Faculty of Science, Engineering and Computing Assessment Form

Module: Design Methods and Materials – AE5121

Setter: Dr Redha Benhadj-Djilali

Title of Assignment: Design Concept & CAD Implementation of an Air Engine

Deadline: 07th April 2017 through Turn-it-in before 10am

Module weighting: 40%

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Submission details: Detailed report with selected 2D & 3D CAD drawings included in the report, weight calculations for each part and the whole air engine assembly. Also, you are required to re-design the air engine to reduce the overall weight and manufacturing cost. See more guideline of your report submission in the assignment brief.

Module Learning Outcomes assessed in this piece of coursework:

- Use traditional design methods and CAD software to undertake engineering design tasks
- Apply a logical and creative approach to solve commercial design problems.

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Abstract

This report contains detailed report on the design of an air engine using CAD software and techniques. It consists of a detailed set of single part drawings fully dimensioned with tolerances with description, an assembly drawing with description and justification of choices as well as a list of parts and materials. Weight calculations were done for each part and then compared with the CAD generated weight. A redesign of the air engine is also done and compared with the original design to reduce the weight and manufacturing cost of the air engine.

Introduction

An air engine was designed using advanced 3D solid and surface modelling techniques and assembly. SolidWorks 2016 is the software used to design the air engine. The engine operates through compressed air entering the cylinder via one of the connecting pipes. The other pipe serves to exhaust the cylinder after the power stroke. The cylinder oscillates in an arc and a hole through the cylinder wall lines up with the inlet and the exhaust pipes at each 180^0 of rotation of the flywheel.

Fully dimensioned single part drawings in third angle orthographic projection with geometrical constraints are clearly shown with detailed explanation and justification of choices on the methods used to design set components. A bill of materials and a materials list is provided I the assembly drawing for the air engine. Also, hand calculations were done to first estimate the weight of each part and the entire weight of the air engine which will be compared to that of the CAD generated weight of each design.

A redesign of the engine is done where some materials for some of the components were changed, the size of some of the components being reduced and the removal of all the sharp edges which will not only make the product safe and user friendly, but will also reduce overall weight and manufacturing cost of the air engine.

All drawings and design strategies follow and incorporate the conventions stated in International/British Standards and Geometric Dimensioning and Tolerancing so that the drawings can be interpreted correctly by designers, engineers and manufacturers.

Design concepts

Initially, about two different designs for the air engine were drafted and discussed, the first design concept being the twin vertical engine, where two pistons are side by side, with a flywheel between each engine and a connecting rod from the piston attached to each end of the flywheel as shown in figure 1. The second design concept was to redesign the 1932 beam engine seen in figure 2, but such designs were impractical because of the geometric complexity and the amount of time and cost that will be used in making these engines.

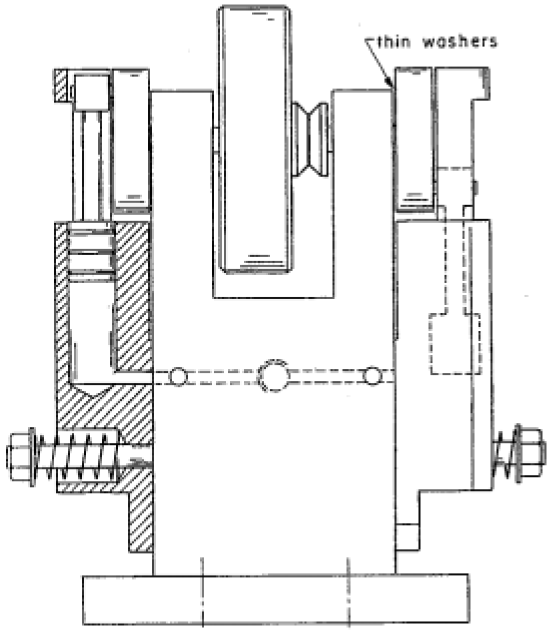


Figure 1 - showing the twin piston vertical engine

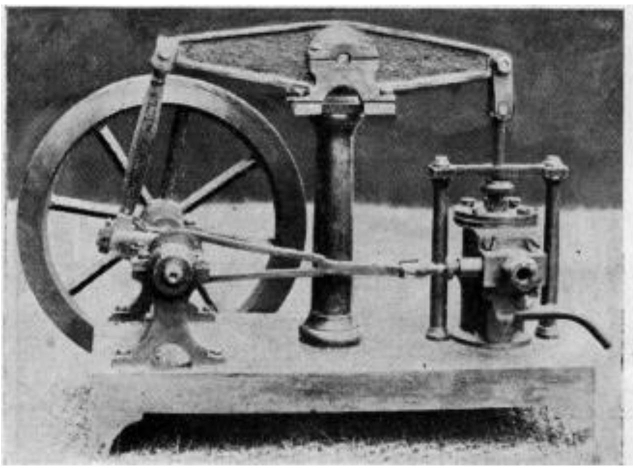


Figure 2 - showing the 1932 beam engine

The beam engine as shown is mounted on a steel bed with a crosshead transferring the cross wheel circular motion through bearing trunnions connected to an eccentric rod into an open and close motion for the piston. The pipe sticking outside the cylinder to the right is the outlet, while the intake of air occurs when the piston cap is raised. This idea was to be used in the manufacture of the air engine but deemed too complex to construct.

Below shows the detailed description and 3D CAD techniques used in the final design of the air engine. It shows the single part drawings and drawings of the final assembly of the air engine.

1. Base

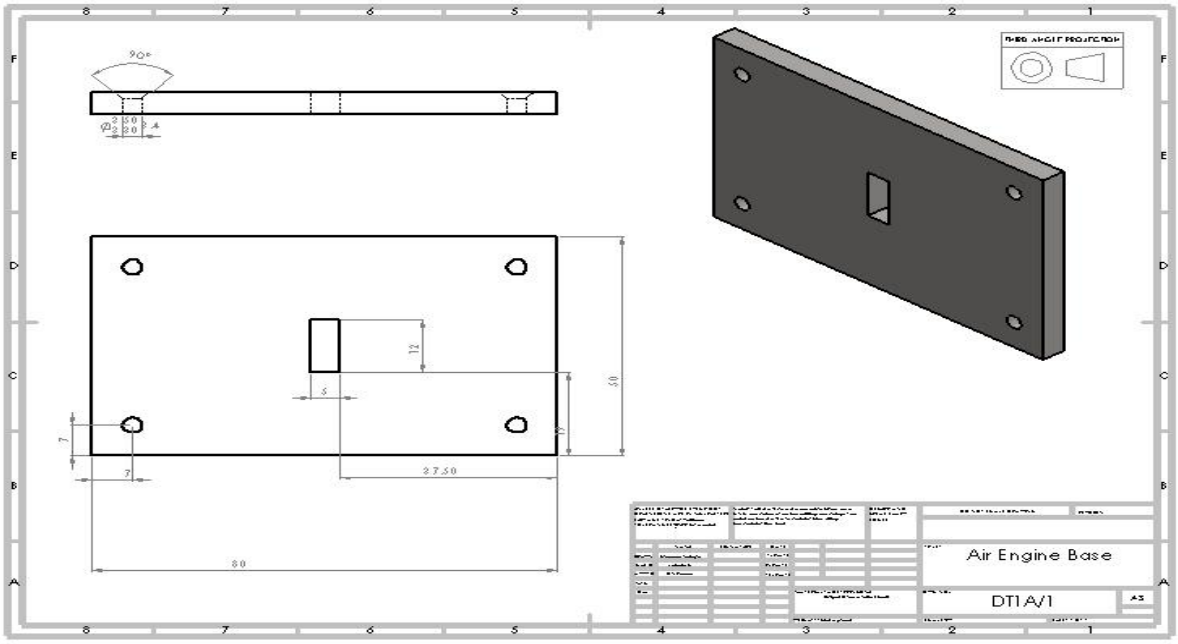
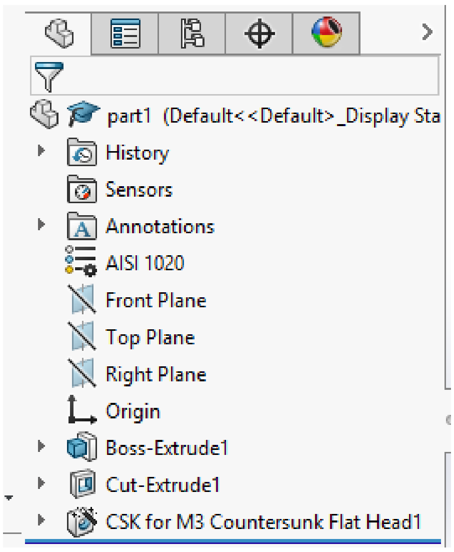


Figure 3 showing fully dimensioned base



The image above shows the fully dimensioned base and a 3D image of the air engine base. Figure 4 shows the how the pat was constructed on SolidWorks. It was drawn on the front making a square shape from the origin. It was then extruded. The holes were extruded cuts and the holes are counter sunk using the hole wizard function. The material allocated to the part as shown in figure 4 is the AISI 1020 which is bright drawn low carbon and low tensile steel. The part can be manufactured on a milling machine. It can also be manufactured on a CNC machine with the aid of a CAM software. The metal can be brushed for a fine surface finish. The tolerance of the holes is stated on figure 3.

Figure 4 show the hierarchy and constraints

Weight calculations:

$$volume\ of\ rectangular\ block = l \times w \times b = 500mm \times 80mm \times 5mm = 20{,}000mm^3$$

$$volume\ of\ central\ rectangle\ cut = 12mm \times 5mm \times 5mm = 300mm^3$$

$$volume\ of\ 4\ holes = 4 \times \pi \times r^2 \times h = 4 \times \pi \times 2^2 \times 2.5 = 125.664mm$$

$$total\ volume = 20000 - 300 - 125.664 = 19574.336mm^3 = 19.574cm^3$$

$$Density\ of\ AISI\ 1020 = 7.9\ g\ /\ cm^3$$

$$density = \frac{mass}{volume}, \therefore mass = density \times volume = 7.9 \times 19.574 = 154.64grams$$

2. Upright

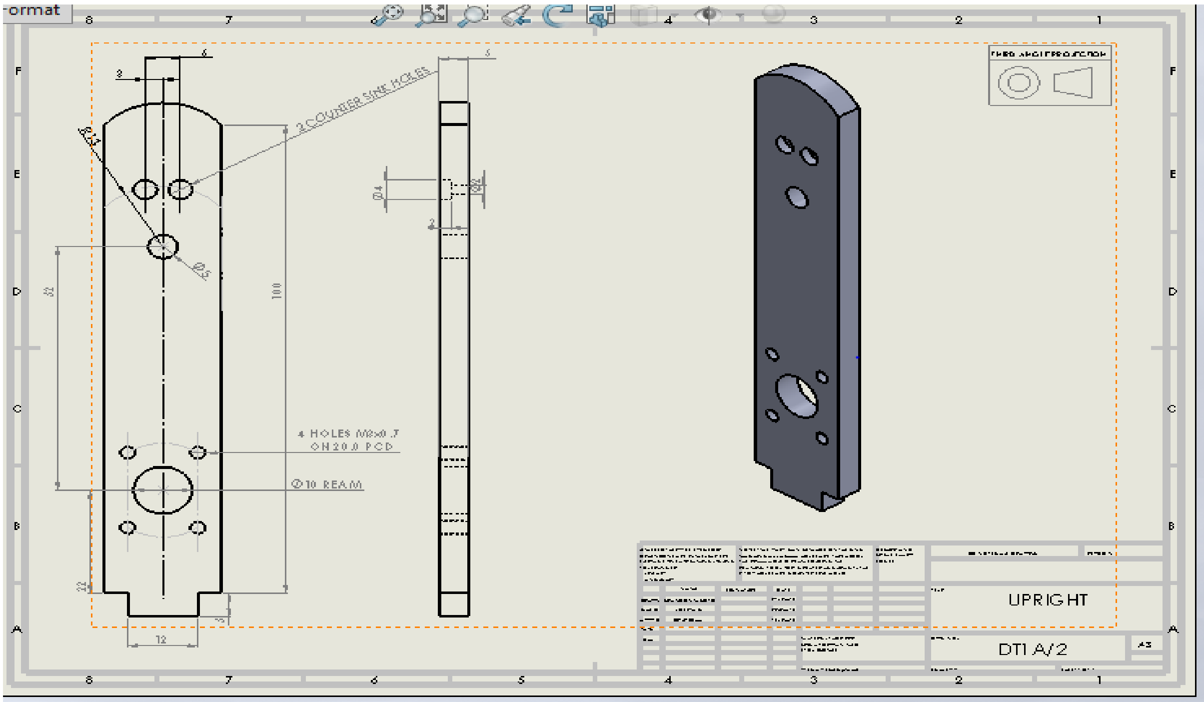
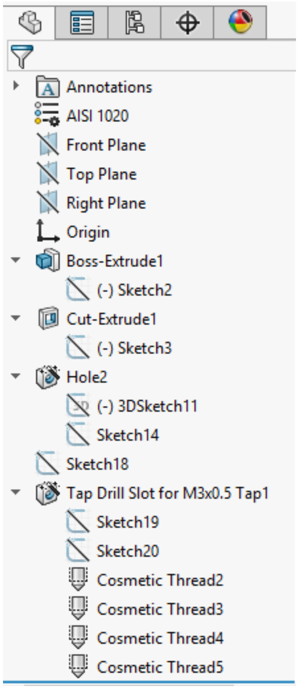


Figure 5 showing fully dimensioned upright



The upright was drawn on the front plane. It was made using a rectangle then extruded. Then, a circle was drawn and four other smaller circles were placed inside and extruded cut to create the holes. The centre hole of radius 5mm is a very accurate hole which is drilled and then reamed by a reaming tool. This part is made from AISI 1020 as shown if figure 6. The other holes are tapped from M3 x 0.5 tap. All these operations can be carried out on a milling machine. The end mill can be used to provide a good surface finish, however brushing the material is preferred as this removes surface imperfections, deburrs the material at the same time and gives the material or part a good surface finish. Figure 6 shows the ways in which the material was made. It is constrained in the XY plane. The holes on the top part of the upright are made for the pipes for air intake and outlet.

Figure 6 showing hierarchy of upright

Weight calculations for upright:

Following the above principles for mass derivation for the component, the hand calculation done to find the weight of the upright;

$$mass\ of\ upright = 78.98 grams$$

3. Flywheel

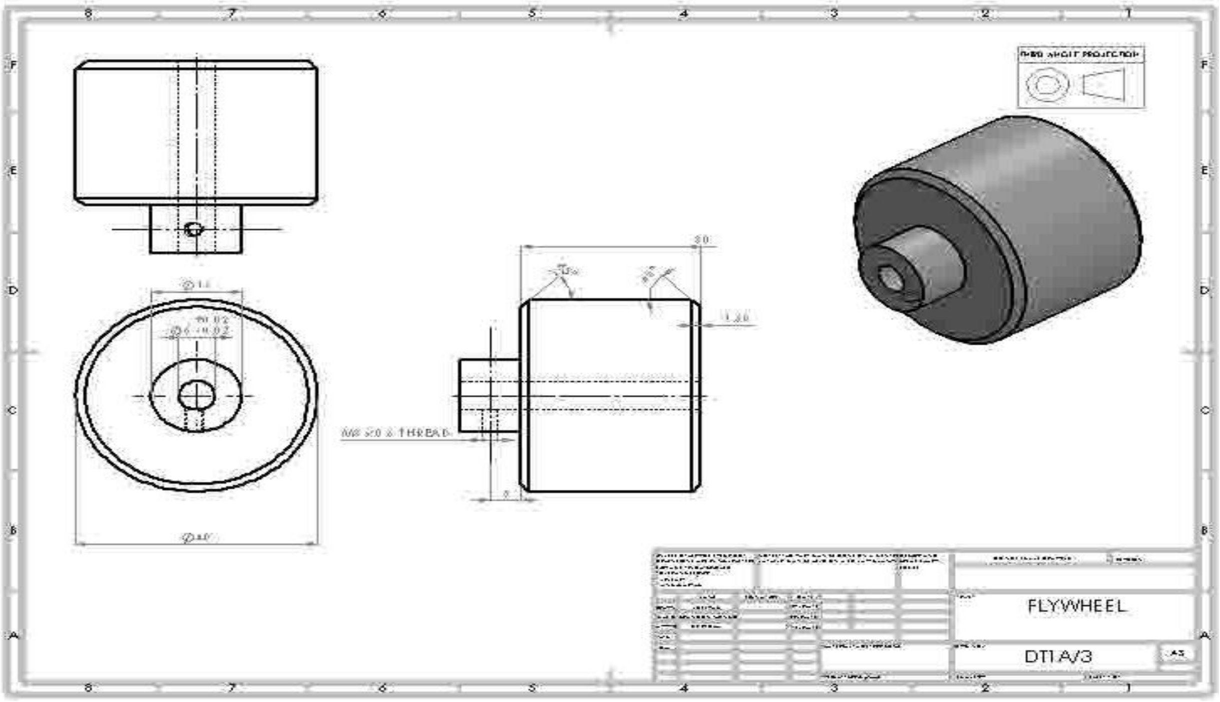


Figure 7 showing fully dimensioned flywheel drawing

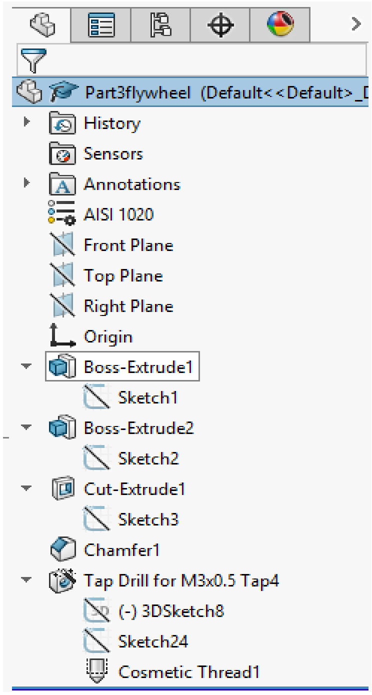


Figure 8 showing hierarchy of flywheel

As seen in figure 7, the flywheel for the air engine is made according to the dimensions following BSI/ISO standards. The flywheel was constrained on the YX plane when being drawn on SolidWorks. A circle was drawn and then extruded, then a smaller circle was also drawn on top of the already generated part and then extruded. A smaller circle of 6mm in diameter was drawn and cut out (extruded cut) to make the hole through the part seen in the drawing. With the aid of centrelines, the 3mm hole was cut 3mm deep through the top of the flywheel and then threaded. Figure 8 shows the hierarchy of how the part was made. The material allocated to the flywheel is the AISI 1020. This material is chosen because of its machinability, its high strength and ductility. Furthermore, this part can be machined on a centre lathe, holding the material on a four-jaw chuck using the turning, cutting and facing off tool. The top M3 threaded hole can be done on a milling machine. The part can be brushed to give it a good and smooth surface finish.

Weight calculation:

The hand calculated weight for this part amounted to:

$$mass\ of\ upright = 311.113\ grams$$

4. Crankshaft

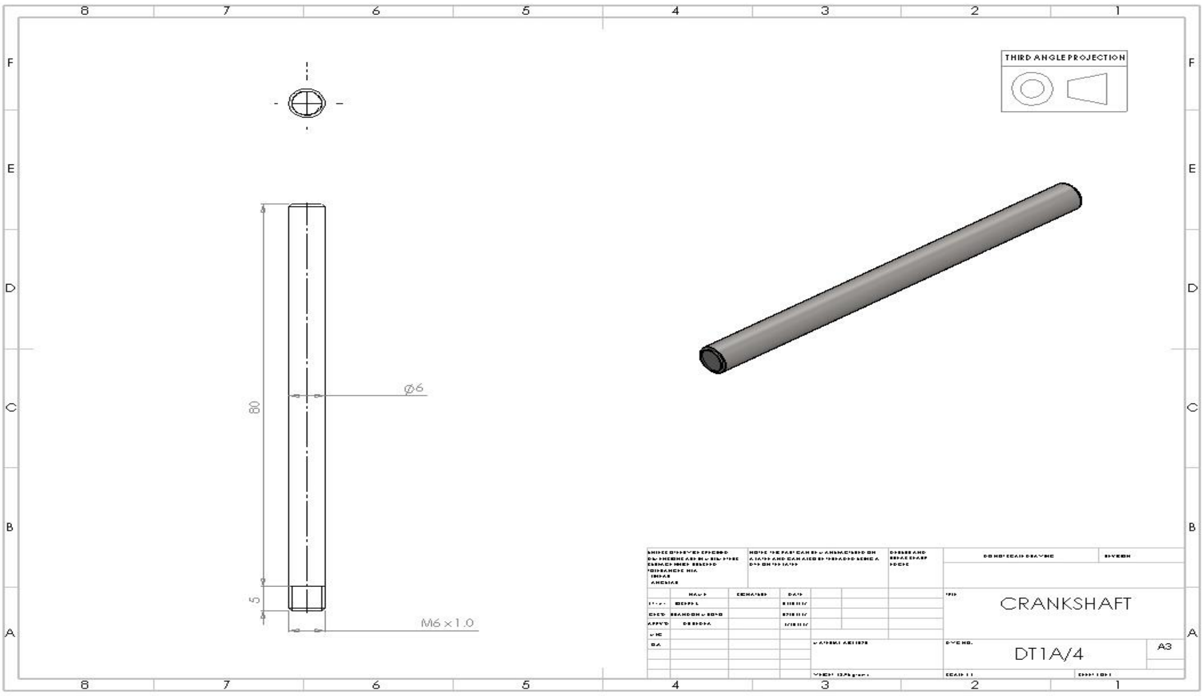


Figure 9 showing fully dimensioned crankshaft

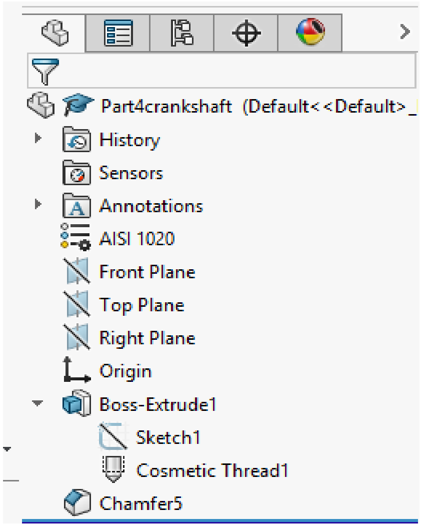


Figure 10 showing part hierarchy

The crankshaft connects the crank web to the flywheel to move the piston. The part was drawn according to the dimensions stated in figure 9. It is a threaded shaft that is 85mm long and 6mm in diameter. The material this part is made from is the AISI 1020 (mild steel). This part can be machined on a centre lathe. Figure 10 shows the geometric hierarchy and how the part was designed on SolidWorks. The part was also constrained on the XY or front plane.

Weight calculations:

$$volume\ of\ cylinder = \pi \times r^2 \times h = \pi \times 3^2 \times 85 = 2403.318mm^3 \equiv 2.403318cm^3$$

$$density\ of\ AISI\ 1020 = 7.9\ g\ /\ cm^3$$

$$mass\ of\ crankshaft = 7.9 \times 2.403318 = 18.99\ grams$$

5. Grub screw

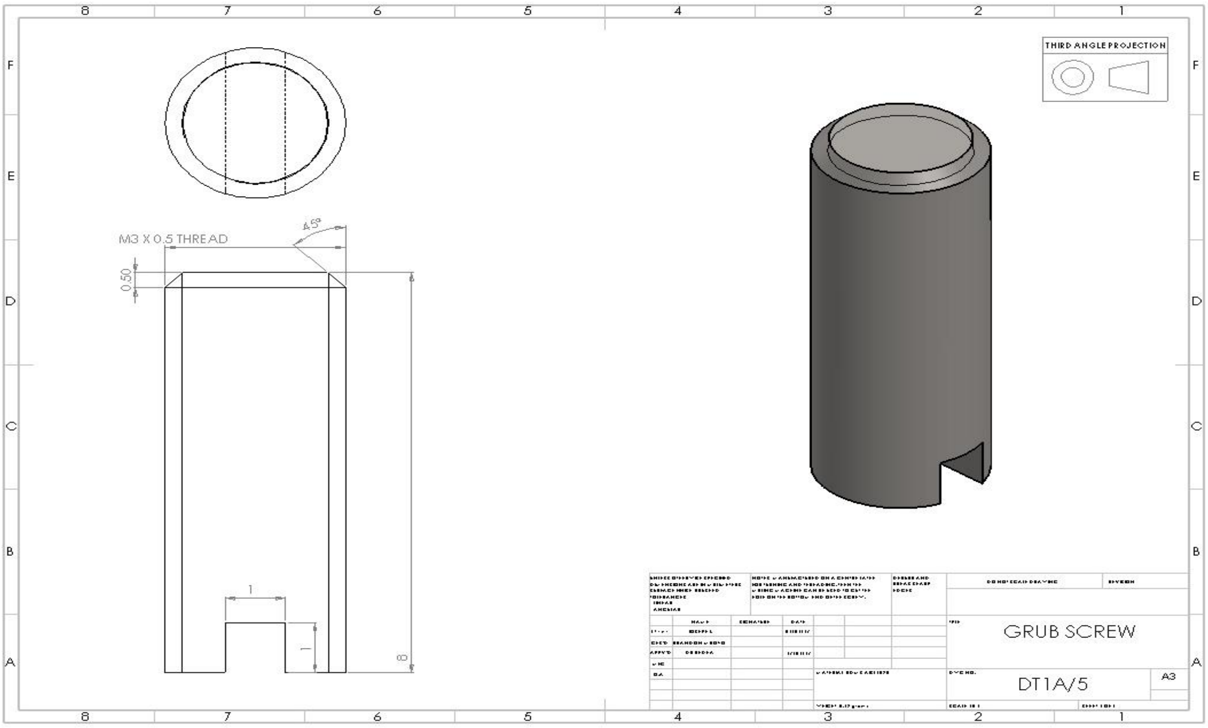


Figure 11 shows fully dimensioned grub screw

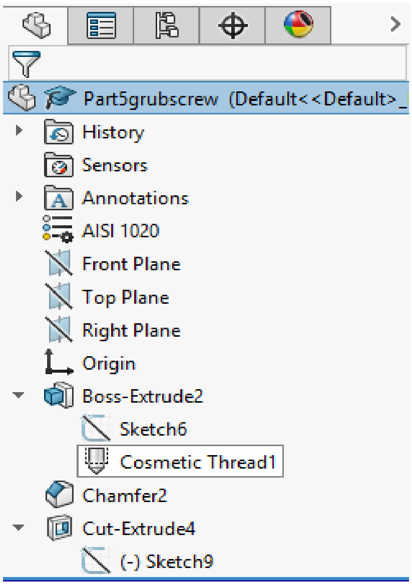


Figure 12 showing hierarchy of grub screw

The grub screw shown in figure 11 is used to lock the crankshaft inserted into the flywheel. The fully dimensioned part shows a threaded rod with a rectangular cut 1mm wide and 1mm deep through the part. As with figure 12, the part is constrained in the top plane or the ZX plane. The grub screw can be made and threaded on the centre lathe, but the cut underneath the part can be done using a cutting on the milling machine. The material assigned to the part is the AISI 1020. The hole is cut so that the screw can be fastened with a screw driver into the threaded hole on the flywheel.

Weight calculations:

$$volume\ of\ cylinder = \pi \times 1.5^2 \times 8 = 58.55mm^3$$
$$volume\ of\ rectangular\ cut = 1 \times 1 \times 1 = 1mm^3$$
$$total\ mass = 58.55 - 1 = 57.55mm^3 \equiv 0.05755cm^3$$
$$mass\ of\ grub\ screw = 7.9 \times 0.05755 = 0.45\ grams$$

6. Back plate

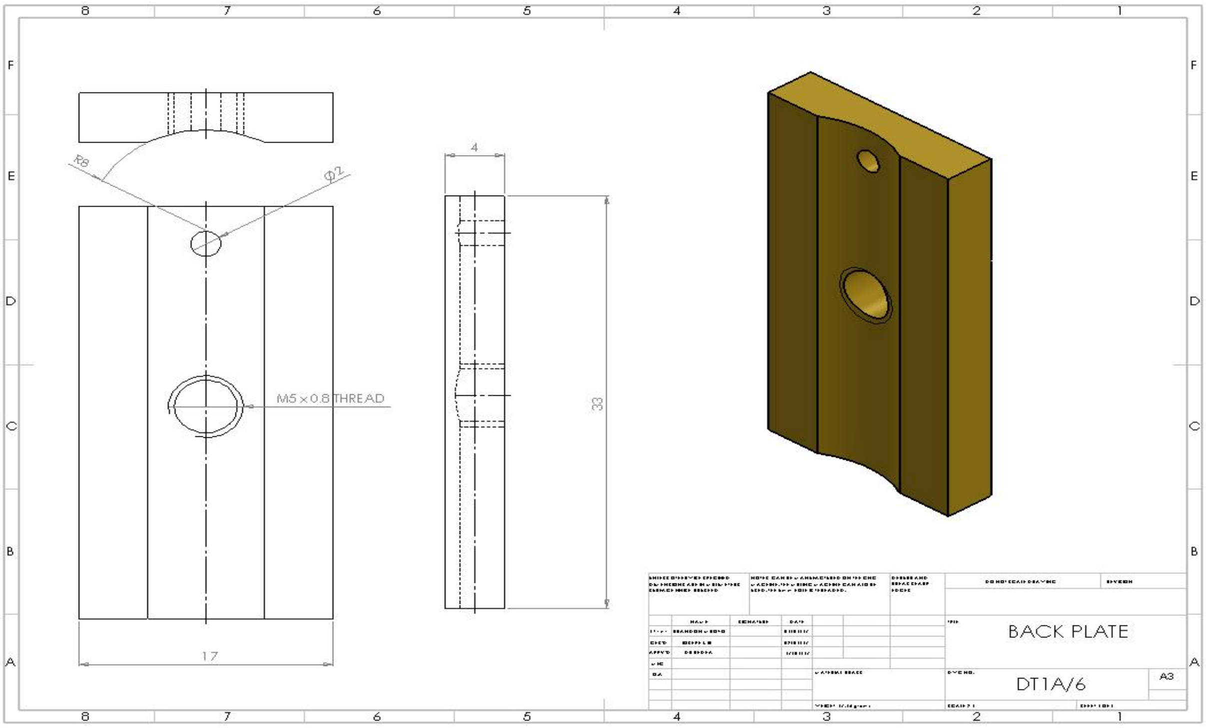


Figure 13 shows fully dimensioned back plate

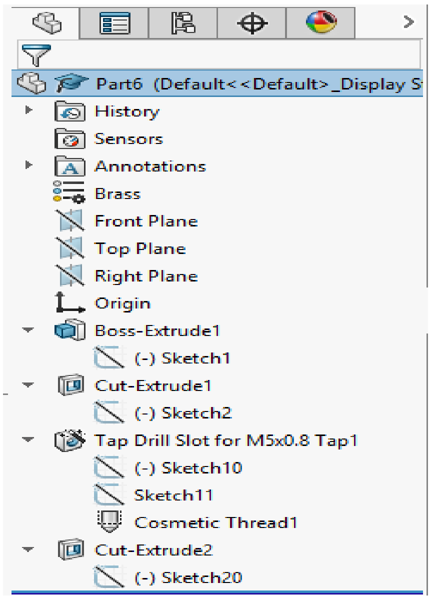


Figure 14 shows part hierarchy

The back plate is made from brass. This was chosen because of it almost frictionless surface, its ease of machinability. It serves to prevent contact between the upright and the piston. Furthermore, figure 13 shows how the par is to be manufactured. The milling machine or a CNC machine will be best suited to make this part. The middle of the plate has been carved to a radius of 6mm to fit the outer surface of the cylinder. The threaded hole is for the cylinder pivot and the plate will allow a smooth movement of the cylinder and for high temperature resistance. The plate is 4 mm thick. Figure 14 shows how the part was constructed and was constrained in the XY plane.

Weight calculations:

The calculated weight of this part was approximately:

$$mass\ of\ back\ plate = 18.795\ grams$$

7. Cylinder

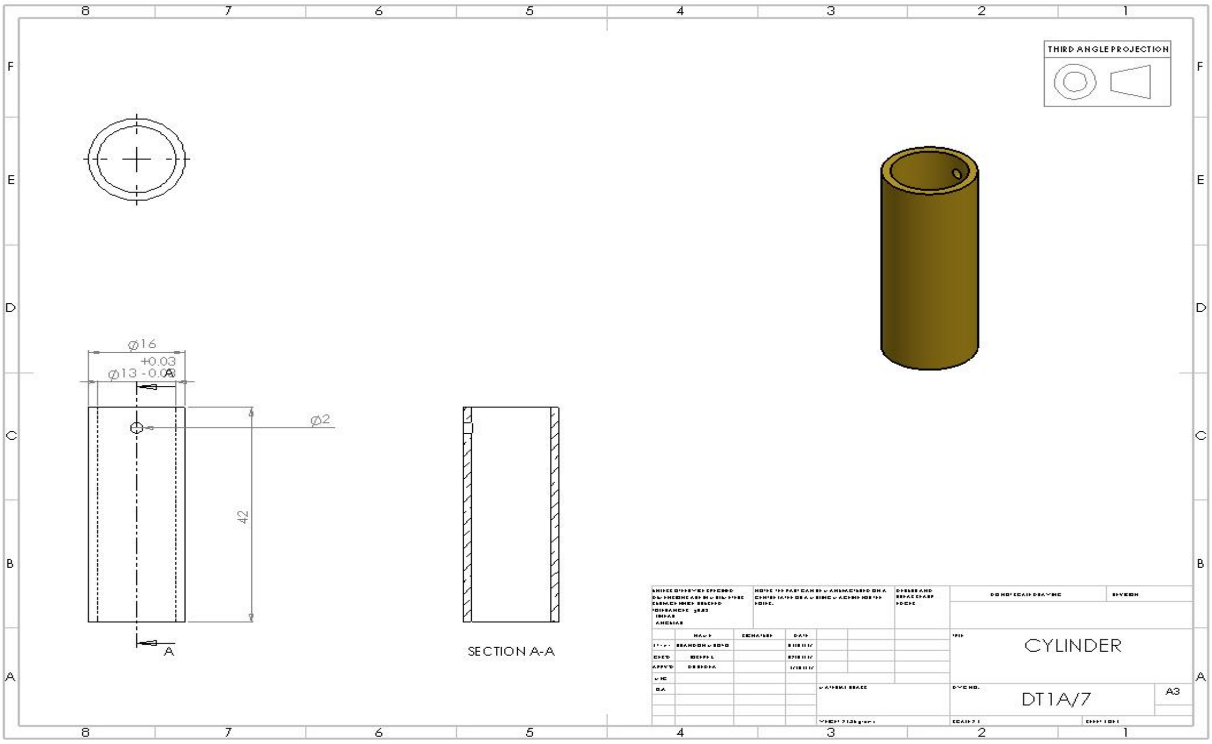


Figure 15 showing fully dimensioned cylinder

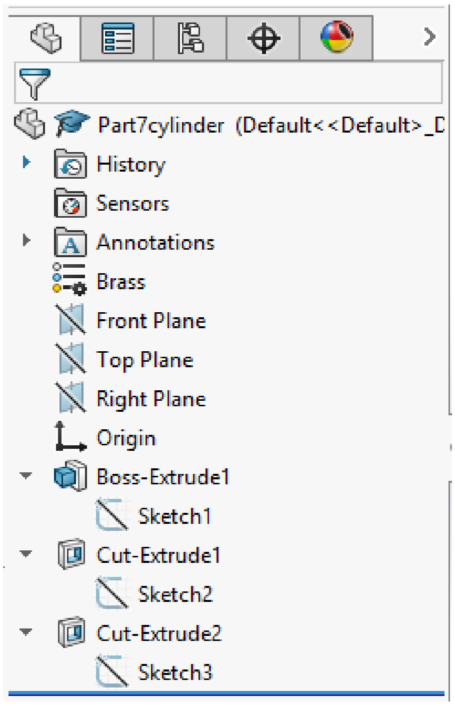


Figure 16 showing cylinder hierarchy

The cylinder is part of the combustion chamber as it houses the piston. Figure 15 shows a fully dimensioned cylinder, 42mm long, 16mm in diameter and 3 mm thick with a 2mm hole drilled through. The top end of the cylinder will hold the cylinder head. Tolerances are indicated in the drawing in figure 15. This part can be made on a lathe and the 2mm hole can then be drilled on a milling machine. Figure 16 shows how the part was constructed. A circle of 16mm in diameter was extruded 42mm long and a smaller circle of 13mm drawn on top as an extruded cut to make the cylinder have 3mm thickness and the a 2mm hole drilled through as an extruded cut. It was constrained in the XY plane. The material chosen is brass of its workability, high corrosion resistance and for its high melting point (900-1000^{0}C), as it will serve as a combustion chamber and it is light.

Weight calculations:

The hand calculated weight for the cylinder:

$$mass\ of\ cylinder = 24.97\ grams$$

8. Head

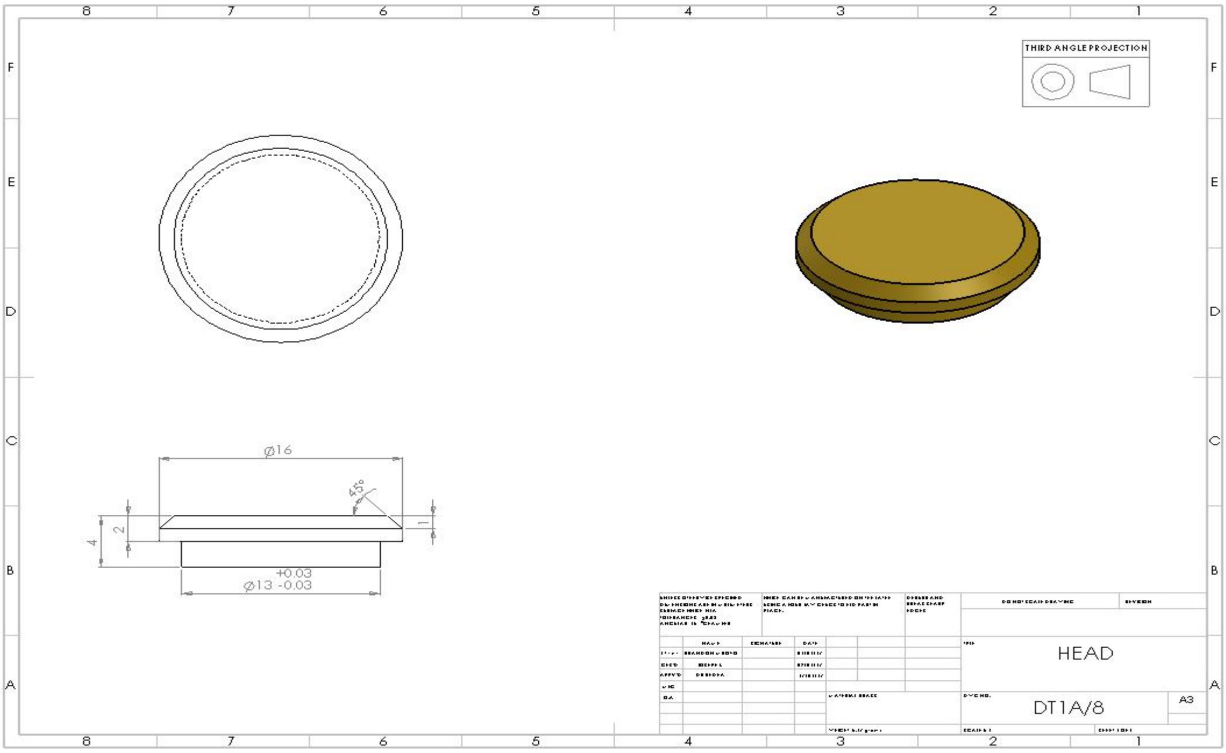


Figure 17 showing fully dimensioned cylinder head

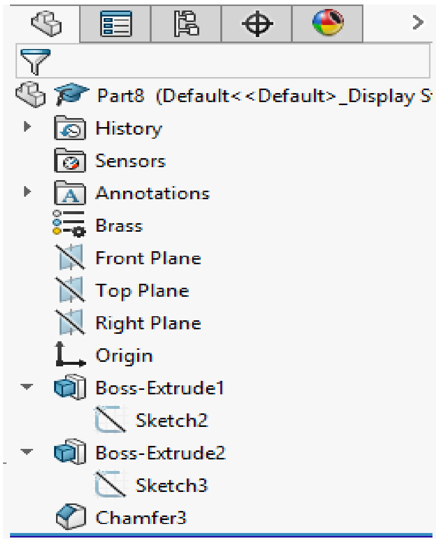


Figure 18 showing hierarchy of

Figure 17 shows a fully dimensioned drawing of the cylinder cap. Figure 18 shows the hierarchy or steps of how the part was constructed. A circle of 16mm in diameter is drawn and extruded to a height of 2mm. then a smaller circle of 13mm in diameter was drawn and extruded to 2mm also. The top extruded circle as shown in figure 17 is chamfered at 45 degrees 1mm down. The tolerance is indicated on the drawing and it was constrained on the ZX (top plane) plane. The material chosen for this part is brass because of its machinability, its high corrosion and temperature resistance, its high wear resistance and it is a low friction material.

Weight calculations:

$$volume\ of\ top = \pi \times 8^2 \times 2 = 402.124mm^3$$

$$volume\ of\ bottom = \pi \times 6.5^2 \times 2 = 265.46mm^3$$

$$total\ volume = 402.124 + 265.46 = 667.58mm^3 \equiv 0.668cm^3$$

$$Density\ of\ brass = 8.73\ g/cm^3$$

$$mass\ of\ head = 8.73 \times 0.668 = 5.832\ grams$$

9. Piston

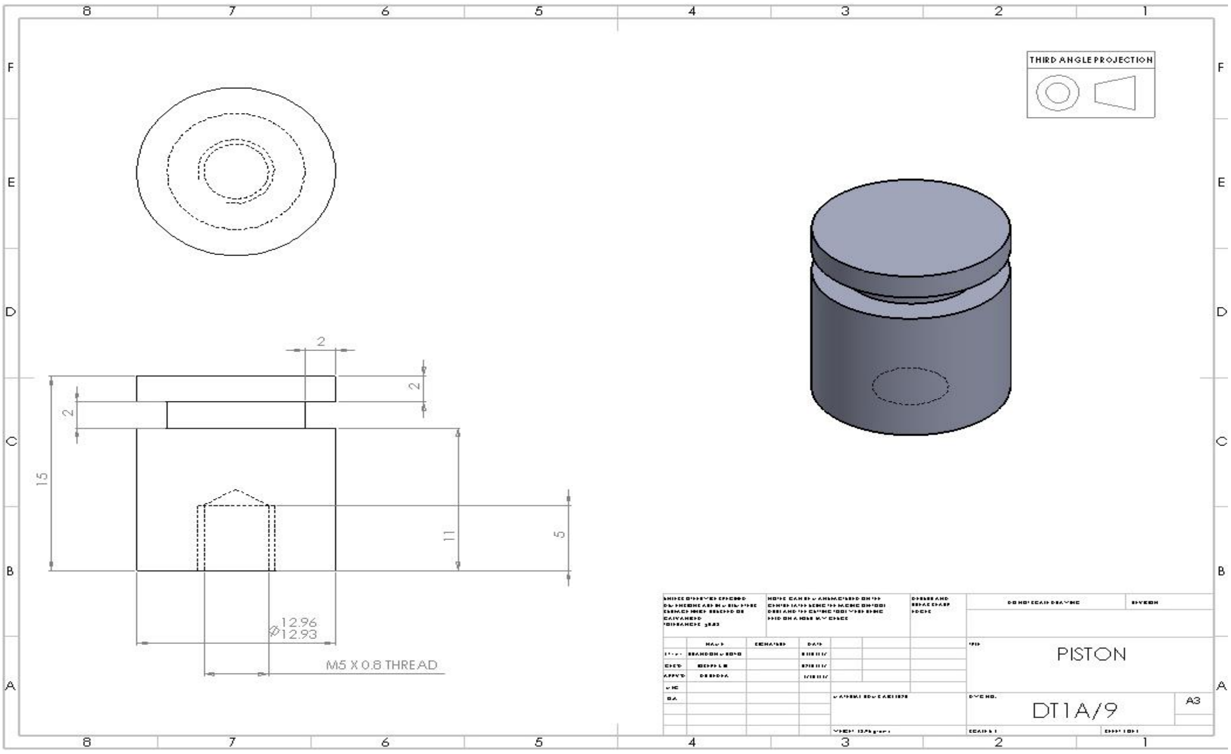


Figure 19 shows fully dimensioned piston

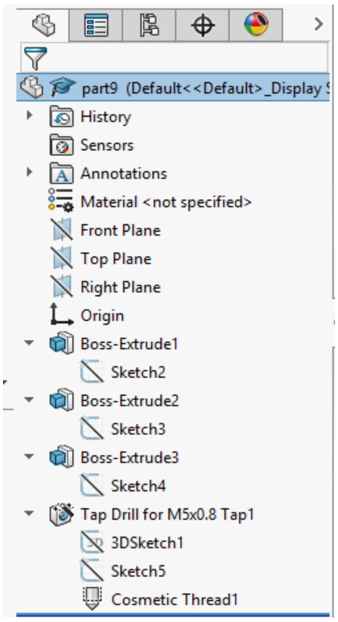


Figure 20 shows hierarchy of piston

The piston was designed according to the dimensioned drawing in figure 19. It shows a 12.96±0.03 mm circle extruded to 2mm then a smaller circle of diameter 10mm extruded to a height of 2mm and then the 12.96±0.03mm circle extruded to 11mm. the hole wizard as shown in figure 20 was used to create the 5mm threaded hole for the connecting rod to be screwed in. The material allocated to this part is the AISI 1020 or bright drawn mild steel. This material was chosen because of its machinability, high strength, high ductility and temperature resistant. The part was constrained in the ZX plane. Figure 20 shows how the part was designed using complex 3D techniques on solid works. The part can b machined on a centre lathe using the turning tool for the smaller circle, facing off tool, cutting tool, M5 x 0.8 drill and a tap for threading.

Weight calculations:

The hand calculated weight for this part was given by:

$mass\ of\ piston = 13.99\ grams$

10. Connecting Rod

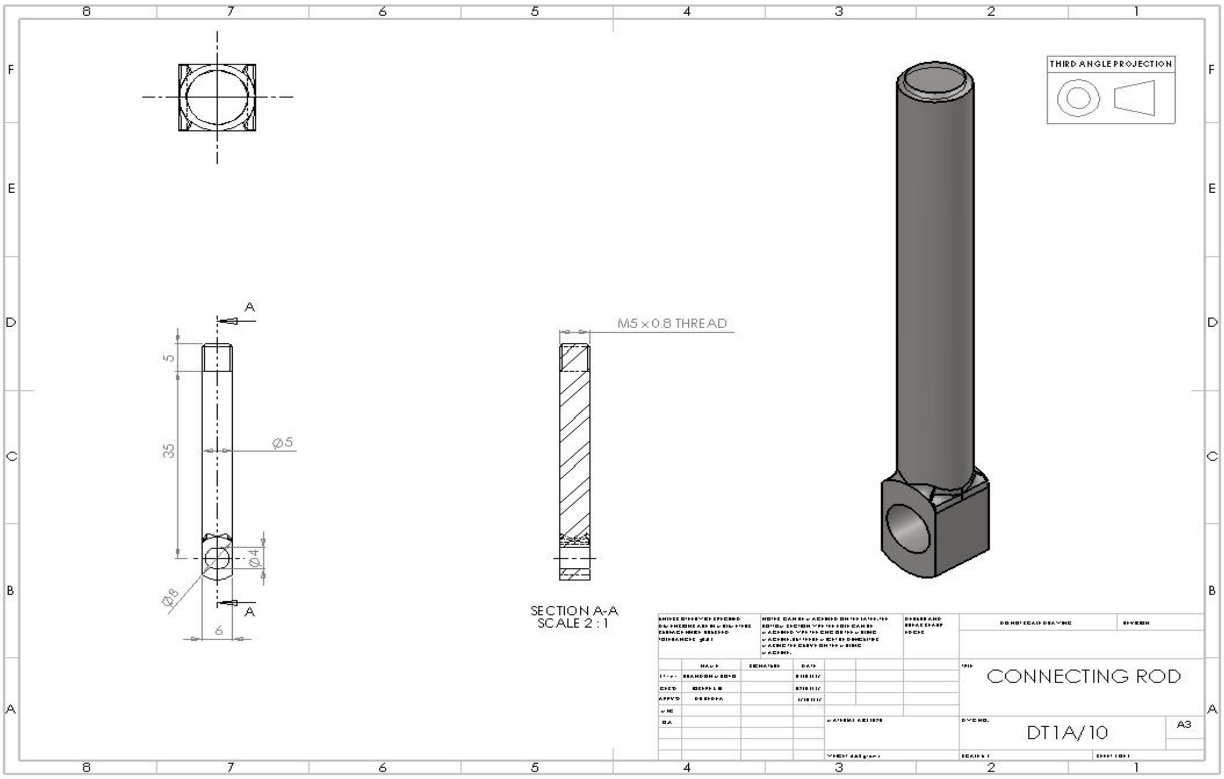


Figure 21 showing fully dimensioned connecting rod

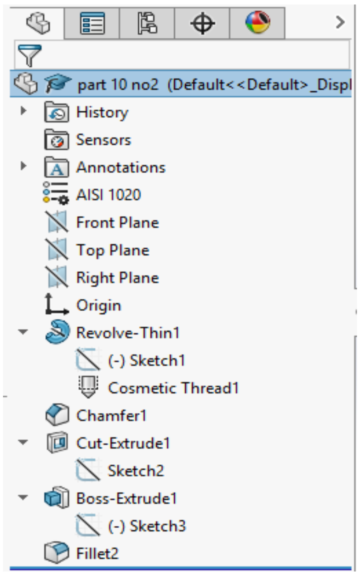


Figure 22 showing how connecting rod was made

Figure 22 shows the detailed 2D third angle orthographic projection of the connecting rod fully dimensioned with a section view. The rod is drawn by first making a circle the extruding to make a cylindrical rod. Then a square was drawn and the extruded and a 4mm diameter hole was cut through the attached drawn square. Then the edges were filleted and then curved. As shown in figure 22 and figure 21shows how the part was made in SolidWorks. The rod is threaded 5mm down and constrained in the ZX plane. The material used is AISI 1020 where the reason is the same as stated above for the material choice. This part can be manufactured on a lathe and then a milling machine for the bottom half of the part.

Weight calculations:

The weight calculated for this part is given as:

$$mass\ of\ connecting\ rod = 7.69\ grams$$

11. Crank Pin

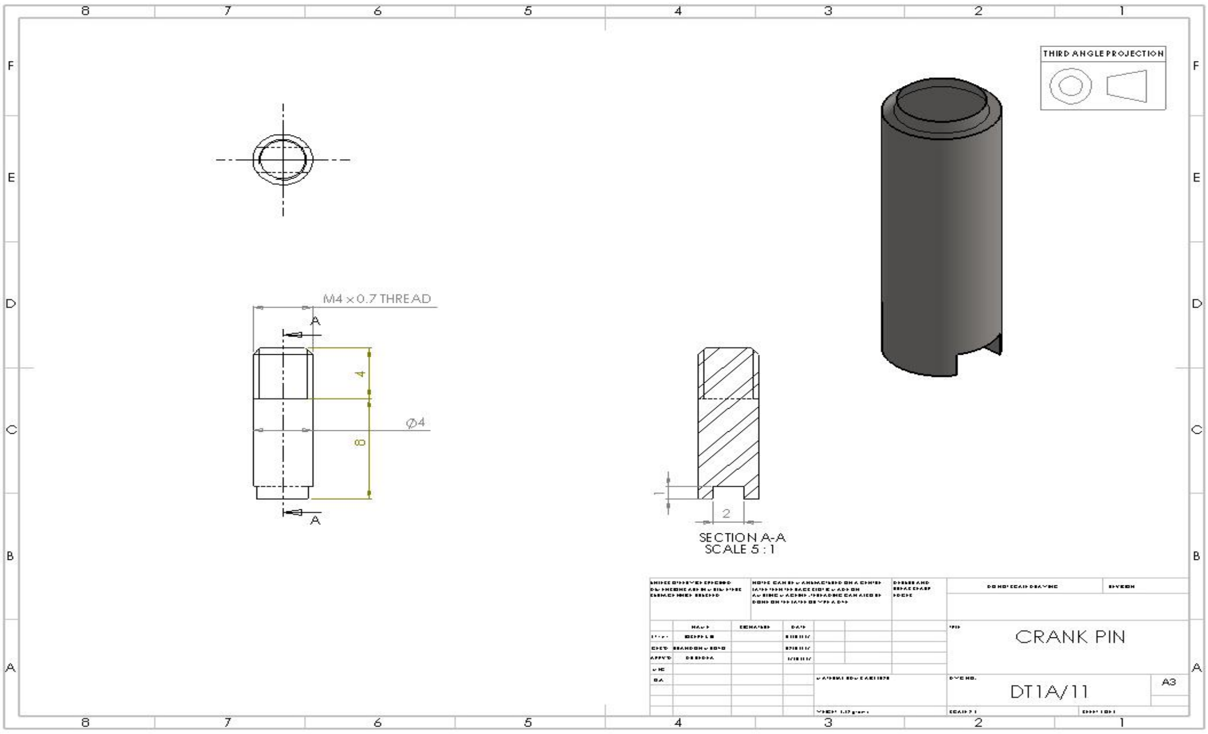
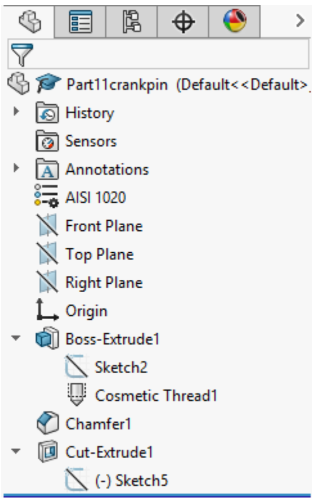


Figure 23 shows a fully dimensioned crank pin



The crank pin is used to lock the connecting rod into the crank web. This part is mad from extruding a circle of 4mm in diameter to a length of 12mm. the crank pin is then threaded 4mm as shown in figure 23. Then as with the grub screw, a centre rectangle 2mmx1mmx1mm was used to cut the bottom part of the material. The screw is also chamfered and constrained in the YX plane. The material the part is made from as shown in figure 24 is AISI 1020 mild steel because of the low wear properties and its strength. Can be threaded and chamfered on the centre lathe and then the slot cut using the cutting tool on the milling machine.

Figure 24 showing geometric hierarchy of crank pin

Weigh calculations:

$$volume\ of\ extruded\ cylinder = \pi \times 2^2 \times 12 = 150.796mm^3$$

$$volume\ of\ slot = \pi \times 1^2 \times 1 = 3.142mm^3$$

$$total\ volume\ of\ crank\ pin = 150.796 - 3.142 = 147.654mm^3 \equiv 0.1477cm^3$$

$$Density\ of\ AISI\ 1020 = 7.9\ g\ /\ cm^3$$

$$mass\ of\ crank\ pin = 7.9 \times 0.1477 = 1.17grams$$

12. Crank web

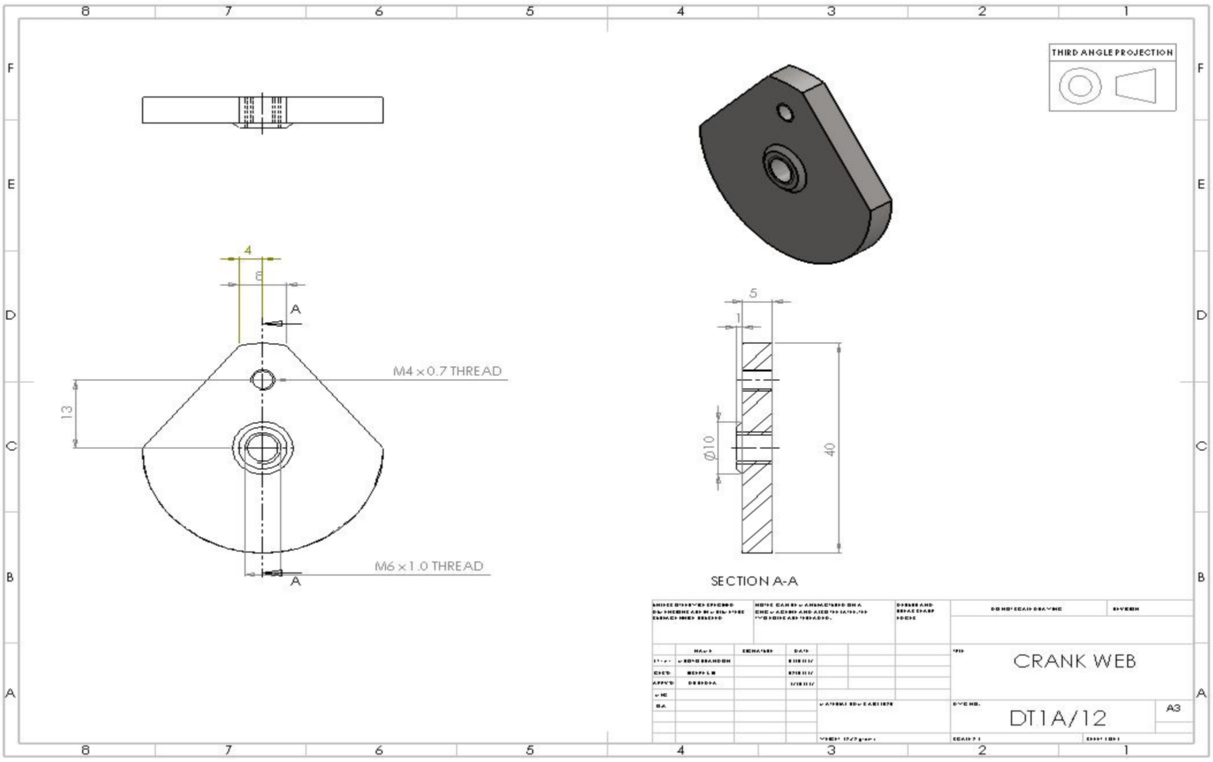


Figure 25 showing fully dimensioned crank web

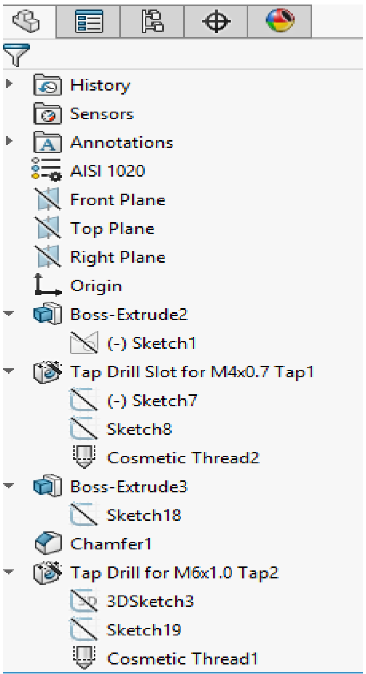


Figure 26 showing crank web hierarchy

The crank web as figure 25 suggests show a conical shape with two holes. The top hole is for the crank pin to connect to the connecting rod and the middle hole is for the crank shaft to be screwed in. both holes are threaded and the sizes indicated above. Figure 26 shows how the crank web was designed on SolidWorks where a full circle was drawn and then two chord lines extended from the middle of the circle to the to end such that the distance between the chord line is 8mm. all other unwanted lines or shapes were trimmed using trim entity function. Then the shape was extruded. The two circles were then drawn and extruded, then threaded. The shape is constrained in the YX or front plane. The part is made from mild steel AISI 1020 because of properties stated earlier as shown in figure 26. Can be machined on a milling machine.

Weight calculations:

The calculated weight for the crank web:

$$mass\ of\ crank\ web = 33.475\ grams$$

13. Bearing housing

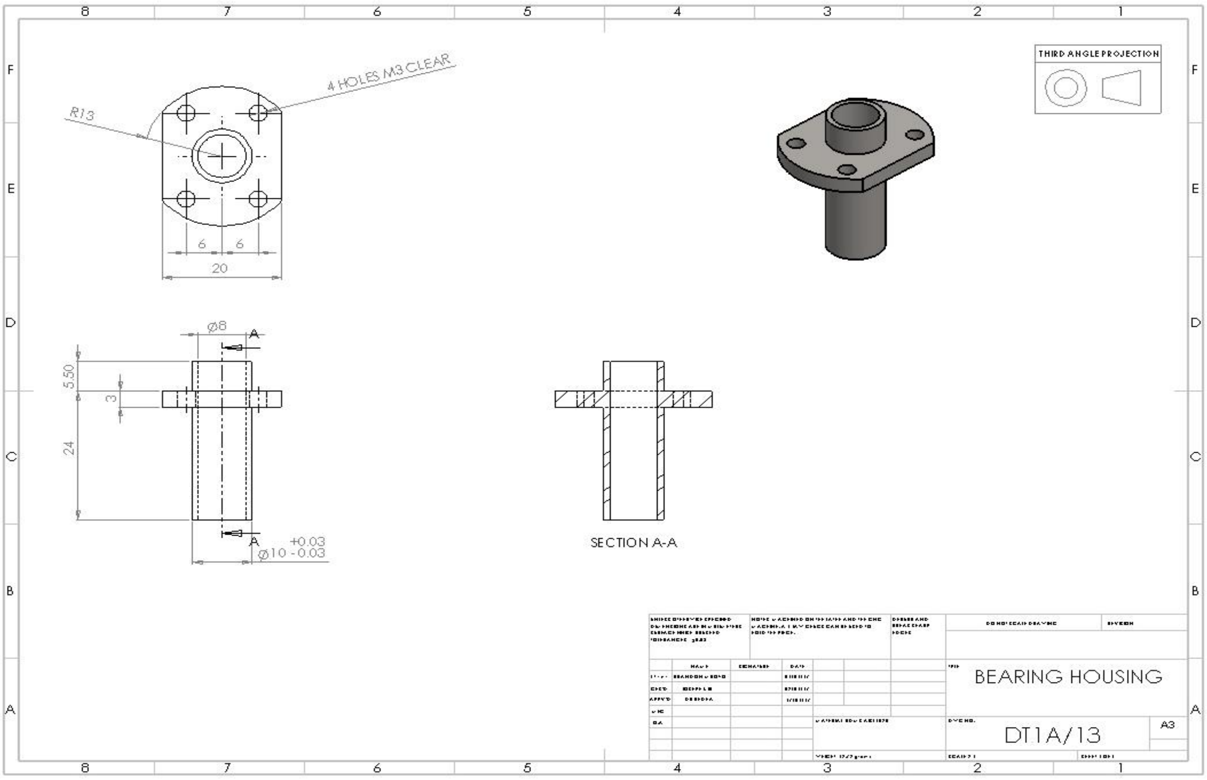


Figure 27 showing fully dimensioned bearing housing

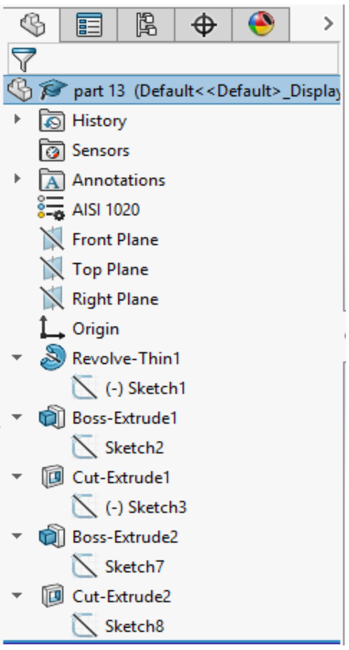


Figure 28 showing the geometry hierarchy of bearing housing

The bearing housing was a circle drawn and extruded 24mm and another circle was drawn and connected using chord lines at both ends and the circle trimmed given the shape shown in the plan view in figure 27. The new generated shape was extruded then an extruded cut by drawing a smaller circle. The hole wizard tool was used to create the 4 M3 clear holes. Also, there is a tolerance on the elongated tube on the part for the bearing. Figure 28 shows how the part was constructed on SolidWorks, it also shows that mild steel, AISI 1020. This part is best machined on the lathe to drill the central hole to fit the bearings for the crankshaft. The rest of the operations such as making the curves and drilling the 4 M3 holes can be done on a milling machine. The part was drawn on the top plane suggesting the part is constrained on the ZX plane.

Weight calculations:

The calculated weight calculated for the part is given as:

$$mass\ of\ bearing\ housing = 18.91\ grams$$

14. Bush

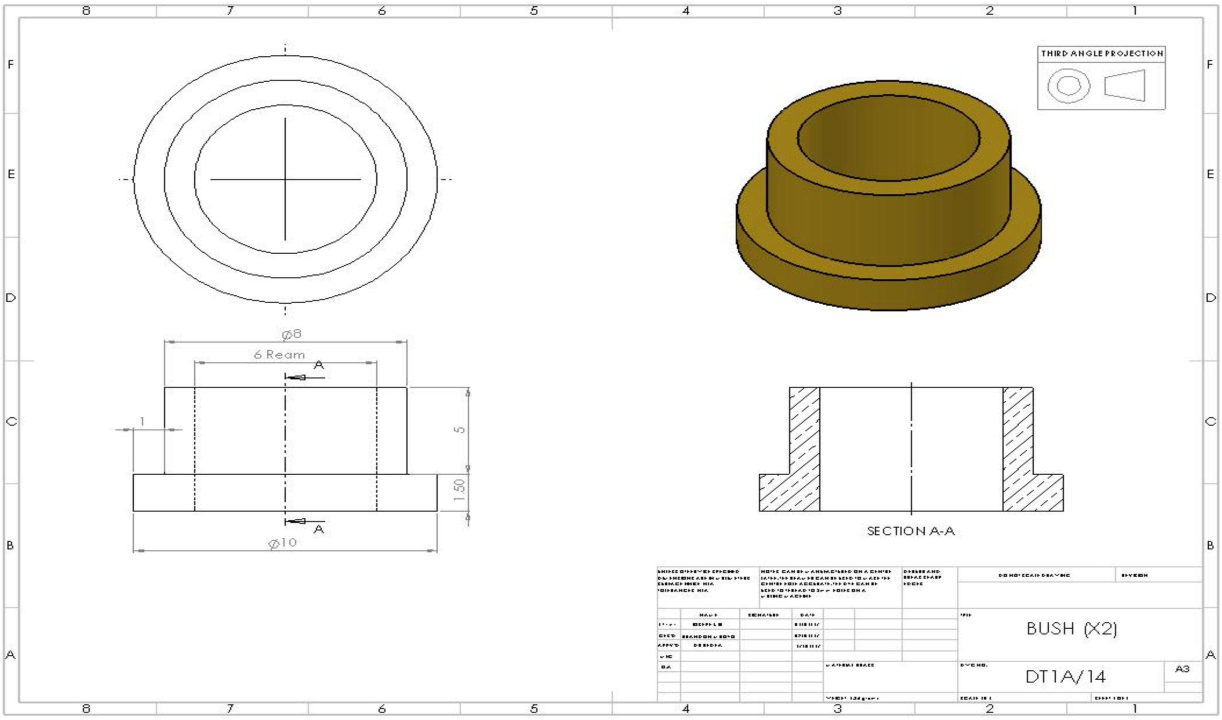


Figure 29 showing a fully dimensioned brass bush

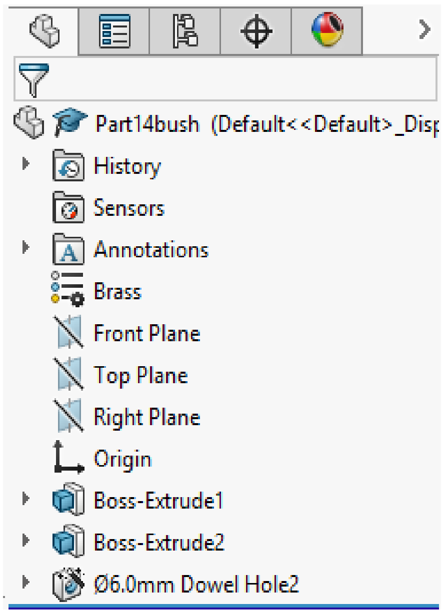


Figure 30 showing hierarchy of bush

The bush follows the dimensions shown in figure 29. It is constrained in the top plane or the ZX plane. A circle was drawn and extruded to a height of 1.5mm having a diameter of 10mm, another circle drawn on the first having a diameter of 8mm with a height of 5mm. Smaller circle of 6mm in diameter is then drawn and extruded cut through the entire part. The material the bush is made from is brass because of its low friction and smooth surface properties to give a free flowing rotational motion. This part can be machined on a centre lathe and two of these are made. Figure 30 shows a breakdown of the part construction.

Weight calculations:

$$volume\ of\ top\ cylinder = \pi \times 5^2 \times 1.5 = 117.8mm^3$$

$$volume\ of\ bottom\ cylinder = \pi \times 4^2 \times 5 = 251.33mm^3$$

$$volume\ of\ hole = \pi \times 3^2 \times 6.5 = 183.78mm^3$$

$$total\ volume = 117.8 + 251.33 - 183.78 = 185.35mm^3 \equiv 0.1854cm^3$$

$$mass\ of\ bush = 8.73\ g\backslash cm^3 \times\ 0.1854\ cm^3 = 1.62\ grams$$

15. Pipes

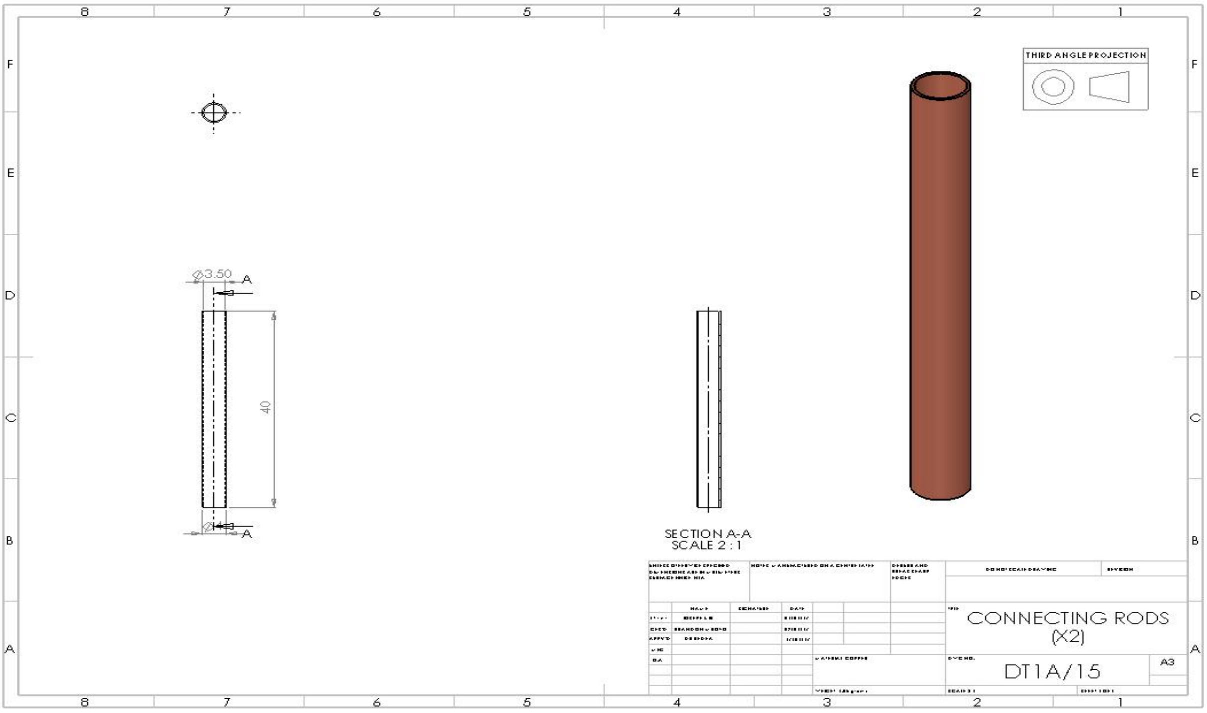


Figure 31 showing pipes dimensions

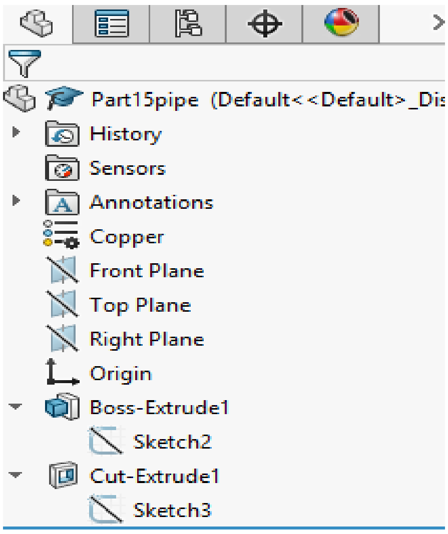


Figure 32 showing pipe hierarchy

The pipe is made from copper as it is light, easily machined and ductile with high thermal properties for gas inlet and outlet when the engine is operational. The part was constrained in the YX plane. A circle of diameter of 4mm was sketched and then extruded to a height of 40mm. A smaller circle of diameter 3.5mm was sketched on the extruded part and made to be an extruded cut through the rod, making a pipe having a thickness of 0.5mm. This component can easily be machined on the centre lathe.

Weight calculations:

$$Density\ of\ copper = 8.92\ g\ per\ cm^3$$

$$volume\ of\ cylinder = \pi \times 2^2 \times 40 = 502.65mm^3$$

$$volume\ of\ hole = \pi \times 1.75^2 \times 40 = 384.85mm^3$$

$$total\ volume\ of\ pipe = 502.65 - 384.85 = 117.8mm^3 \equiv 0.1178cm^3$$

$$mass = 8.92 \times 0.1178 = 1.05\ grams$$

16. Spring

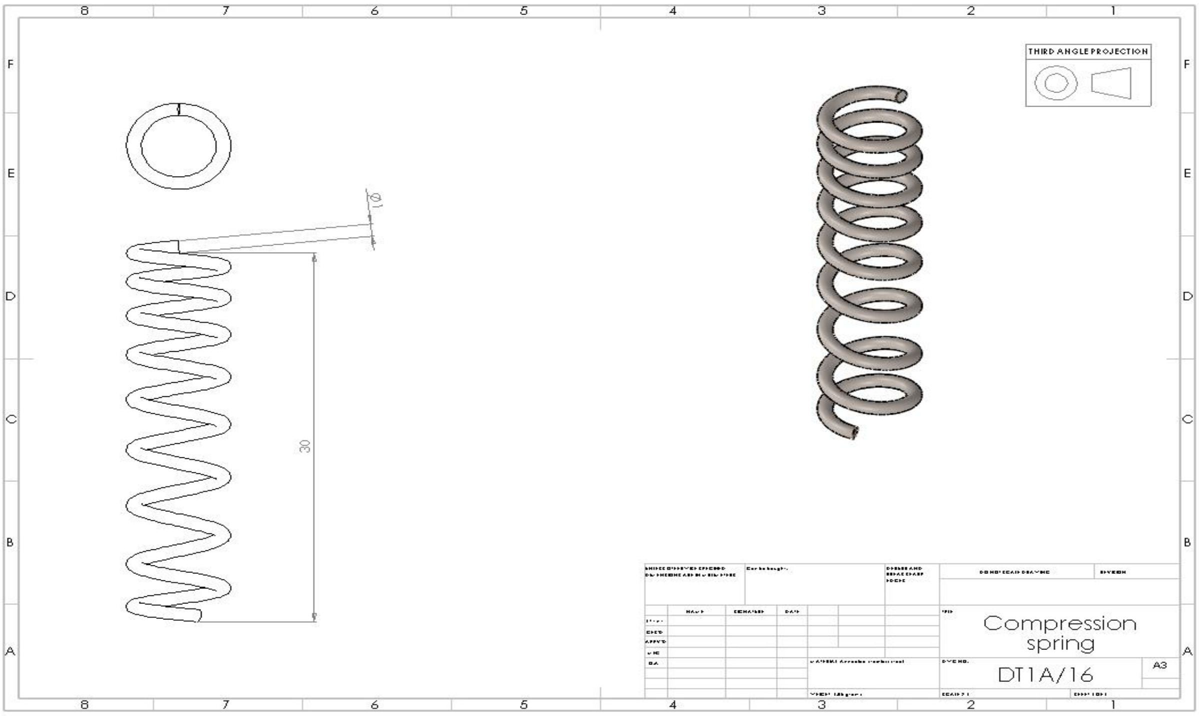


Figure 33 showing full dimensioned spring

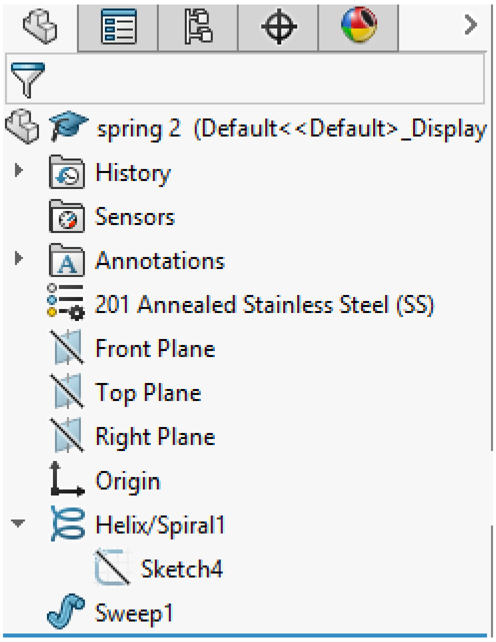


Figure 34 showing hierarchy of part

The spring is made from stainless steel which is annealed to make the spring softer and less stiff and more elastic which are the properties required for a spring. The pitch is 5mm and 7-8 revolutions and a diameter of 6mm, having a height as shown in figure 33 30mm. Figure 34 shows how the spring was constructed using advanced 3D techniques on SolidWorks with functions like helix/spiral and sweep.

Weight calculations:

The weight calculated for the spring;

$$mass\ of\ spring = 1.01\ grams$$

17. Knurled Nut

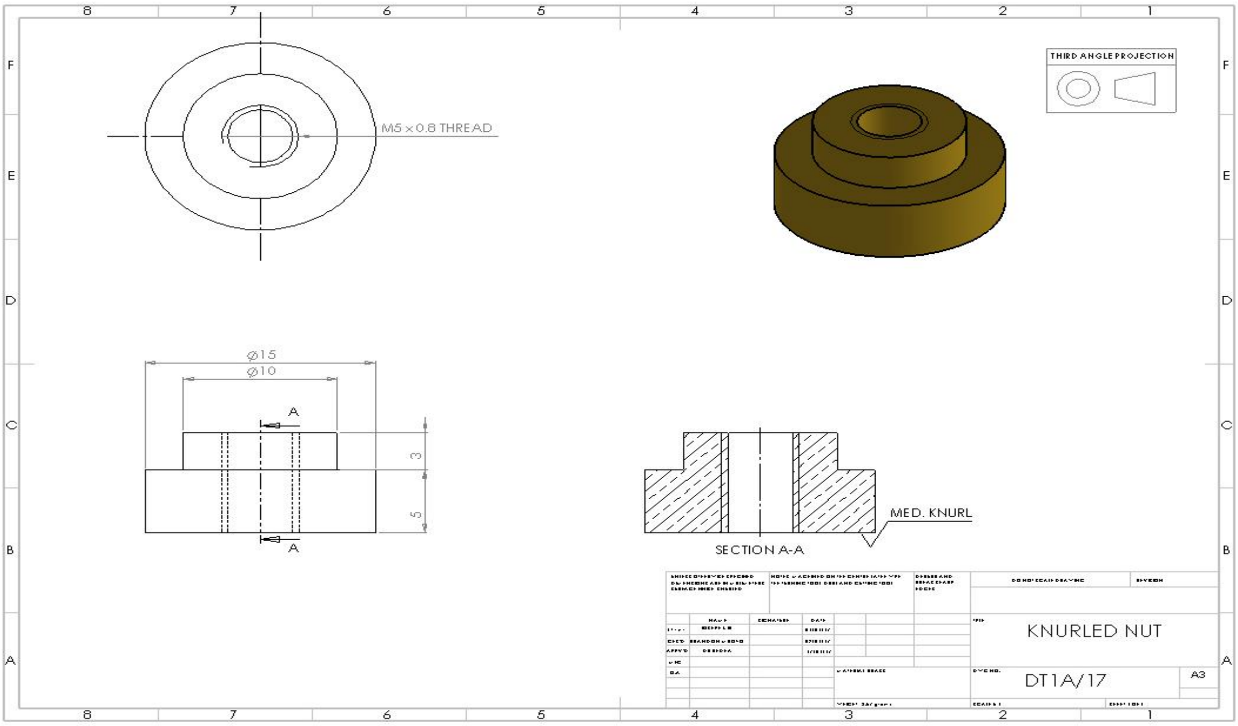


Figure 35 showing fully dimensioned knurled nut

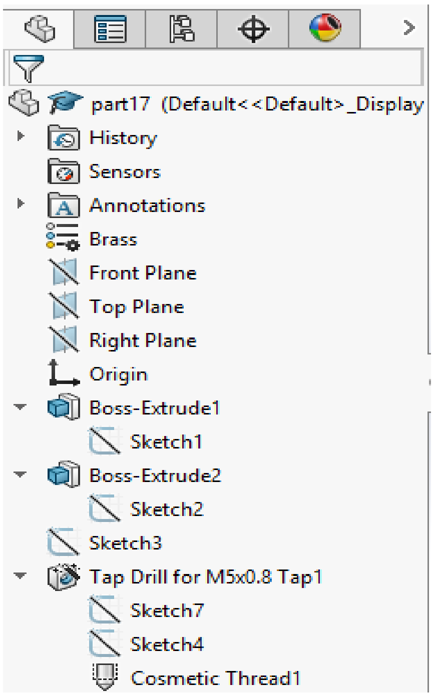


Figure 36 showing knurled nut hierarchy

The knurled nut was drawn with the same method as the brass bush. The part is constrained in the ZX plane. It is a circle drawn and extrude with a smaller circle on top with an extruded cut which is threaded with the sizes specified in figure 35. The part is made from brass because of the same reasons discussed in section 14. The part can be machined and threaded on the centre lathe. This part is connected to the cylinder pivot.

Weight calculations:

The calculated weight of this part is:

$$mass\ of\ kurled\ nut = 8.4\ grams$$

18. Cylinder Pivot

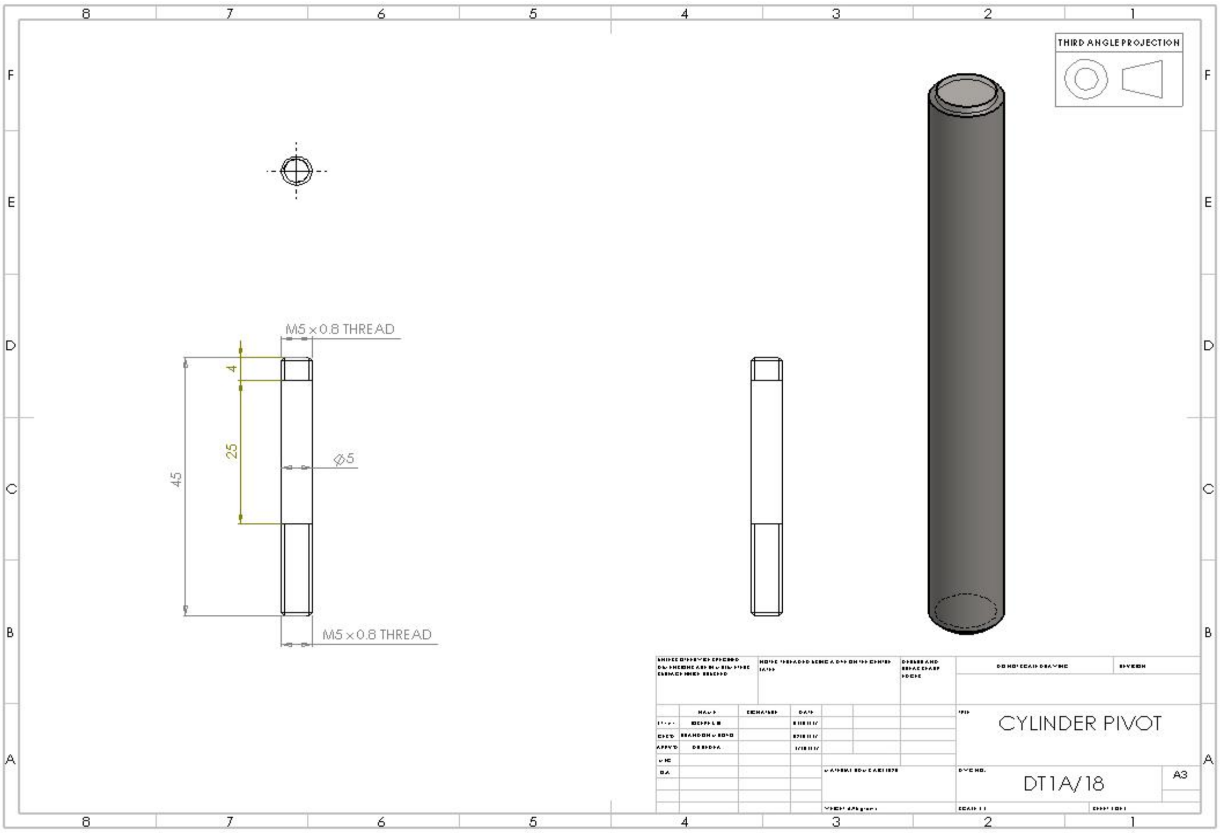


Figure 37 showing a fully dimensioned cylinder pivot

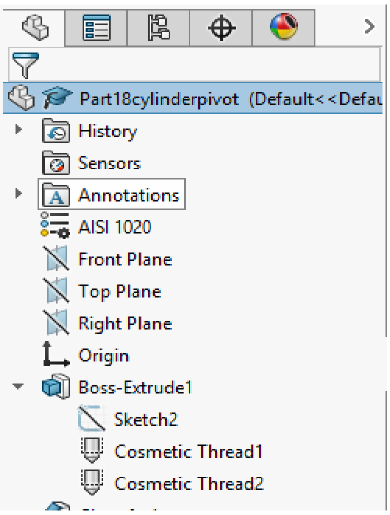


Figure 38 shows part hierarchy

This part is a circle drawn having a diameter of 5mm and extruded to give a length of 45 mm. One end s shown in figure 37 is threaded 4 mm down, while the other end is threaded 16mm. The top is to be screwed into the back plate while the other threaded end is for the knurled nut to be screwed into the cylinder pivot. Figure 38 shows how the part was construct and the material it is made from is AISI 1020. Can be easily machined on a centre lathe. The cosmetic thread function is used to give a thread annotation in the drawing without applying an actual thread to the designed part

Weight calculations:

$$volume\ of\ ylinder\ pivot = \pi \times 2.5^2 \times 45 = 883.57mm^3 \equiv 0.884cm^3$$

$$Mass\ of\ cylinder\ pivot = 7.9 \times 0.884 = 6.98\ grams$$

Assembly

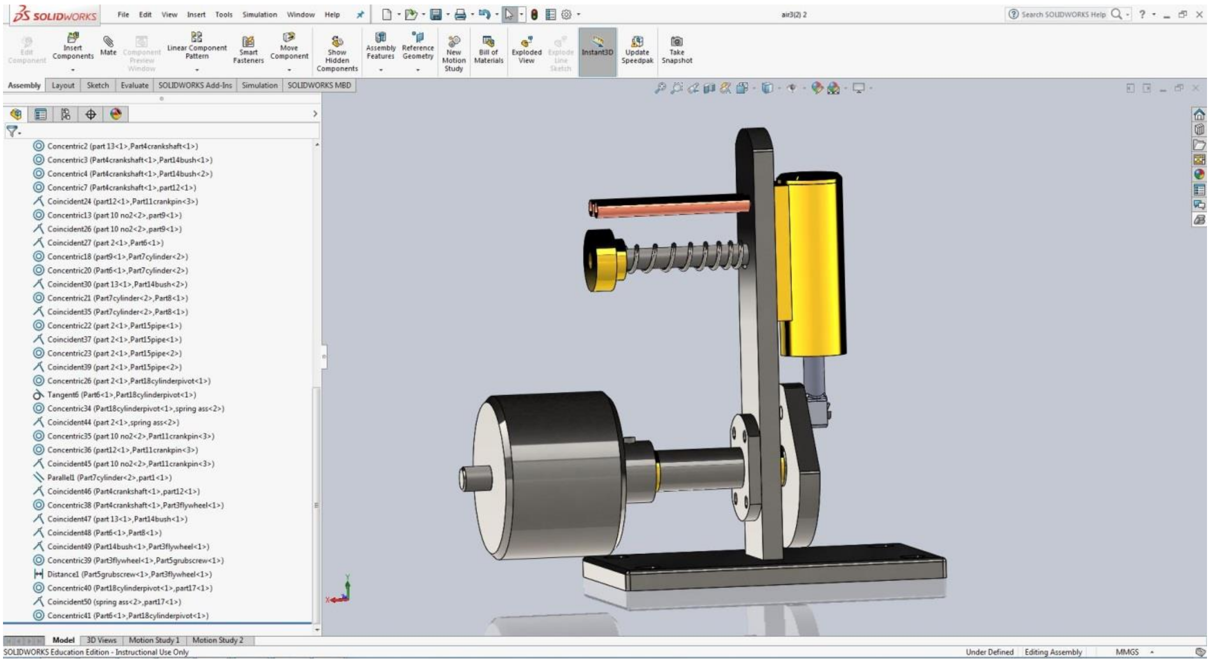
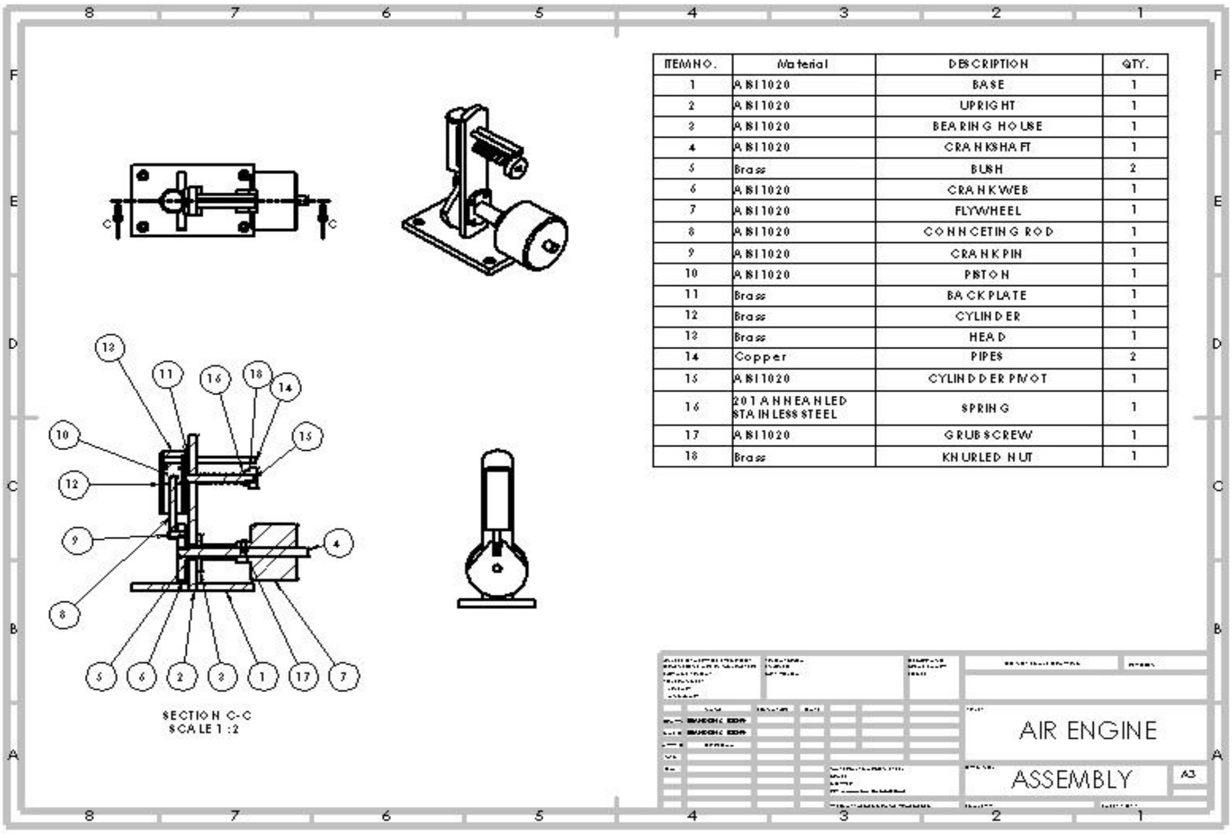


Figure 39 showing a fully assembled 3D air engine



ITEM NO.	Material	DESCRIPTION	QTY.
1	AISI 1020	BASE	1
2	AISI 1020	UPRIGHT	1
3	AISI 1020	BEARING HOUSE	1
4	AISI 1020	CRANKSHAFT	1
5	Brass	BUSH	2
6	AISI 1020	CRANKWEB	1
7	AISI 1020	FLYWHEEL	1
8	AISI 1020	CONNCETING ROD	1
9	AISI 1020	CRANKPIN	1
10	AISI 1020	PISTON	1
11	Brass	BACKPLATE	1
12	Brass	CYLINDER	1
13	Brass	HEAD	1
14	Copper	PIPES	2
15	AISI 1020	CYLINDDER PIVOT	1
16	201 ANNEANLED STAINLESS STEEL	SPRING	1
17	AISI 1020	GRUBSCREW	1
18	Brass	KNURLED NUT	1

Figure 40 showing 2D representation of assembly with bill of materials

For the assembly of the air engine, the first step was to insert the base into SolidWorks assembly so it becomes a fixed point, meaning it does move around and becomes stationary. By doing this the base becomes a starting point for assembling the air engine. The second component which is the upright was inserted to a point where the upright is free to move in any direction, this allow the upright to be mated with the base in the location the upright is supposed to go. By mating the upright edges and faces of the base with coincident mating feature, the upright goes in the slot that has been designed on the base. With this done other components can be inserted and mated so the air engine can come together.

To mate the cylindrical components such as the crank shaft and the bush and screw, the tool used is the concentric mate feature on SolidWorks, this allows the cylindrical pieces to be lined up with where it is supposed to go. For example, the mating of the crank shaft with the bearing housing was done by using the concentric which allows the crank shaft to slide in the bearing house so that the crank shaft was constrained meaning it is only allowed to move in and out of the hole in the centre of the bearing house as seen in figure 39.

By applying the coincident and concentric mate function to the rest of the parts, the components were placed in their desired location with the right constrains which allows the air engine parts move how it so supposed to. When the flywheel spins, the motion is transferred into an up and down motion with the help of the crank web and crank pin. Air is put into the combustion chamber through the right pipe and the left copper pipe as the out let.

Calculation of Total Weight and Cost of Manufacturing the Air Engine

- Weight calculation

Parts	Hand Calculated mass (grams)	CAD generated mass (grams)
1. Base	154.64	153.74
2. Upright	78.98	78.75
3. Flywheel	311.113	300.50
4. Crankshaft	18.99	18.95
5. Grub screw	0.45	0.42
6. Back plate	18.80	17.16
7. Cylinder	24.97	24.35
8. Head	5.83	5.47
9. Piston	13.77	13.95
10. Connecting rod	7.69	6.58
11. Crank pin	1.17	1.12
12. Crank web	33.48	42.72
13. Bearing housing	18.91	15.03
14. Bush	3.24	2.72
15. Pipes	2.1	2.1
16. Spring	1.01	1.01
17. Knurled nut	8.4	8.57
18. Cylinder pivot	6.98	6.95
Total mass =	709.513	699.95

Table 1 showing weight of parts obtained

$$Percentage\ error = \frac{calculated - CAD\ generated}{CAD\ generated} \times 100$$

$$Percentage\ error = \frac{709.513 - 699.95}{699.95} \times 100 = 1.36\%$$

The percentage error above between the hand calculated mass and the CAD generated mass shows that the hand calculated mass is close to the actual CAD generated total mass as the error shown above is 1.36% which is close to zero.

Looking at the Appendix, the cost is shown in USD which was obtained from SolidWorks and then converted into GBP which turns out to have a total of $119.51 (USD), in GBP the total gives approximately £100.

Redesign

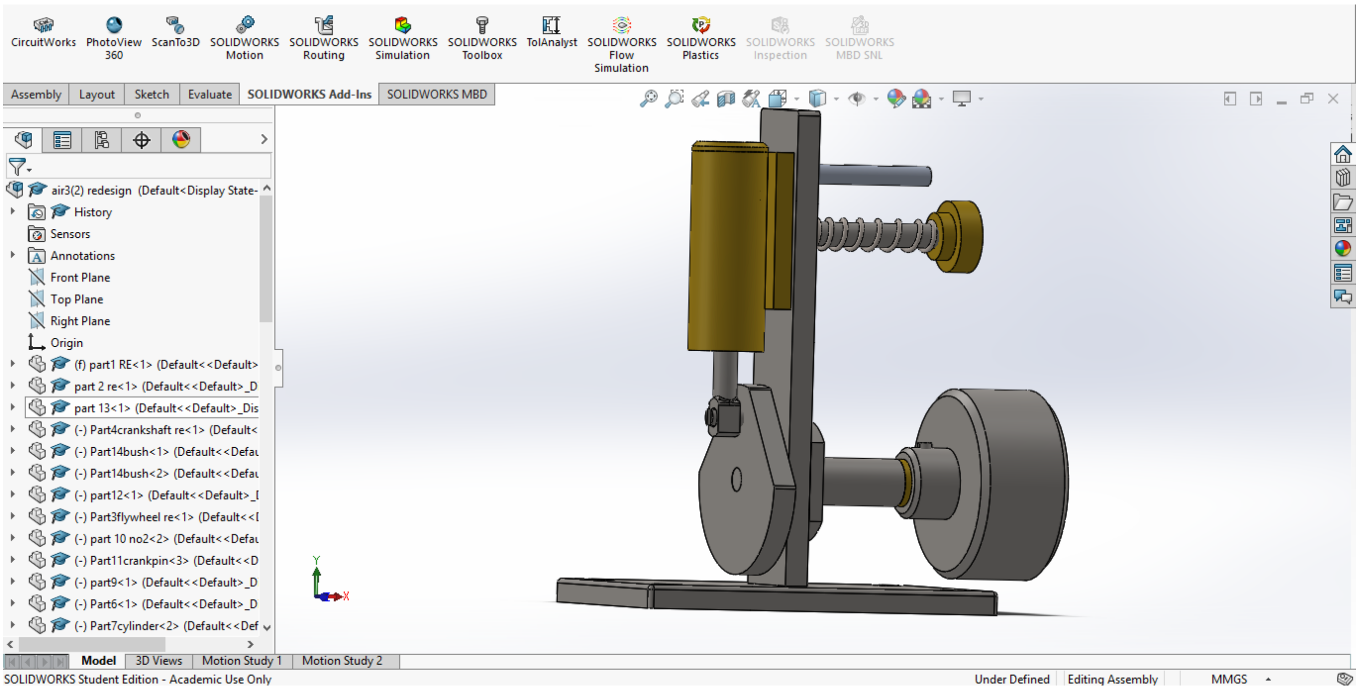


Figure 41 showing redesign or improvements

After long discussions and following the DFMA steps, a decision was made to remove material so the overall weight of the air engine is reduced making it lighter. Also, the edges of all parts of the air engine were filleted so there are there no sharp corners as shown in figure 41.

Another change made was the reduction of the size of the flywheel as there is no need for such a large fly wheel for the engine to function. The length of the upright has been shortened to remove excess unwanted material adding to weight and cost of the product. Likewise, the intake and outlet pipes have also been reduced in length, followed by a change in the material which the pipes are made from. The change is from copper to aluminium alloy because the aluminium alloy is lighter and cheaper and the air engine lighter. By making these changes the production cost and time have been reduce which is a good advantage for large scale production.

Although the redesign is to be done to improve or reduce the geometric complexity, however, when such was tried, it was discovered that the design will no longer behave like an air engine as its structural integrity will diminish due to drastic changes that were initially made. Therefore, to chamfer each edge and make the pipes to be manufactured from aluminium alloy as the answer. The validity of our choice on the method of redesigning the air engine is reinforced as the new SolidWorks generated mass for the modified part is 594.53 grams compared to the initial design which weighed 699.95 grams which is approximately a 20 per cent reduction in weight.

Conclusion

The main aim of this report is to carry out a detailed description in the design of an air engine using complex 3D design techniques. Initially, meetings had to be held and potential designs were discussed to get the most reliable, suitable and economical design of the air engine. The design of the product was done on SolidWorks as stated in the report. Fully dimensioned single part drawings of each component used in the complete and fully operational engine is provided as well as justification of choice of materials the part should be made from.

Since it was noticed that the notes on the 2D orthographic projection of each drawing cannot be seen clearly, most tips on how some of the parts can be manufactured and surface textures and finishes written on the title block cannot be seen. Therefore, where the material used is AISI 1020, copper, aluminium alloy or steel, these parts should be deburred and brushed after being machined to give a smooth and fine surface finish to the part to not only improve the components aesthetics but also the functionality.

The calculations were done to find out a rough estimate of the total weight of the air engine before it was designed. This was then compared to the CAD generated weight to give a percentage error close to zero which indicates that the calculations and methods used were almost accurate. The errors could have come from the rounding up of numbers or getting the wrong values for the density of the materials used during research. The cost of manufacturing a single air engine was also derived with the help of the costing function on SolidWorks which considers all the manufacturing procedures not just material costs.

Also, to maintain the design of the product and at the same time wanting to avoid complications, only minor changes were done to reduce the air engine’s weight and manufacturing cost. As with the redesign section, all sharp edges were chamfered and some pats such as the fly wheel and upright were reduced in size after following DFMA techniques which enables the identification of excess and unwanted materials on a product to reduce weight and manufacturing cost.

Overall, carrying out this task has given a large amount of practice hours on the use of 3D modelling of a product and the design procedures needed to create a fully functional product. It has also lead to exposure and broader understanding of ISO/BSI standard as well as geometric dimensioning and tolerancing.

References

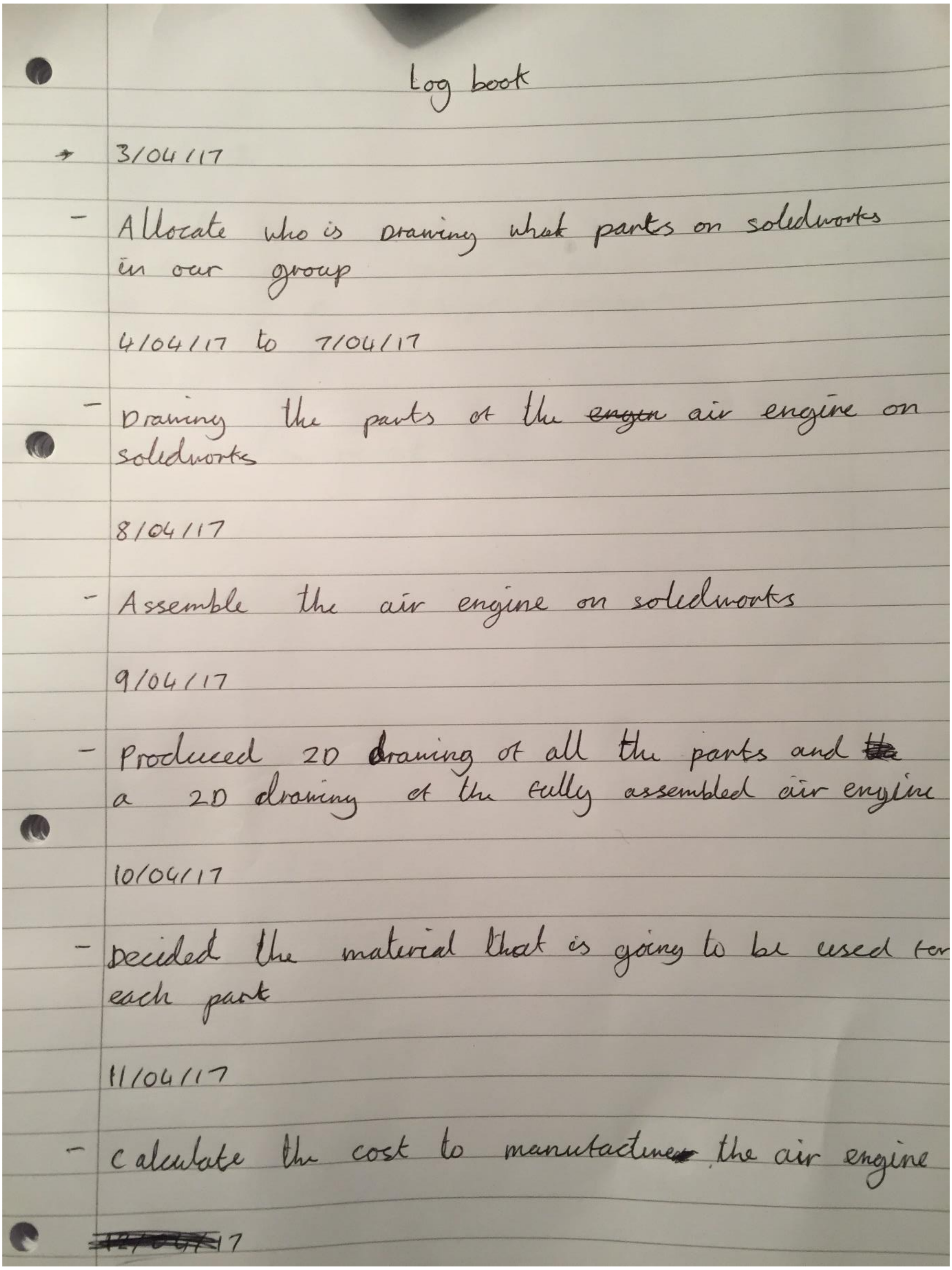
- Simmons, C., Maguire, D. and Phelps, N. (2009). *Manual of engineering drawing*. 1st ed. Oxford [etc.]: Elsevier Newnes.
- Dr B. Redha, Dr J Garcia lecture note 2017.

Contribution

- Brandon Mongo carried out 12 component drawings and did the assembly and redesign on CAD software as discussed. Also, contributed to 40% of the report.
- Joseph Inegbenebor carried out 6 drawings and contributed to 60% of the report and compiling all the work. The researcher and carried out necessary calculations required.

Appendix

Log book



Log book

3/04/17

- Allocate who is drawing what parts on solidworks in our group

4/04/17 to 7/04/17

- Drawing the parts of the ~~engin~~ air engine on solidworks

8/04/17

- Assemble the air engine on solidworks

9/04/17

- Produced 2D drawing of all the parts and ~~the~~ a 2D drawing of the fully assembled air engine

10/04/17

- Decided the material that is going to be used for each part

11/04/17

- Calculate the cost to manufacture the air engine

~~[illegible]~~17

Cost Breakdown for Each Part

Calculated Parts	Method	Quantity	Part Cost (USD/Part)	Total Cost (USD)
Part6 [Default]	Machining	1	8.91	8.91
Part15pipe [Default]	Machining	2	5.86	11.72
Part5grubscrew [Default]	Machining	1	2.80	2.80
Part7cylinder [Default]	Machining	1	11.08	11.08
part17 [Default]	Machining	1	6.04	6.04
Part18cylinderpivot [Default]	Machining	1	2.83	2.83
Part8 [Default]	Machining	1	3.03	3.03
part 2 [Default]	Machining	1	9.04	9.04
part1 [Default]	Machining	1	6.45	6.45
part 13 [Default]	Machining	1	6.53	6.53
part12 [Default]	Machining	1	8.81	8.81
Part3flywheel [Default]	Machining	1	10.73	10.73
part 10 no2 [Default]	Machining	1	5.68	5.68
Part11crankpin [Default]	Machining	1	2.81	2.81
part9 [Default]	Machining	1	5.73	5.73
Part4crankshaft [Default]	Machining	1	2.88	2.88
Part14bush [Default]	Machining	2	5.74	11.47
spring 2 [Default]	Machining	1	2.85	2.85
Total			107.80	119.39