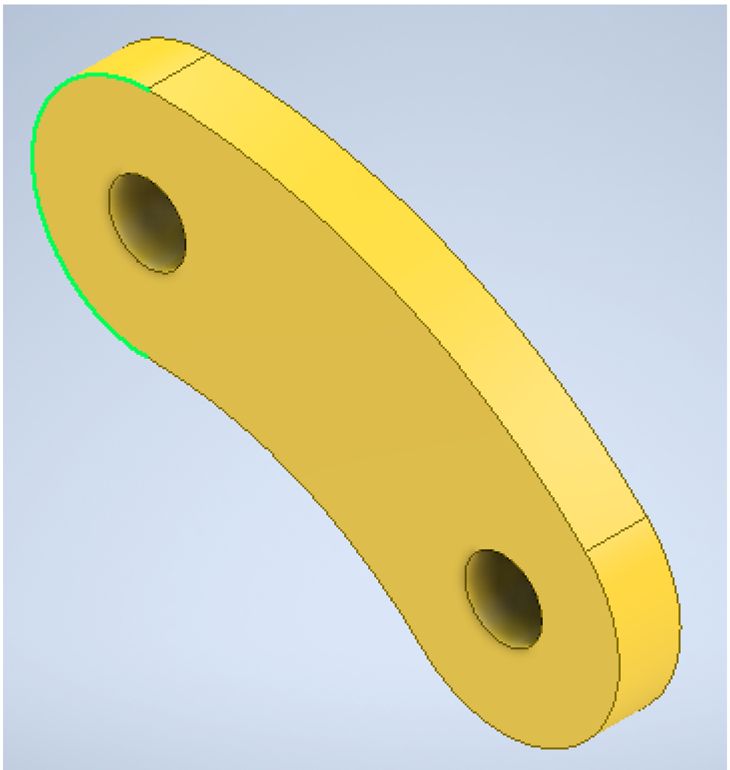

Figure 8. CAD Model of the Support

f. Handle support

We initially intended to use plasma cutting but the plasma cutting at the welding workshop isn't CNC operated. We then decided to use the milling operation. Two facing operations were conducted to come up with the two heights on the other side of the top of the workpiece. On one end of the workpiece, we created a flat bottomed cavity using another end milling operation. Joining holes were drilled into the workpiece, after which the final operation, adaptive milling, was executed.

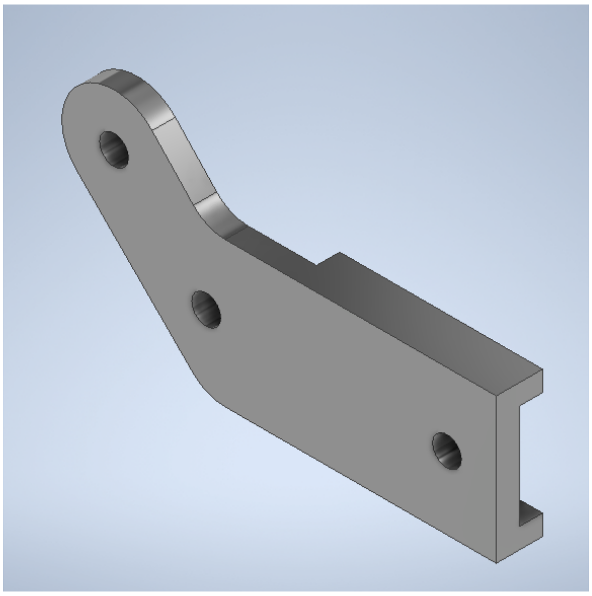

Figure 9. CAD Model of the Handle Support

g. Washer

This was purchased at the local stores together with the nuts and bolts used for assembly

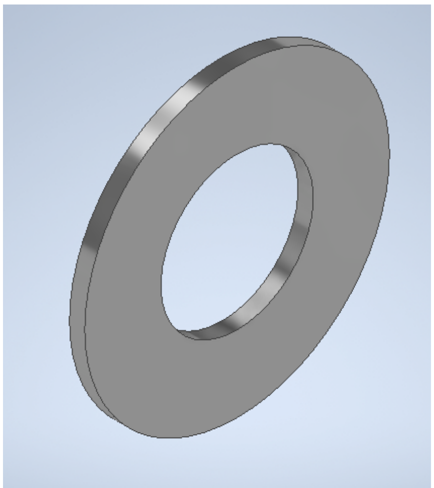

Figure 10. CAD Model of the Washer

2. Joining

After coming up with the individual parts, we need to put multiple parts together to make one piece. Some of the joining processes used include welding and the use of fasteners (nuts and bolts). The body is fabricated as three parts and joined together using a weld. Arc welding is the most preferred method.

The other parts are assembled together using the fasteners. The lower blade is attached to the body using bolts and nuts. The support, handle, handle support and upper blade are all joined together using bolts and nuts.

3. Coating

The final manufacturing process is coating both for aesthetic value and to protect against surface corrosion, that is, rusting.

Evaluation

After coming up with the design, and manufacturing of the shearing machine, we need to make sure it works by simulating it in the CAD software.
This was done through dynamic simulation and Finite element analysis. For Dynamic simulation, we introduced a torque of 300.000 N/mm on the pivot of the lower blade to be able to see if the handle could be driven down to simulate the pressing action. This was justified as the handle moved down simulating the cutting mechanism. We also checked our mechanism and found out that 4 bodies were mobile with a 1 degree of freedom.
For the Finite Element Analysis, we were testing the maximum load the shearing machine can hold before fracture. We placed a test material on the bed which produces an opposite force of magnitude 10N majorly on the z-axis. We then added a 100N push force on the handle and observed the changes. The body was selected to be fixed while the blade had a frictionless surface to allow smooth motion.

Name	Steel, Mild	
General	Mass Density	7.85 g/cm^3
	Yield Strength	207 MPa
	Ultimate Tensile Strength	345 MPa
Stress	Young's Modulus	220 GPa
	Poisson's Ratio	0.275 ul
	Shear Modulus	86.2745 GPa
Part Name(s)	Body.ipt, Lower blade.ipt, Upper blade.ipt, Support.ipt, handlesupport.ipt, handle.ipt, Stand.ipt	

Name	Stainless Steel	
General	Mass Density	8 g/cm^3
	Yield Strength	250 MPa
	Ultimate Tensile Strength	540 MPa
Stress	Young's Modulus	193 GPa
	Poisson's Ratio	0.3 ul
	Shear Modulus	74.2308 GPa
Part Name(s)	Bolt.ipt, Washer.ipt, Nut.ipt, Bolt.ipt	

Table 2: Initial conditions

From our results, we were able to see that this motion induced a reaction moment of 1.12543 Nm.

Name	**Minimum**	**Maximum**
Volume	1112060 mm^3	
Mass	8.73379 kg	
Von Mises Stress	0.000000946634 MPa	5.50151 MPa
1st Principal Stress	-0.770633 MPa	2.74524 MPa
3rd Principal Stress	-5.69371 MPa	0.262106 MPa
Displacement	0 mm	0.00527388 mm
Safety Factor	15 ul	15 ul

Table 3: Finite Element Analysis

With a 15ul safety factor, we are at liberty to say that this machine increases its lifetime by a great margin. The maximum stress occurs at the cutting region demonstrated by *Figure 10* below.

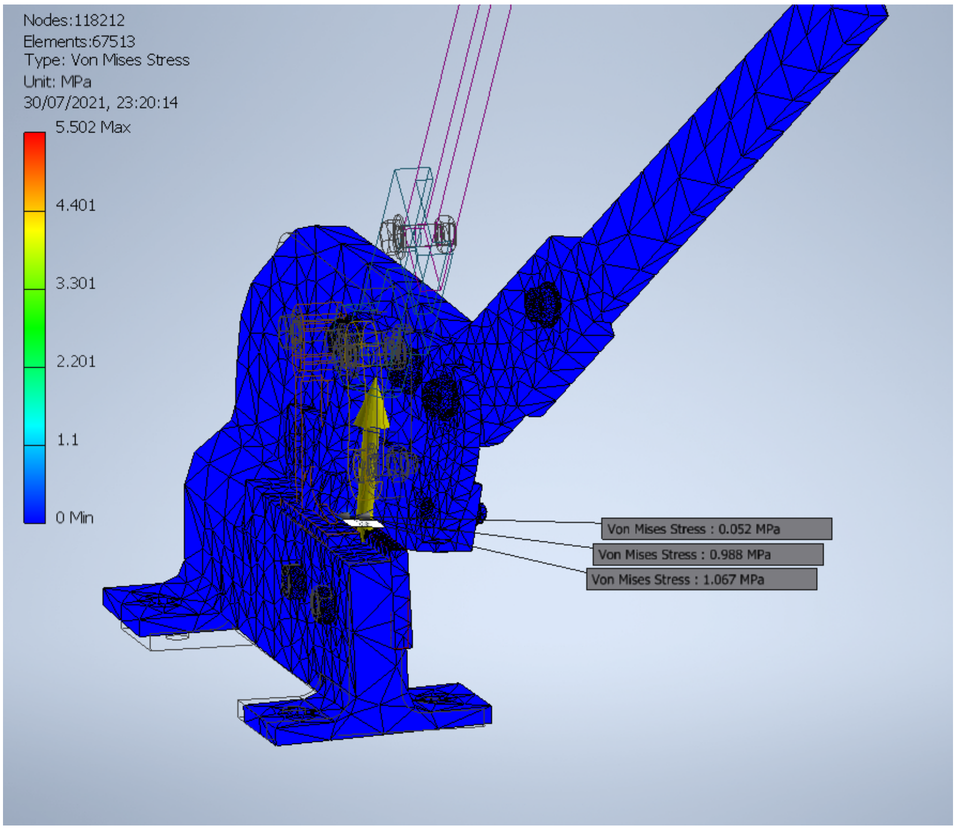

Figure 11: Von Mises Stress

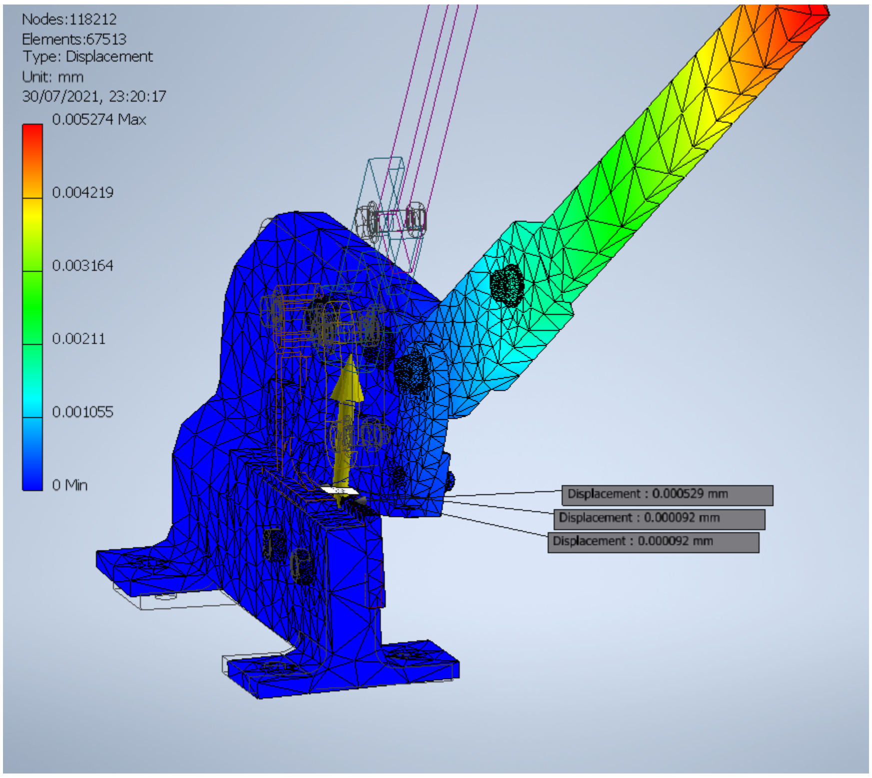

Figure 12: Displacement

As demonstrated we can be able to see that the handle is the one that moves, objecting to the physics behind the shearing machine.

Conclusion

The design above seeks to employ a cheap and reliable way to cut sheets of metal. As the design procedure shows, it can be produced readily and quickly using basic workshop processes, including facing, turning, drilling among others. We have also proved that it has increased functionality compared to the previous design. As per our design requirements, our design increases the cutting force, thus enabling thicker sheets to be cut. Our design is also quite reliable as evidenced by the 15ul safety factor.

Challenges

1. A complex design that needs casting processes.
2. Obtaining MasterCAM as it failed to start even with the Home education license.

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6. R. Hambli, A. Potiron, and A. Kobi, "Application Of Design Of Experiment Technique For Metal Blanking Processes Optimization," Mécanique& Industries, vol. 4, no. 3, pp. 175
7. Joseph E. Shigley, Mechanical Engineering Design, Sixth Edition, Tata Mcgraw Hill, 2005.
8. Bhandari V.B., Design Of Machine Elements, eighteenth edition, Mcgraw Hill Companies, 2003.

Appendix

1. https://github.com/KelvinGitu/Manufacturing-Technology-1-Project Project link
2. https://github.com/KelvinGitu/Manufacturing-Technology-1-Project/tree/main/Src/Codes Machining codes
3. Example of milling part

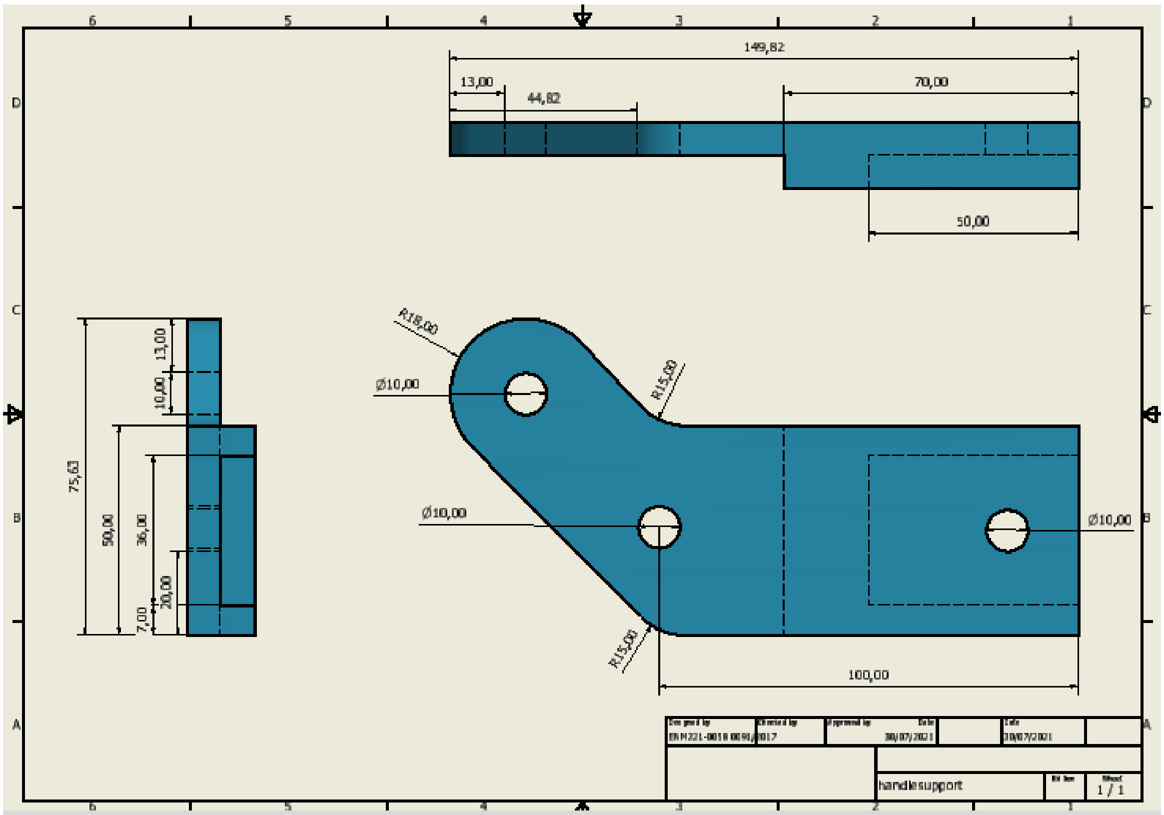

Figure 12: Handle support

4. Sample Generated codes for the handle support

```
; %_N_HANDLESUPPORT_MPF
N10 ; handlesupport
N11 ; T1 D=50 CR=0 - ZMIN=16 - face mill
N12 ; T2 D=5 CR=0 - ZMIN=0.51 - flat end mill
N13 ; T30 D=10 CR=0 TAPER=118deg - ZMIN=0 - drill
N14 WORKPIECE(,,,"BOX",112,21,0,80,74.91,37.815,-74.91,-37.815)
N15 G90 G94
N16 G71
N17 G64
N18 G17
N19 G0 SUPA Z0 D0

N20 ; Face1
N21 T1 D1
N22 M6
N23 T2
N24 S955 M3
N25 G54
N26 G0 X107.41 Y-24.375
N27 G0 Z36
N28 M8
N29 G0 Z26
```

```
N30 G1 Z24.333 F460
N31 G17
N32 G3 X102.41 Z19.333 I-5 K0
N33 G1 X74.91 Y-24.375
N34 G1 X-74.91
N36 G2 X-93.892 Y-5.393 CR=18.982
N38 G2 X-74.91 Y13.59 CR=18.982
N39 G1 X74.91 Z19.333
N41 G2 X79.91 Z24.333 I0 K5
N42 G0 Y13.59 Z26
N43 G0 X107.41 Y-24.375
N44 G1 Z22.667 F460
N46 G3 X102.41 Z17.667 I-5 K0
N47 G1 X74.91 Y-24.375
N48 G1 X-74.91
N50 G2 X-93.892 Y-5.393 CR=18.982
N52 G2 X-74.91 Y13.59 CR=18.982
N53 G1 X74.91 Z17.667
N55 G2 X79.91 Z22.667 I0 K5
N56 G0 Y13.59 Z26
N57 G0 X107.41 Y-24.375
N58 G1 Z21 F460
N60 G3 X102.41 Z16 I-5 K0
N61 G1 X74.91 Y-24.375
N62 G1 X-74.91
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N66 G2 X-74.91 Y13.59 CR=18.982
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N69 G2 X79.91 Z21 I0 K5
N70 G0 Y13.59 Z36
N72 G0 SUPA Z0 D0
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