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Design and Development of V-Twin Stirling Engine

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ABSTRACT

This project aims to address environmental issues like air pollution and noise generated by internal combustion (IC) engines through the development of a V-Twin Stirling engine. Stirling engines, which operate through cyclic expansion and contraction of gas via external heat sources, offer a more efficient and cleaner alternative to traditional IC engines. The design leverages a unique mechanism where one piston drives the motion of both pistons using a gear system, reducing fuel consumption and emissions. The project involves comprehensive analysis and design, with the engine components, such as flywheels, gears, and pistons, being meticulously crafted for optimized performance. The development process includes part drawings, weight and volume calculations, and precision manufacturing using aluminum. The Stirling engine's potential to harness renewable energy, integrate into power generation systems, and recover waste heat positions it as a viable alternative for future sustainable automotive technologies. The total project budget is approximately INR 6000, covering materials, manufacturing, and necessary accessories.

Keywords: *Environmental Issues, Air Pollution, Internal Combustion (IC) Engine, V-Twin Stirling Engine*

1. INTRODUCTION

A Stirling engine is a heat engine that is operated by the cyclic expansion and contraction of air or other gas (the working fluid) by exposing it to different temperatures, resulting in a net conversion of heat energy to mechanical work. More specifically, the Stirling engine is a closed-cycle regenerative heat engine, with a permanent gaseous working fluid. *Closed-cycle*, in this context, means a thermodynamic system in which the working fluid is permanently contained within the system. *Regenerative* describes the use of a specific type of internal heat exchanger and thermal store, known as the re-generator Strictly speaking, the inclusion of the re-generator is what differentiates a Stirling engine from other closed-cycle hot air engines.

The Stirling engine was invented by Scotsman Robert Stirling in 1816 as an industrial prime mover to rival the steam engine, and its practical use was largely confined to low-power domestic applications for over a century.

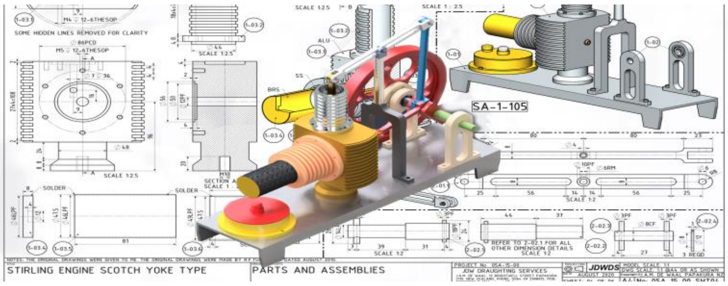


Chart – 1: Fig 01- Stirling Engine

1.1 Problem Statement:

To find a solution to the increasing pollution caused due to exhaust gas emissions and the noise pollution caused due to internal combustion engines.

To find energy efficient replacement to internal combustion engines.

1.2 Benefits:

Compact Design
High Torque
Distinctive Sound
Better Balance

2. LITERATURE REVIEW

2.1 Literature Survey:

1. ***Volume 63***, 2022 Pages 737-744

Title: Study on some aspects of Stirling engine: A path to solar Stirling Engines

Literature Summary:

Stirling engine is a wide field, plenty of research has been done on Stirling engine in past but it is not used to its maximum capacity due to several reasons

Credit Authorship Contribution Statement:

Gaurav Moona: Conceptualization. **Harsh Surana:** Resources. **Hemant Raj Singh:** Supervision, Methodology, Investigation

2. ***Volume 154*****,** July 2020, Pages 581 – 597

Title: Assessment of the Stirling Engine performance comparing two renewable energy sources: Solar Energy and Biomass

Conclusion:

This paper presented an analysis regarding the impact of different renewable energy sources, i.e. solar energy and biomass, in the performance of an alpha Stirling engine for small scale systems. Stirling engines were used in the study because of their technical specifications and because they are suitable technology for single and multi-family residential applications (1-50 KW).

Credit authorship contribution statement:

Ana Cristina Ferreira: Writing – original draft, Formal analysis, Software.
João Silva: Writing – original draft, Formal analysis, Software.
José Carlos Teixeira: Supervision, Funding acquisition.

3. ***Volume 171*****,** 1 September 2018, Pages 1365 – 1387

Title: Technological challenges and optimization efforts of the Stirling machine

Conclusion:

A detailed literature review of the research efforts made on Stirling generators and Stirling refrigerators has been performed. The aim is to provide comprehensive information about these machines.

2.2 Gap Analysis

Conclusion:

From the above journal papers, we can conclude that Stirling Engine is not used to its maximum capacity. There is a lack of use of Stirling engines in the automotive world. Our project aims towards replacing internal combustion engine's in the future with Stirling Engines as Stirling Engines can be much more efficient than I.C. engines.

We can find out the thermal efficiency of Stirling Engine using the given formula:-

$$\eta = 1 - \frac{T_2}{T_1}$$

2.3 Problem Statement

To find a solution to the increasing pollution caused due to exhaust gas emissions and the noise pollution casued due to internal combustion engines.

To find energy efficient replacement to internal combustion engines.

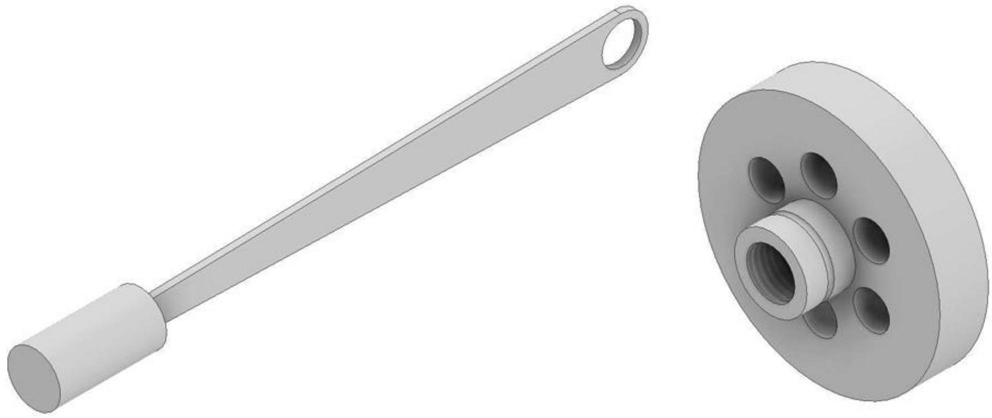


Chart - 2: Fig 2.1 : Parts

3. RESEARCH METHODOLOGY

3.1 Choice of Components

I. **Block Holding Cylinder:** Designed the Block so we could properly fit the cylinder which we require at the exact measure.

II. **Cylinder:** Designed the cylinder of exact measure as we require by the reciprocating motion of the piston so a smooth motion of piston will occur in the cylinder.

III. **Small Piston:** Designed the Piston for the reciprocating motion inside the cylinder which will be produced due to heat source below the cylinder.

IV. **Heat Source:** Camping stove will be used as the heat source so a sufficient amount of heat will be produced which will cause expansion and compression of air in the cylinder which will lead to reciprocating motion of the small piston.

V. **Rectangular Block:** Designed the Rectangular Block to give a support for the shaft and flywheels which will be used further.

VI. **Flywheel:** Designed the Flywheel of desired measure so it should be joined with the small piston as per the requirement as there are holes in the flywheels to use bolts to join the small piston.

VII. **Flywheel with ring:** It will be placed on the opposite side of the first Flywheel and both of them will be connected by a shaft which will pass through the rectangular block.

VIII. **Shaft connecting Flywheel:** Shaft will join both the flywheel so when the piston moves with the reciprocating motion which will cause rotational movement in the flywheel and with the help of shaft the flywheel with ring will also rotate in the same rotational axis.

IX. **Ring:** The Ring attached to flywheel will be welded to the flywheel and it will have a groove cut in it so when the flywheel rotates the ring will also rotate and the groove in it will be working as a conveyor and pulley.

X. **Rubber Band:** The rubber band will be used as a conveyor belt which will be placed in the groove of the ring so when the ring will start rotating the rubber will pull its other end in the same direction of the rotation as per the same direction of the rotation as per the same mechanism which is used in the conveyor belt.

XI. **Gear with Ring:** Designed the gear with the all the measures we needed the diameters, pitch, teeth gap and all other measures the gear will also have a ring attached same as one of the flywheel and ring will have the groove of same depth as of the one before the other end of the rubber band will be placed in this groove and then the rubber will complete the conveyor belt mechanism and will rotate the gear in same direction as of the flywheel.

XII. **Ball Bearings:** For smooth rotation the ball bearings will be attached to both the rings of required diameters which will not disturb the mechanism of rotation.

XIII. **Gear:** Another gear of the same dimensions is going to be used parallel to the first gear so we could get a type of sprue gear. The rotation of the second gear will be opposite to the fist gear due to the mechanism of sprue gear.

XIV. **Crank:** Another gear of the same dimensions is going to be used parallel to the first gear so we could get a type of sprue gear the rotation of the second gear will be opposite to the fist gear due to the mechanism of sprue gear.

XV. **Shaft connecting Gears:** Shaft of required dimensions is designed so both the gears will have a support the shaft will be further welded to the metal sheet.

XVI. **Piston:** Designed the pistons according to the measurements required the piston will consist of it's head, connecting rod, rod cap and holes for bolts the piston will be fitted together with crank at a specific angle just the way it is placed in the engines.

XVII. **Nuts and Bolts:** Nuts and Bolts of different sizes will be used for joining the parts such as small piston with flywheel and pistons with crank.

XVIII. **Split Pin:** Split Pins will be used to keep the parts attached together so they don't move from the exact position which we needed.

XIX. **PVC pipes:** PVC pipes will be used as the cylinder for piston these pipes will be attached to the metal sheet with the help of rods.

XX. **Wooden Planks:** Two wooden planks will be used where both of them will be connected in the L shape to mount the complete project.

XXI. **Metal Sheet:** Metal sheet will be hammered on the wooden plank so the parts will be easily welded and a strong support will be given.

XXII. **Aluminum:** All the parts will be manufactured in aluminum, are light in weight, have a lower density and will be suitable for complete mechanism of the project.

XXIII. **Butane Gas Can:** Butane gas will be used to light up the camp stove.

Table - 1 : Table 3.1: List of Components

NAME	Quantity
Gears	2 N
Rings	2 N
Crankshaft	2 N
Flywheels	2 N
Shafts	3 N
Ball Bearings	1 N
Piston	3 N
Rectangular Block	1 N
Circular Block	1 N
Cylinder	1 N
Plywood	2 N
Rubber Band	1 N
Connecting Rod	3 N
PVC Pipe	2 N
Nuts, Bolts and Split Pin	1 Dozen Each
Camping Stove	1 N
Butane Gas Can	1 N

3.2 Design Calculations and CAD Model:

1. Block Holding Cylinder:

a) Hollow Pipe:

Area of Hollow Pipe:

Formula: $A = \frac{\pi}{4}(D_0{}^2 - D^2{}_1)$

$A = = \frac{\pi}{4}(30^2 - 22.5^2) = 309.25\ mm^2$

Volume of Hollow Pipe:

Formula: $V = A * L$

$V = 309.25\ x\ 40 = 12370\ mm^3$

Weight of Hollow Pipe:

Formula: $w = v * \rho$

$w_1 = 12370 * 0.0027 = 33.399\ gm$

b) Circular Part:

Volume of Circular Part:

Formula: $V = \pi * r^2 * l$

$V = \pi * 15^2 * 40 = 28247.33\ mm^3$

Weight of Circular Part:

Chart - 3: Fig 3.1: Block Holding Cylinder

Formula: $w = v * \rho$

$w_2 = 28247.33 * 0.0027 = 76.26\, gm$

c) Lofted Shaft:

Volume of Lofted Shaft:

Formula: $V = \frac{\pi L}{3}(r^2{}_1 + r_1 r_2 + r^2{}_2)$

$V = \frac{\pi * 35}{3}(15^2 + 15 * 11.25 + 11.25^2) = 19070.44\, mm^3$

Weight of Lofted Shaft:

Formula: $w = v * \rho$

$w_3 = 19070.44 * 0.0027 = 51.49\, gm$

TOTAL Weight:

Formula: $W = w_1 + w_2 + w_3$

$W = 33.399 + 76.26 + 51.49 = 161.14\, gm$

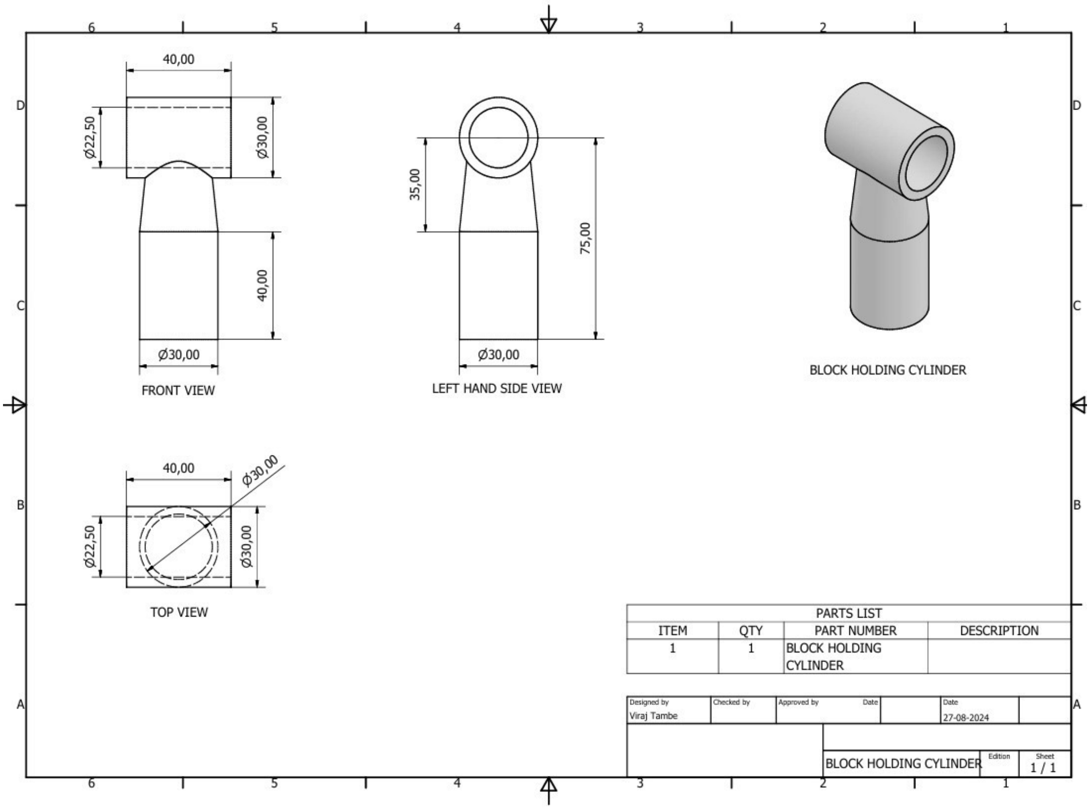


Chart-4: Fig 3.2: Part Drawing of Block Holding Cylinder

2. Bolt for Piston:

Volume of Lower Part:

Formula: $V = \pi * r^2 * l$

$V = \pi * 7.5^2 * 40 = 7068.58\, mm^3$

Weight of Lower Part:

Formula: $w = v * \rho$

$w_1 = 7068.58 * 0.0027 = 19.08\, gm$

Volume of Upper Part:

Formula: $V = \pi * r^2 * l$

$V = \pi * 10^2 * 10 = 3141.59\, mm^3$

Weight of Upper Part:

Formula: $w = v * \rho$

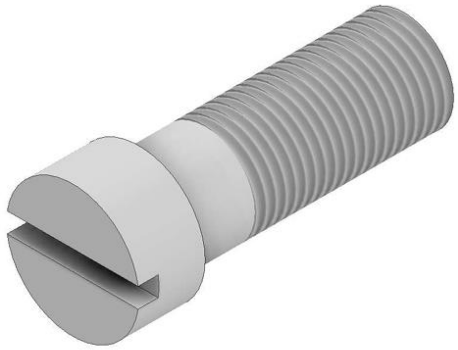
$w_2 = 3141.59 * 0.0027 = 8.48\, gm$

Volume of Rectangular Cut:

Formula : $V = l * b * h$

$V = 3 * 3 * 20 = 180\, mm^3$

Weight of Block:



Formula: $w = v * \rho$

$w_3 = 180 * 0.0027 = 0.486\ gm$

Chart-5: Fig 3.3 : Bolt for Piston

Total Weight:

Formula: $W = w_1 + w_2 + w_3$

$W = 19.08 + 8.48 + 0.486 = 28.04\ gm$

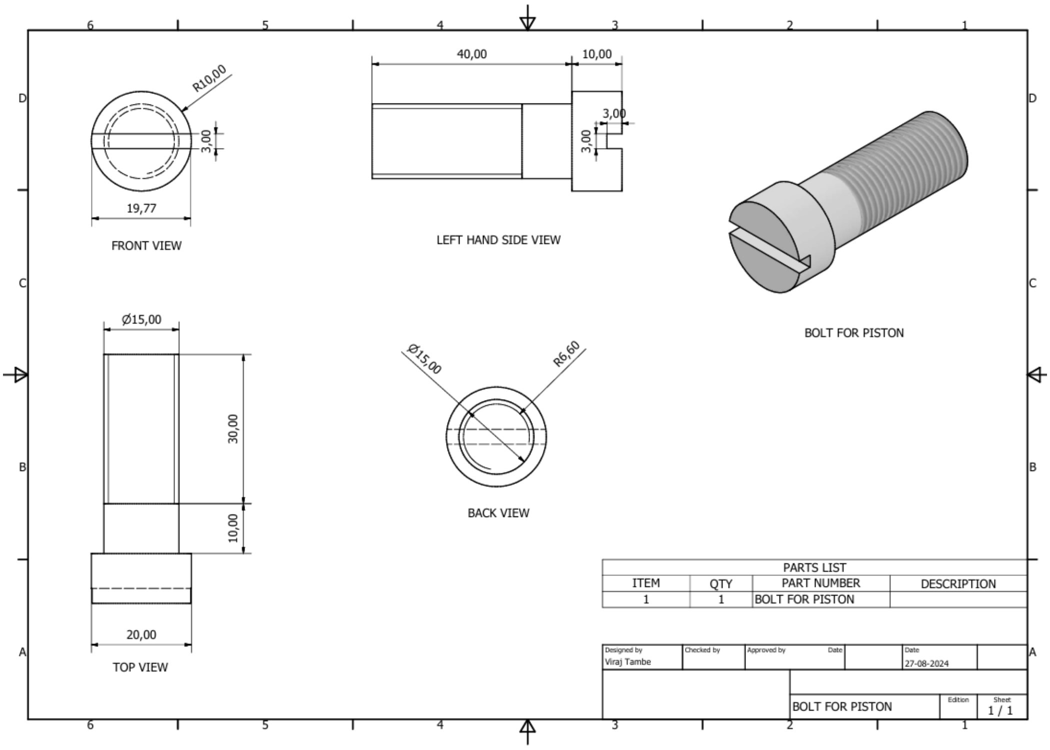


Chart - 6: Fig 3.4: Part Drawing of Bolt for Piston

3. Flywheel:

Volume without Holes:

Formula: $V = \pi * r^2 * l$

$V = \pi * 50^2 * 20 = 157079.63\ mm^3$

Weight without Holes:

Formula: $w = v * \rho$

$w_1 = 157079.63 * 0.0027 = 424.11\ gm$

Volume of centre Holes:

Formula: $V = \pi * r^2 * l$

$V = \pi * 10^2 * 20 = 6283.18\ mm^3$

Weight of Centre Holes:

Formula: $w = v * \rho$

$w_2 = 6283.18 * 0.0027 = 16.96\ gm$

Volume of other Holes:

Formula: $V = \pi * r^2 * l$

$V = \pi * 7.5^2 * 20 = 3534.29\ mm^3$

Weight of other Holes:

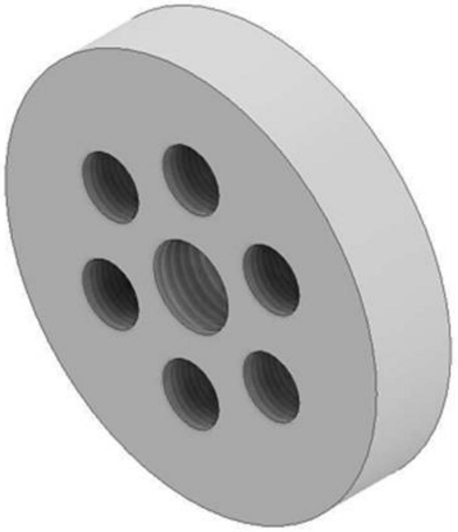


Chart - 7: Fig 3.5 : Flywheel

Formula: $w = 6 * v * \rho$

w_3 = 6*3534.29*0.0027 = 57.24 gm

Total Weight:

Formula: $\boldsymbol{W = w_1 - w_2 - w_3}$

$\boldsymbol{W = 424.11 - 16.96 - 57.24 = 349.91\ gm}$

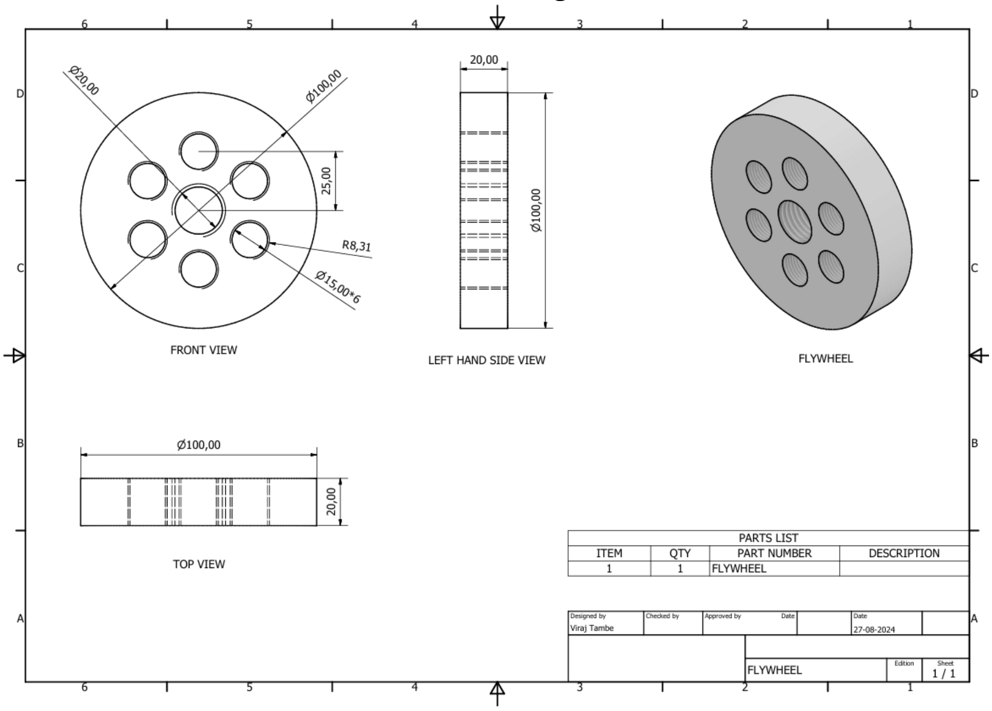


Chart - 8: Fig 3.6: Part Drawing of Flywheel

4. Flywheel with Ring:

a) Flywheel:

Volume without Holes:

Formula: $V = \pi * r^2 * l$

$V = \pi * 50^2 * 20 = 157079.63\ mm^3$

Weight without Holes:

Formula: $w = v * \rho$

$w_1 = 157079.63 * 0.0027 = 424.11\ gm$

Volume of centre Holes:

Formula: $V = \pi * r^2 * l$

$V = \pi * 10^2 * 20 = 6283.18\ mm^3$

Weight of Centre Holes:

Formula: $w = v * \rho$

$w_2 = 6283.18 * 0.0027 = 16.96\ gm$

Volume of other Holes:

Formula: $V = \pi * r^2 * l$

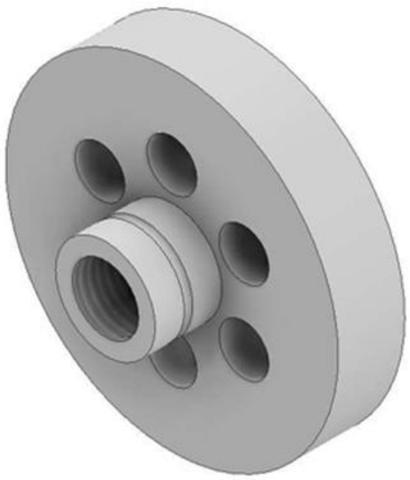


Chart - 9: Fig 3.7: Flywheel with Ring

$V = \pi * 7.5^2 * 20 = 3534.29\ mm^3$

- Weight of other Holes:

  Formula: $w = 6 * v * \rho$

  w_3 = 6*3534.29*0.0027 = 57.24 gm

b) Ring:

- Area of Ring:

  Formula: $A = \frac{\pi}{4}(D_0{}^2 - D^2{}_1)$

  $A = \frac{\pi}{4}(30^2 - 20^2) = 392.69\ mm^3$

- Volume of Ring:

  Formula: V = A * l

  V = 392.69 * 20 = $7853.8\ mm^3$

- Weight of Ring:

  Formula: $w = v * \rho$

  $w_4 = 7853.8 * 0.0027 = 21.20\ gm$

- **Total Weight:**

$$\boldsymbol{Formula: W = w_1 - w_2 - w_3 + w_4}$$

$$\boldsymbol{W = 424.11 - 16.96 - 57.24 + 21.20 = 37.11\ gm}$$

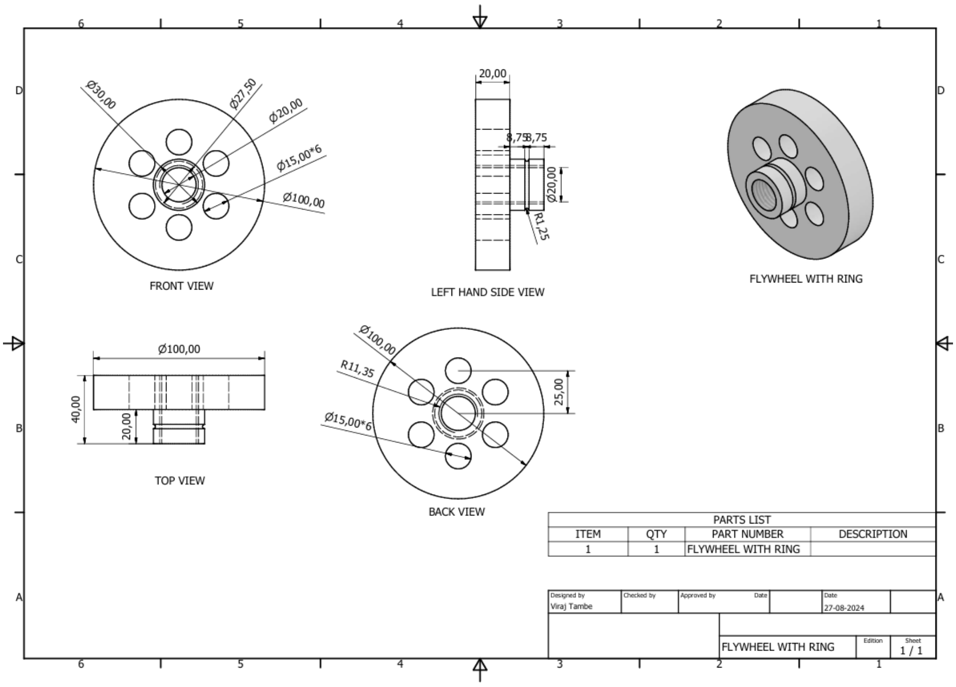


Chart - 10 : Fig: 3.8: Part Drawing of Flywheel with Ring

5. Gear:

a) Gear:

Area of Gear:

1) Area of Outer Circle:

Formula: $A_0 = \pi * {R_G}^2$

$A_0 = \pi * 37.60^2 = 4441.45\ mm^2$

2) Area of Inner Circle:

Formula: $A_I = \pi * {R_I}^2$

$A_I = \pi * 30^2 = 2827.43\ mm^2$

3) Area of Hole:

Formula: $A_h = \pi * R^2{}_h$

$A_h = \pi * 10^2 = 314.15\ mm^2$

4) Area of Teeth:

Formula: $A_T = A_o - A_I$

$A_T = 4441.45 - 2827.43 = 1614.02\ mm^2$

5) Total Area of Gear:

Formula: $A = A_o - A_I - A_h + A_t$

A = 4441.45-2827.43-314.15+1614.02 = 2913.89 mm^2

b) Crank:

Area of Crank with Hole

1) Area of Larger Arc:

Formula: $A_l = \frac{\pi * R^2{}_L}{2}$

$A_l = \frac{\pi * 15^2}{2} = 353.42mm^2$

2) Area of Smaller Arc:

Formula: $A_s = \frac{\pi * {R_S}^2}{2}$

$A_s = \frac{\pi * 7.5^2}{2} = 88.35\ mm^2$

3) Area of Hole:

Formula: $A_h = \pi * R^2{}_h$

$A_h = \pi * 5^2 = 78.53\ mm^2$

- Total Area of Crank with Hole:

Formula: $A = A_l + A_s - A_h$

$A = 353.42 + 88.35 - 78.53 = 363.24\, mm^2$

- Volume of Crank with Hole:

  Formula: $V = A * t$

  $V = 363.24 * 5 = 1816.2\, mm^3$
- Weight of Crank with Hole:

  Formula: $w = v * \rho$

  $w_1 = 1816.2 * 0.0027 = 4.90\, gm$

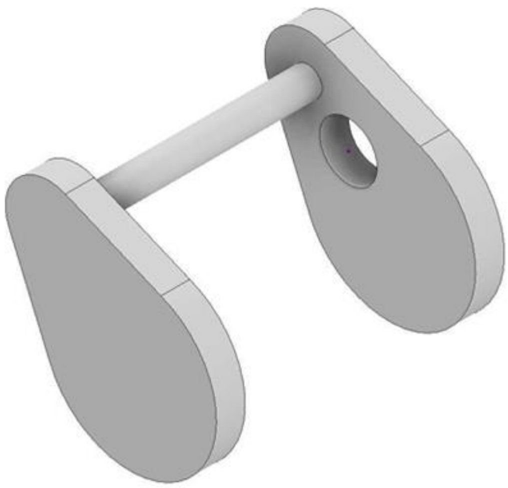


Chart - 11 : Fig: 3.9: Crank Shaft

- Area of Crank:
  1) Area of Larger Arc:

     Formula: $A_l = \frac{\pi * R^2{}_l}{2}$

     $A_l = \frac{\pi * 15^2}{2} = 353.42\, mm^2$
  2) Area of Smaller Arc:

     Formula: $A_s = \frac{\pi * R^2{}_s}{2}$

     $A_s = \frac{\pi * 7.50^2}{2} = 88.35\, mm^2$
  3) Total Area of Crank

     Formula: $A = A_l + A_s$

     $A = 353.42 + 88.35 = 441.77\, mm^2$
- Volume of Crank

  Formula: $V = A * t$

  $V = 441.77 * 5 = 2208.85\, mm^3$
- Weight of Crank

  Formula: $w = v * \rho$

  $w_2 = 2208.85 * 0.0027 = 5.96\, gm$

c) Shaft:

- Volume of Shaft:

  Formula: $V = \pi * r^2 * l$

  $V = \pi * 2.5^2 * 40 = 785.39\, mm^3$
- Weight of Shaft:

  Formula: $w = v * \rho$

  $w_3 = 785.39 * 0.0027 = 2.12\, gm$
- **Total Weight:**

  Formula: $W = w_q + w_1 + w_2 + w_3$

  $W = 157.35 + 4.90 + 5.96 + 2.12 = 170.33\, gm$

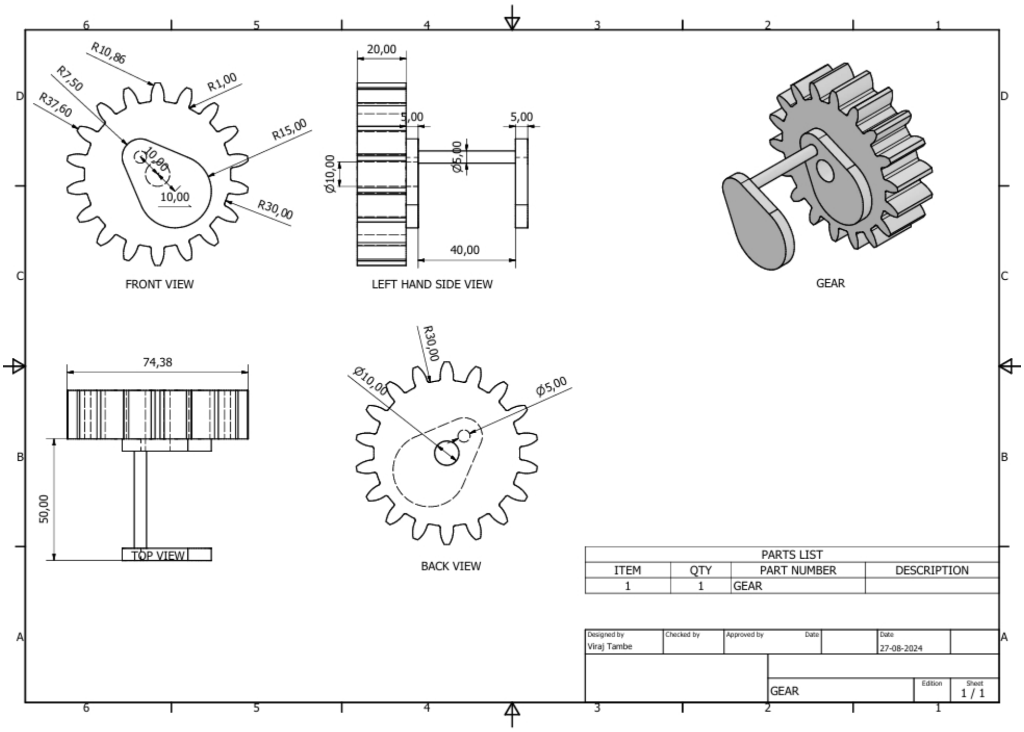


Chart - 12: Fig: 3.10: Part Drawing of Gear

6. Gear with Ring:

a) Gear:

Area of Gear

1) Area of Outer Circle:
Formula: $A_0 = \pi * R^2{}_0$
$A_0 = \pi * 37.60^2 = 4441.45\ mm^2$

2) Area of Inner Circle:
Formula: $A_I = \pi * R_i{}^2$
$A_i = \pi * 30^2 = 2827.43\ mm^2$

3) Area of Hole:
Formula: $A_h = \pi * R^2{}_h$
$A_h = \pi * 10^2 = 314.15\ mm^2$

4) Area of Teeth:
Formula: $A_T = A_0 - A_I$
$A_T = 4441.45 - 2827.43 = 1614.02\ mm^2$

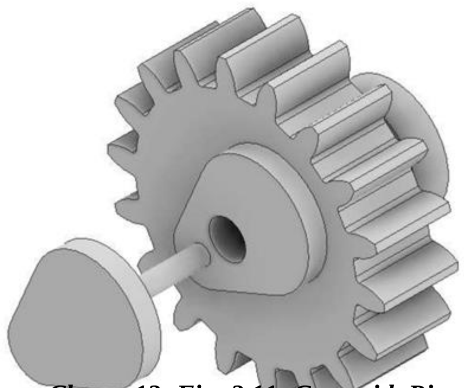


Chart - 13: Fig: 3.11: Gear with Ring

5) Total Area of Gear:
$$Formula: A = A_0 - A_I - A_H + A_T$$
$$A = 4441.45 - 2827.43 - 314.15 + 1614.02 = 2913.89\ mm^2$$

Volume of Gear
Formula: $V = A * T$
$V = 2913.89 * 20 = 58277.8\ mm^3$

Weight of Gear
Formula: $w = v * \rho$
$w_g = 58277.8 * 0.0027 = 157.35\ gm$

b) Crank:

Area of Crank with Hole:

1) Area of Larger Arc
Formula: $A_L = \frac{\pi * R_L{}^2}{2}$
$A_L = \frac{\pi * 15^2}{2} = 353.42\ mm^2$

2) Area of Smaller Arc:
Formula: $A_S = \frac{\pi * R^2{}_S}{2}$
$A_s = \frac{\pi * 7.5^2}{2} = 88.35\ mm^2$

3) Area of Hole:
Formula: $A_h = \pi * R^2{}_H$
$A_H = \pi * 5^2 = 78.53\ mm^2$
Total Area of Crank with Hole
Formula: $A = A_l + A_s - A_h$
$A = 353.42 + 88.35 - 78.53 = 363.24\ mm^2$
Volume of Crank with Hole
Formula: $V = A * t$
$V = 363.24 * 5 = 1816.2\ mm^3$
Weight of Crank with Hole
Formula: $w = v * \rho$
$w_1 = 1816.2 * 0.0027 = 4.90\ gm$
Area of Crank:
1) Area of Larger Arc
Formula: $A_l = \frac{\pi * R^2{}_l}{2}$
$A_l = \frac{\pi * 15^2}{2} = 353.42\ mm^2$
2) Area of Smaller Arc:
Formula: $A_S = \frac{\pi * R^2{}_S}{2}$
$A_s = \frac{\pi * 7.5^2}{2} = 88.35\ mm^2$
3) Total Area of Crank:

Formula: $A = A_l + A_s$
$A = 353.42 + 88.35 = 441.77\ mm^2$
Volume of Crank
Formula: $V = A * T$
$V = 441.77 * 5 = 2208.85\ mm^3$

Weight of Crank
Formula: $w = v * \rho$
$w_2 = 2208.85 * 0.0027 = 5.96\ gm$

c) Ring:

Area of Ring:
Formula: $A = \frac{\pi}{4}(D_0{}^2 - D^2{}_I)$
$A = \frac{\pi}{4}(30^2 - 20^2) = 392.66\ mm^2$

Chart -14: Fig:3.12: Ring

d) Shaft:

Volume of Shaft
Formula: $V = \pi * R^2 * l$
$\boldsymbol{V = \pi * 2.5^2 * 40 = 785.39\ mm^3}$
Weight of Shaft
Formula: $w = v * \rho$
$w_s = 785.39 * 0.0027 = 2.12\ gm$

Total Weight:
Formula: $W = w_g + w_1 + w_2 + w_r + w_s$
$W = 157.35 + 4.90 + 5.96 + 21.20 + 2.12 = 191.53\ gm$

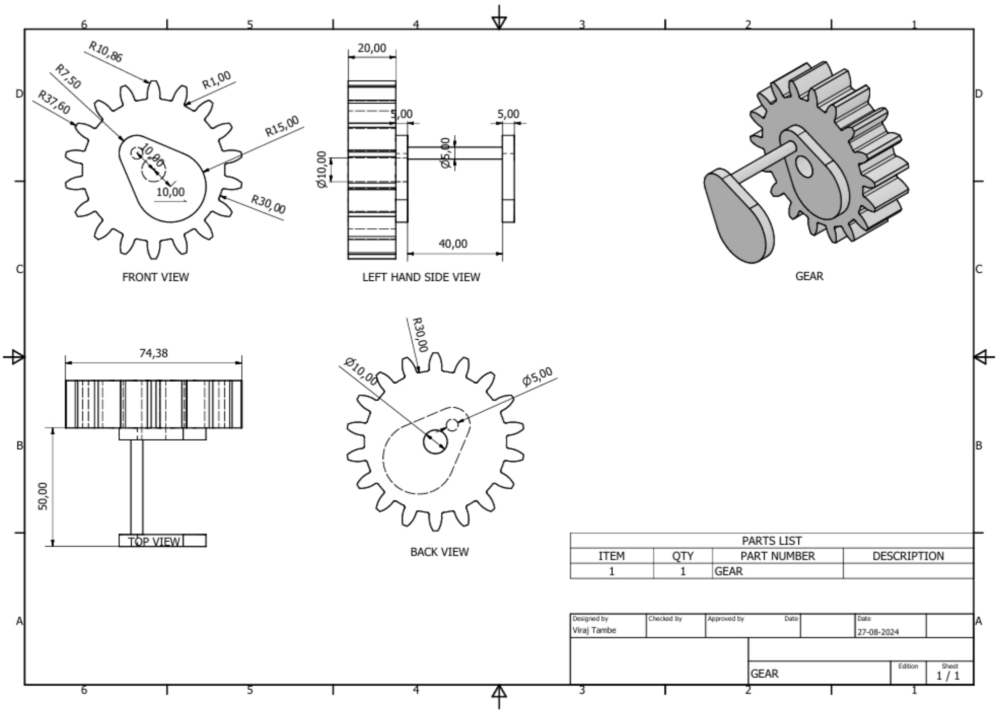


Chart - 15: Fig 3.13: Drawing of Gear with Ring

7. Nut for Flywheel:

Volume of Hexagonal Prism
Formula: $V = (3\frac{\sqrt{3}}{2} * l^2) * h$
$V = (3\frac{\sqrt{3}}{2} * 15^2) * 3 = 1753.70\ mm^3$
Weight of Hexagonal Prism:
Formula: $w = v * \rho$
$w_1 = 1753.70 * 0.0027 = 4.73\ gm$
Volume of Hole:
Formula: $V = \pi * r^2 * l$
$V = \pi * 10^2 * 3 = 942.47\ mm^3$
Weight of Hole:
Formula: $w = v * \rho$
$w_2 = 942.47 * 0.0027 = 2.54\ gm$
Total Weight:
Formula: $W = n(w^2{}_1 - w_2{}^2)$
$W = 2(4.73 - 2.54) = 4.38\ gm$

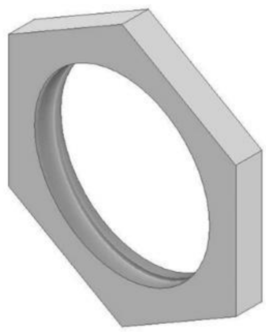


Chart-16: Fig:3.14: Nut for Flywheel

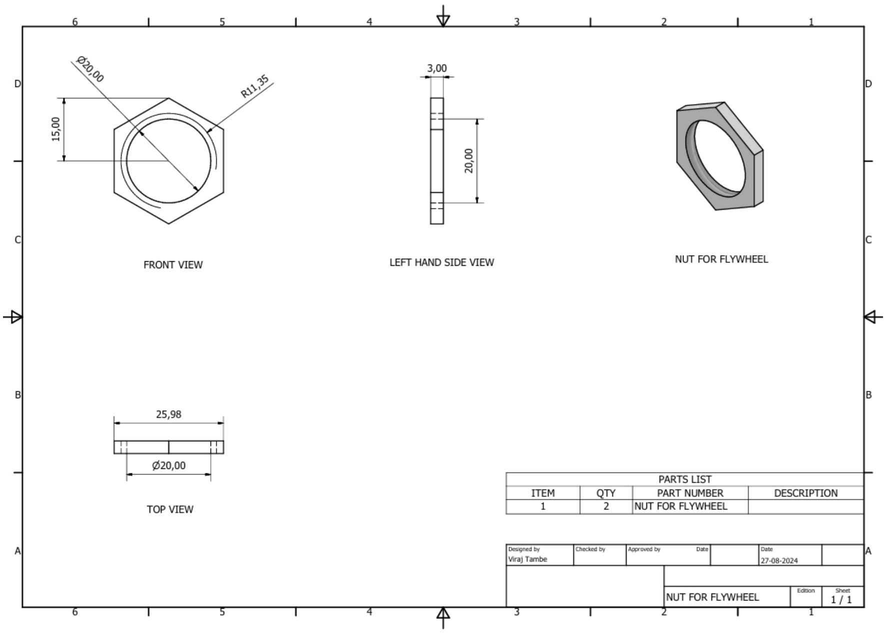


Chart - 17 : Fig: 3.15: Part Drawing of Nut for Flywheel

8. Nut for Gear:

Volume of Hexagonal Prism

Formula: $V = (3\frac{\sqrt{3}}{2} * l^2) * h$

$V = (3\frac{\sqrt{3}}{2} * 7^2) * 3 = 381.91\, mm^3$

Weight of Hexagonal Prism

Formula: $w = v * \rho$

$w_1 = 381.91 * 0.0027 = 1.03\ gm$

Volume of Hole

Formula: $V = \pi * r^2 * l$

$V = \pi * 5^2 * 3 = 235.61\, mm^3$

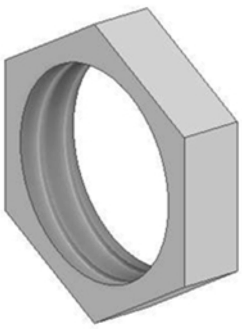


Chart -18: Fig:3.16: Nut for Gear

Weight of Hole

Formula: $w = v * \rho$

$w_2 = 235.61 * 0.0027 = 0.63\ gm$

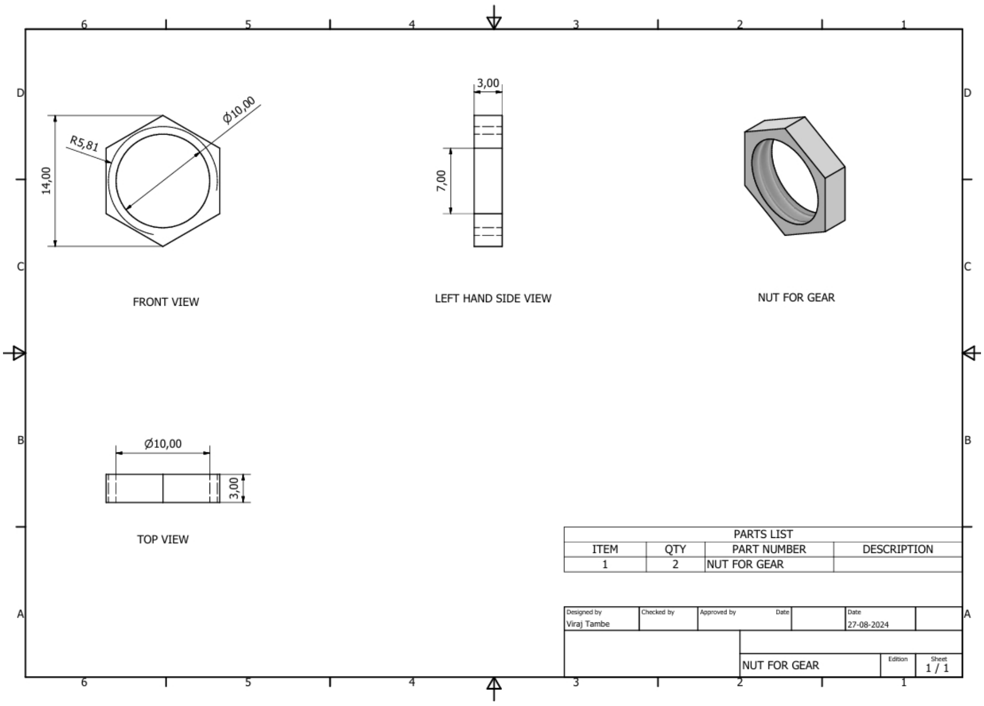


Chart - 19: Fig: 3.17 : Part Drawing of Nut for Gear

9. Nut for Piston:

Volume of Hexagonal Prism:

Formula: $V = (3\frac{\sqrt{3}}{2} * l^2) * h$

$V = (3\frac{\sqrt{3}}{2} * 12.5^2) * 5 = 2029.74\ mm^3$

Weight of Hexagonal Prism:

Formula: $w = v * \rho$

$w_1 = 2029.74 * 0.0027 = 5.48\ gm$

Volume of Hole

Formula: $V = \pi * R^2 * l$

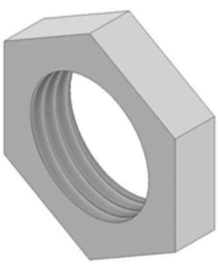


Chart - 20: Fig: 3.18: Nut for Piston

$V = \pi * 7.5^2 * 5 = 883.57\ mm^3$

Weight of Hole

Formula: $w = v * \rho$

$w_2 = 883..57 * 0.0027 = 2.38\ gm$

Total Weight:

Formula: $W = (w_1 - w_2)$

$W = (5.48 - 2.38) = 3.1\ gm$

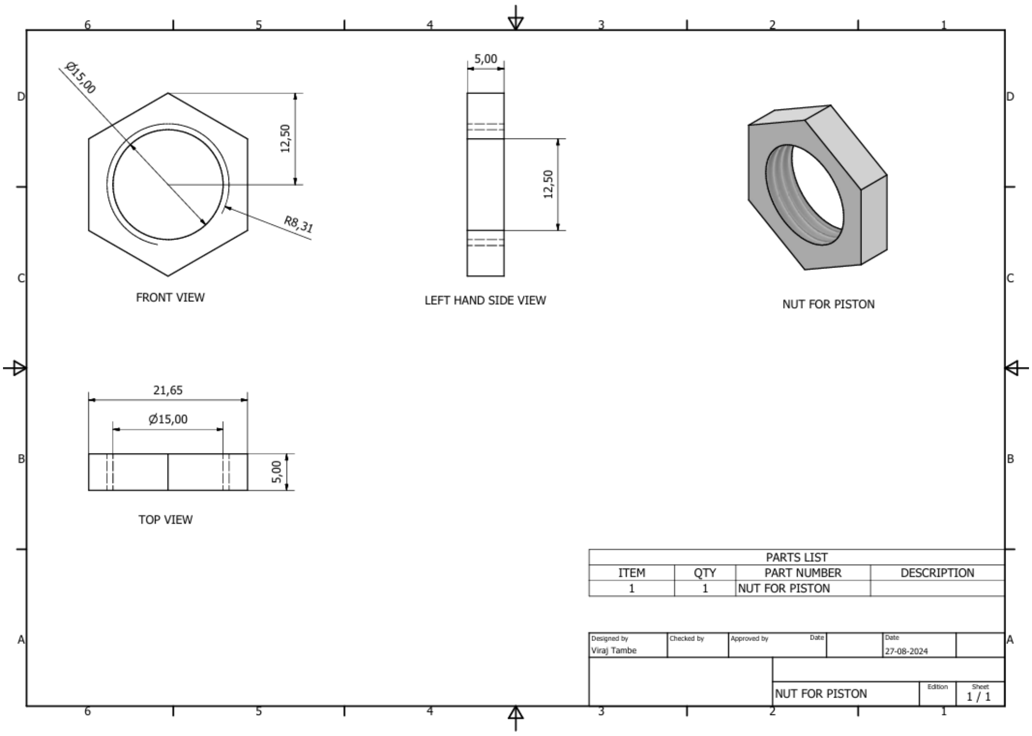


Chart-21: Fig:3.19: Part Drawing of Nut for Piston

10. Piston:

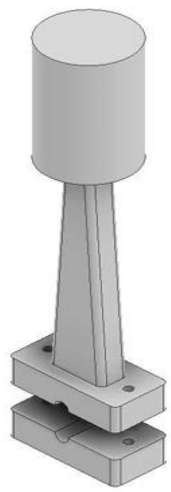


Chart - 22: Fig: 3.20 : Piston

Volume of Cylinder:

Formula: $V = \pi * R^2 * l$

$V = \pi * 15^2 * 45 = 31808.62\ mm^3$

Weight of Cylinder:

Formula: $w = v * \rho$

$w_1 = 31808.62 * 0.0027 = 85.88\ gm$

Average width of Connecting Rod

Formula: $w = \frac{w_1+w_2}{2}$

$w = \frac{10+20}{2} = 15\ mm$

Volume of Connecting rod

Formula: $V = l * b * h$

V = 80*10*15 = $12000\ mm^3$

Weight of Connecting Rod

Formula: $w = v * \rho$

$w_2 = 12000 * 0.0027 = 32.4\ gm$

Area of Rectangle with rounded corners

Formula: $A = l * b - (4 - \pi)r^2$

$A = 40 * 20 - (4 - \pi)2^2$=796.56 mm^2

Volume of Rectangle with rounded corners

Formula: $V = A * t$

$V = 796.56 * 10 = 7965.6\ mm^3$

Weight of Rectangle with rounded corners

Formula: $w = v * \rho$

$w_3 = 7956.6 * 0.0027 = 21.5\ gm$

Volume of Small Holes

Formula: $V = \pi * R^2 * l$

$V = \pi * 1.77^2 * 10 = 98.42\ mm^3$

Weight of Small Holes

Formula: $w = v * \rho$

$w_4 = 2 * 98.42 * 0.0027 = 0.53\ gm$

Volume of Semicircle hole

Formula: $V = \frac{\pi * r^2 * h}{2}$

$V = \frac{\pi * 2.50^2 * 20}{2} = 78.53\ mm^3$

Weight of Semi-circle hole

Formula: $w = v * \rho$

$w_3 = 78.53 * 0.0027 = 0.27\ mm^3$

Total Weight:

Formula: $W = w_1 + w_2 + 2w_3 - 2w_4 - 2w_5$

$W = 85.88 + 32.4 + 2(21.5) - 2(0.53) - 2(0.21) = 159.8\ gm$

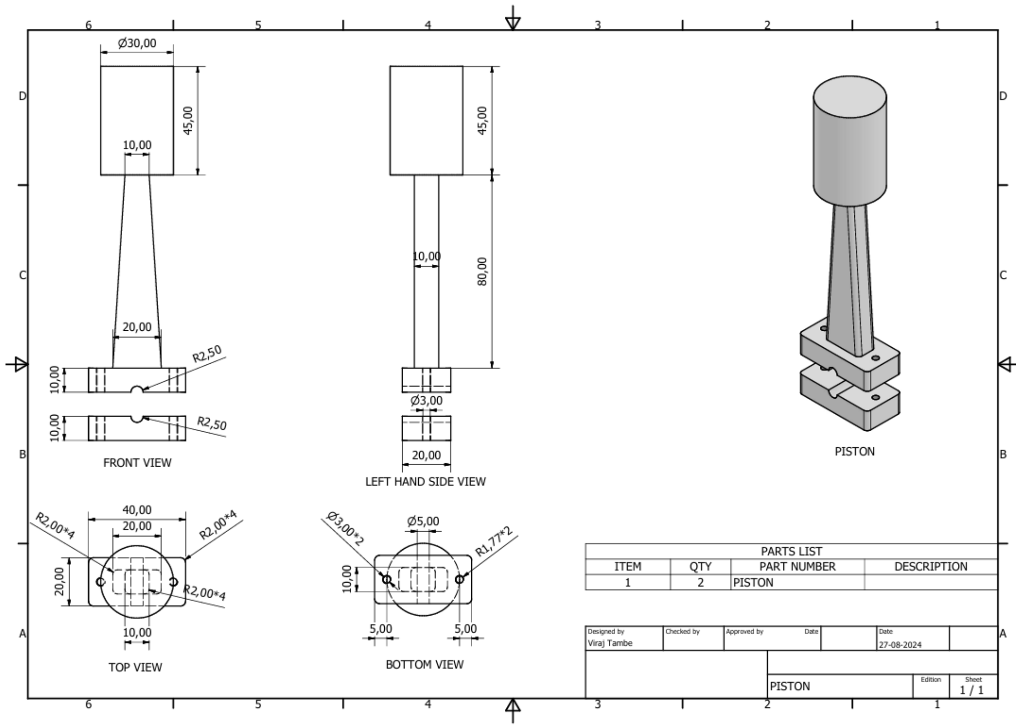


Chart 23: Fig:3.21: Part Drawing of Piston

11. Rectangular Block:

Volume of Block:

Formula: $V = L * B * H$

$V = 30 * 30 * 100 = 90000\ mm^3$

Weight of Block:

Formula: $w = v * \rho$

$w = 90000 * 0.0027 = 243\ gm$

Volume of Hole:

Formula: $V = \pi * R^2 * l$

$V = \pi * 10.05^2 * 30 = 9519.26\ mm^3$

Weight of Hole:

Formula: $w = v * \rho$

$w_2 = 9519.26 * 0.0027 = 25.70\ gm$

Total Weight:

Formula: $W = w_1 - w_2$

$W = 243 - 25.70 = 217.3\ gm$

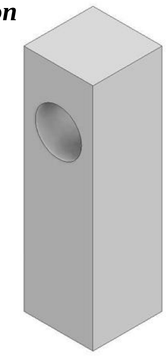


Chart-24: Fig 3.22: Rectangular Block

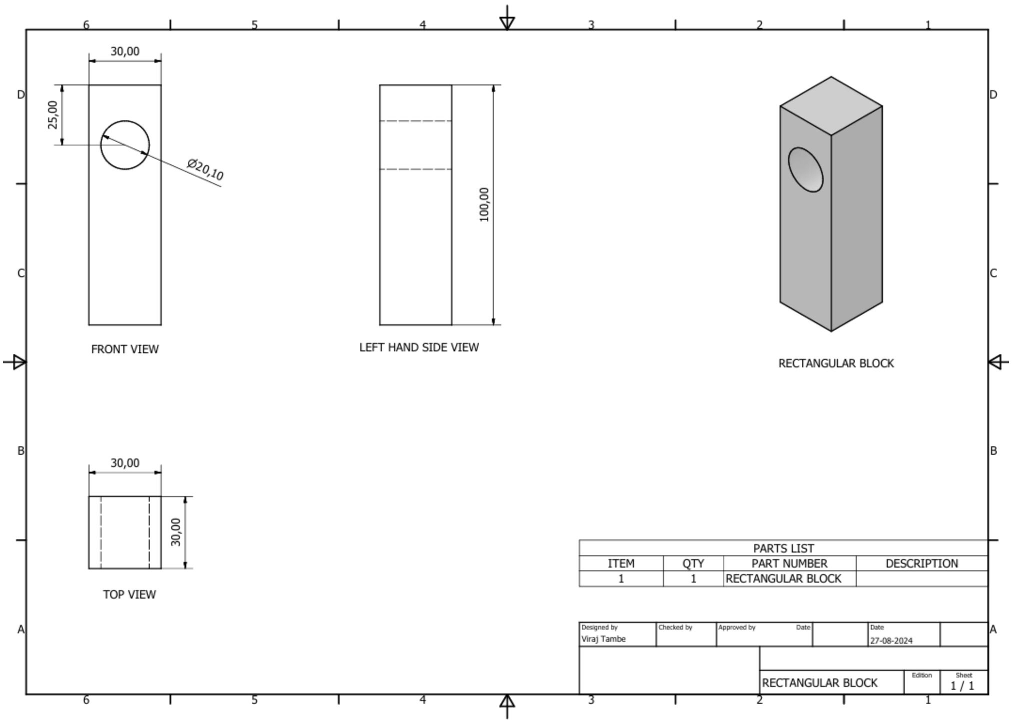


Chart-25: Fig: 3.23: Part Drawing of Rectangular Block

12. Shaft connecting Flywheel:

Volume of Shaft:

Formula: $V = \pi * R^2 * l$

$V = \pi * 100 * 160 = 50265.48\, mm^3$

Weight of Shaft:

Formula: $w = v * \rho$

$w_1 = 50265.48 * 0.0027 = 135.71\ gm$

Volume of Hole:

Formula: $V = \pi * r^2 * l$

$V = \pi * 2.5^2 * 20 = 392.69\, mm^3$

Weight of all Holes:

Formula: $w = 2 * v * \rho$

$w_2 = 2 * 392.69 * 0.0027 = 2.12\ gm$

Total Weight:

Formula: $W = w_1 - w_2$

$W = 135.71 - 2.12 = 133.59\ gm$

Chart - 26: Fig:3.24:Shaft Connecting Flywheel

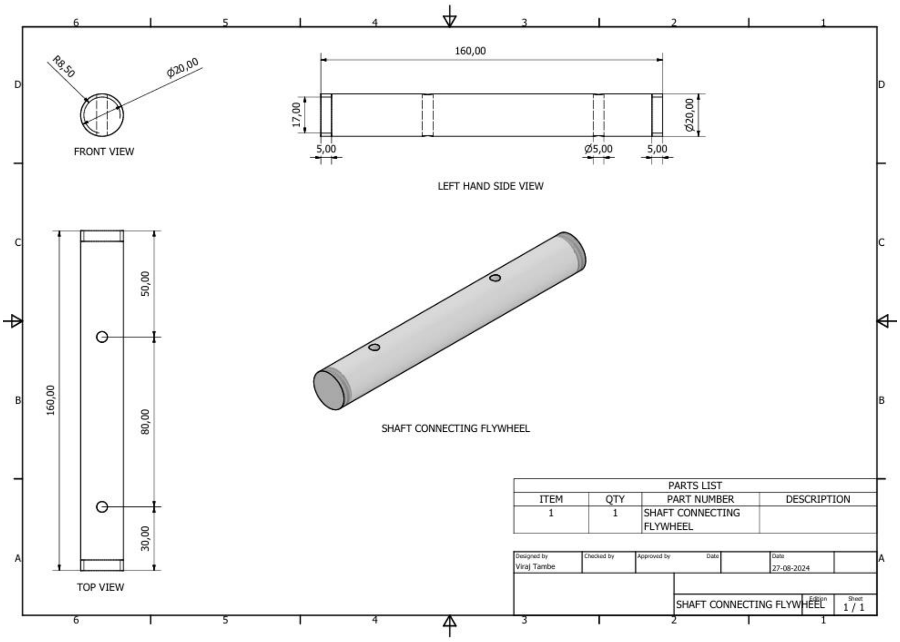


Chart-27: Fig: 3.25: Part Drawing of Shaft Connecting Flywheel

13. Shaft connecting Gear with Ring:

Volume of Shaft:

Formula: $V = \pi * R^2 * l$

$V = \pi * 5^2 * 110 = 8639.37\, mm^3$

Weight of Shaft:

Formula: $w = v * \rho$

$w_1 = 8639.37 * 0.0027 = 23.32\, gm$

Volume of Hole:

Formula: $V = \pi * r^2 * l$

$V = \pi * 2.5^2 * 10 = 196.34\, mm^3$

Weight of Hole:

Formula: $w = v * \rho$

$w_2 = 196.34 * 0.0027 = 0.53\, gm$

Total Weight:

Formula: $W = w_1 - w_2$

$W = 23.32 - 0.53 = 22.79\, gm$

Chart-28: Fig:3.26 Shaft Connecting Gear with Ring

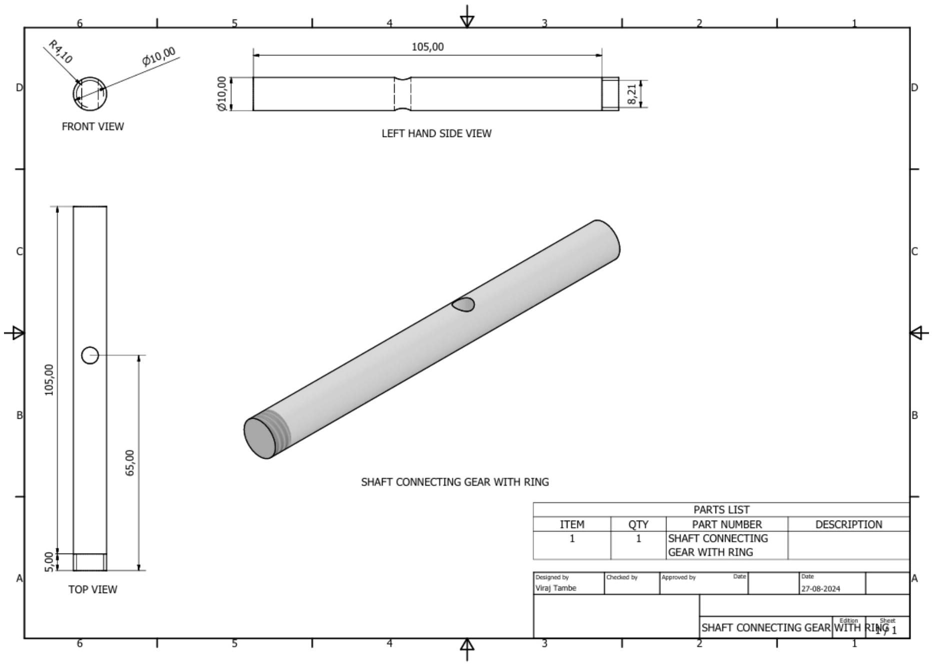


Chart - 29: Fig 3.27: Part Drawing of Shaft Connecting Gear with Ring

14. Shaft connecting Gear:

Volume of Shaft:

Formula: $V = \pi * R^2 * l$

$V = \pi * 5^2 * 110 = 8639.37\,mm^3$

Weight of Shaft:

Formula: $w = v * \rho$

$w_1 = 8639.37 * 0.0027 = 23.32\,gm$

Volume of Hole:

Formula: $V = \pi * r^2 * l$

$V = \pi * 2.5^2 * 10 = 196.34\,mm^3$

Weight of Hole:

Formula: $w = v * \rho$

$w_2 = 196.34 * 0.0027 = 0.53\,gm$

Total Weight:

Formula: $W = w_1 - w_2$

$W = 23.32 - 0.53 = 22.79\,gm$

15. Small Piston

a) Cylinder:

Volume of Cylinder:

Formula: $V = \pi * R^2 * h$

$V = \pi * 100 * 40 = 12566.37\,mm^3$

Weight of Hollow Pipe:

Formula: $w = v * \rho$

$w_1 = 12566.37 * 0.0027 = 33.92\,gm$

b) Rectangular Plate:

Average height of Rectangular Plate:

Formula: $h = \frac{h_1+h_2}{2}$

$h = \frac{10+20}{2} = 15\,mm$

Volume of Rectangular Plate:

Formula: $V = l * b * h$

$V = 180 * 2.5 * 15 = 6750\,mm^3$

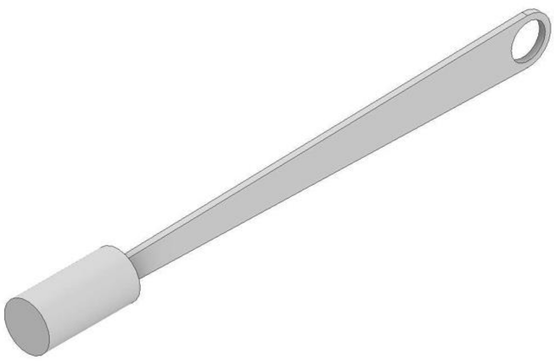
Weight of Circular Part:

Formula: $w = v * p$

$w_2 = 6750 * 0.0027 = 18.22\,gm$

c) Semicircular plate:

Volume of Semicircular Plate:



Formula: $V = \frac{\pi * r^2}{2} * b$

$V = \frac{\pi * 100}{2} * 2.5 = 392.69\, mm^3$

Weight of Circular Part:

Formula: $w = v * p$

$w_3 = 392.69 * 0.0027 = 1.06\, gm$

d) Hole:

Chart-30: Fig: 3.28: Small Piston

Volume of Hole:

Formula: $V = \pi * r^2 * l$

$V = \pi * 7.5^2 * 2.5 = 441.78\, mm^3$

Weight of Hole:

Formula: $w = v * \rho$

$w_4 = 441.78 * 0.0027 = 1.19\, gm$

Total Weight:

Formula: $W = w_1 + w_2 + w_3 - w_4$

$W = 33.92 + 18.22 + 1.06 - 1.19 = 52.01\, gm$

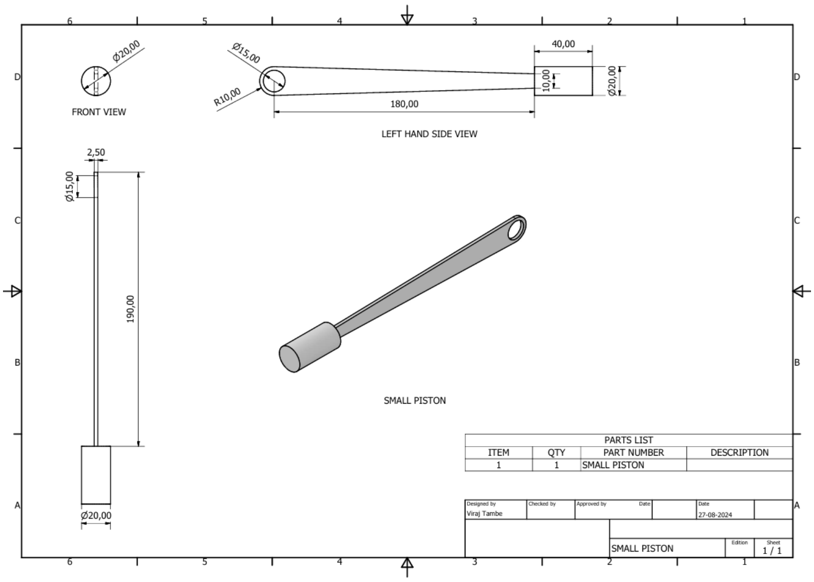


Chart - 31: Fig: 3.29: Part Drawing of Small Piston

16. Cylinder:

a) Hollow Pipe:

Area of Hollow Pipe:

Formula: $A = \frac{\pi}{4}(D^2{}_0 - D^2{}_i)$

$A = \frac{\pi}{4}(22.5^2 - 20^2) = 83.44\, mm^2$

Volume of Hollow Pipe:

Formula: $V = A * l$

$V = 83.44 * 130 = 10847.2\, mm^3$

Weight of Hollow Pipe:

Formula : $w = v * \rho$

$w_1 = 10847.2 * 0.0027 = 29.28\, gm$

Chart-32: Fig 3.30 Cylinder

b) Half Sphere:

Volume of Half Sphere:

Formula: $V = (\frac{4}{3}) * \pi * r^3$

$V = (\frac{4}{3}) * \pi * 11.25^3 = 5964.11\, mm^3$

Weight of Half Sphere:

Formula: $w = v * \rho$

$w_2 = 5964.11 * 0.0027 = 16.10\, gm$

Total Weight:

Formula: $W = w_1 + w_2$

$W = 29.28 + 16.10 = 45.38\, gm$

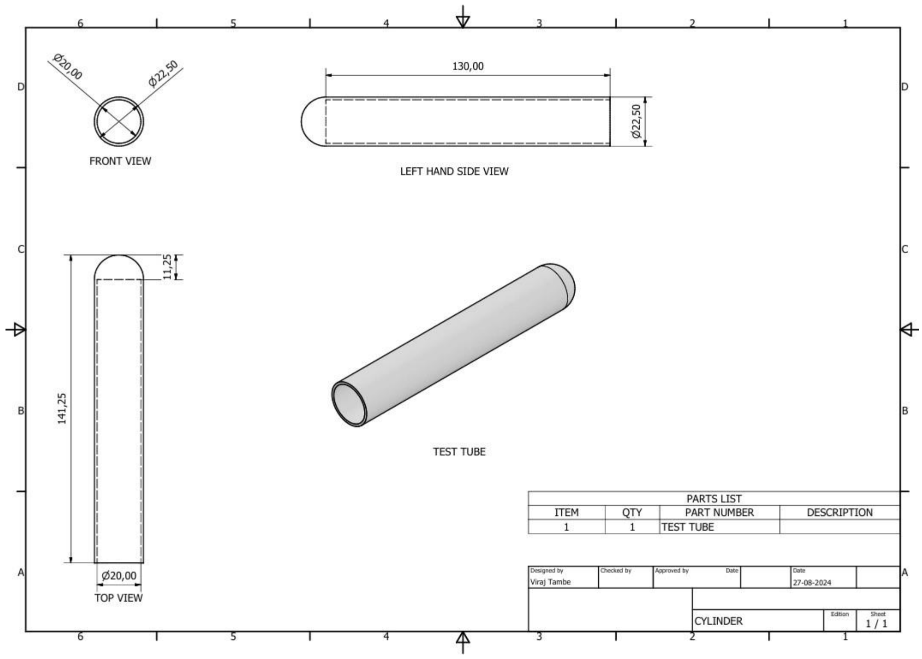


Chart - 33: Fig 3.31: Part Drawing of Cylinder

Total Weight of All the Parts: (All parts are manufactured in Aluminium)

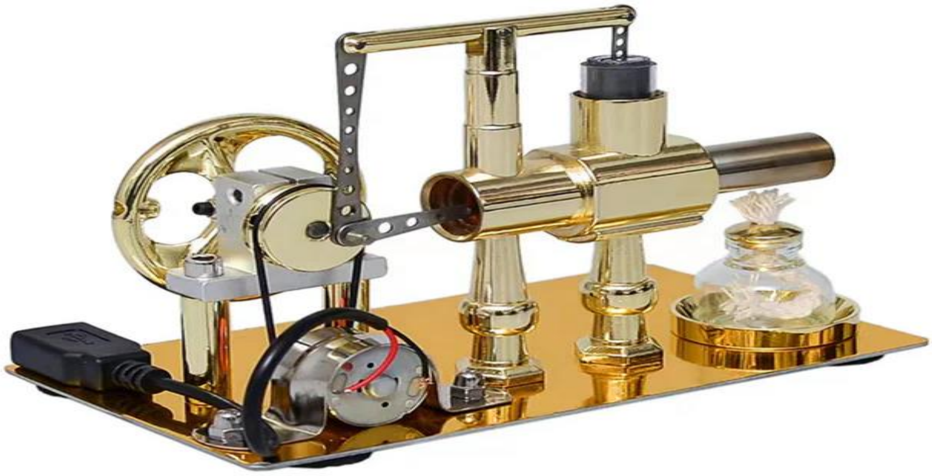


Chart-34: Fig 3.32: Stirling Engine

3.3 Manufacturing Operations:

Use of Lathe Machine:

Using Lathe machine for various operations like cutting, sanding, facing, threading, knurling, drilling, deformation, facing, threading and turning.

Operations done:

i Cutting
ii Sanding
iii Facing
iv Threading
v Knurling
vi Drilling
vii Deformation
viii Facing
ix Threading
x Turning

Chart - 35: Fig 3.33: Using Lathe Machine

Welding Process: Using Arc Welding for welding the parts together. Welding is the process of joining two or more pieces of material together using heat, pressure, or both. The heat melts the base material, creating a weld pool that solidifies into a single piece after cooling. The resulting joint is called a weldment, and the material used to create the weld is known as a filler or consumable.

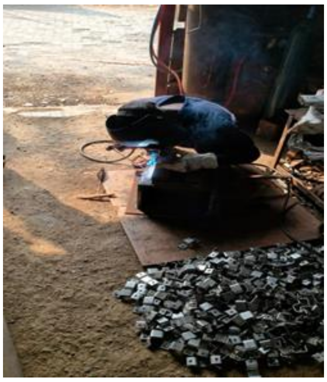


Chart - 36: Fig 3.34: Welding Process

Drilling Process: Using Vertical Drilling machine for drilling holes and for making threads of different sizes.

Chart - 37: Fig 3.35: Drilling Process

RESULTS AND DISCUSSIONS

Results:

Efficiency and Pollution Reduction:

The design aims to replace traditional internal combustion (IC) engines with Stirling engines with Stirling engines in a V-Twin configuration to address pollution issues. The stirling engine, powered by gases rather than fuel combustion, promises a more environmentally friendly alternative by reducing exhaust and noise pollution

Use of Gases and Gear Mechanism:

In the proposed design, one piston is powered while the second piston operates alternately using a gear system, reducing complexity and potentially increasing efficiency.

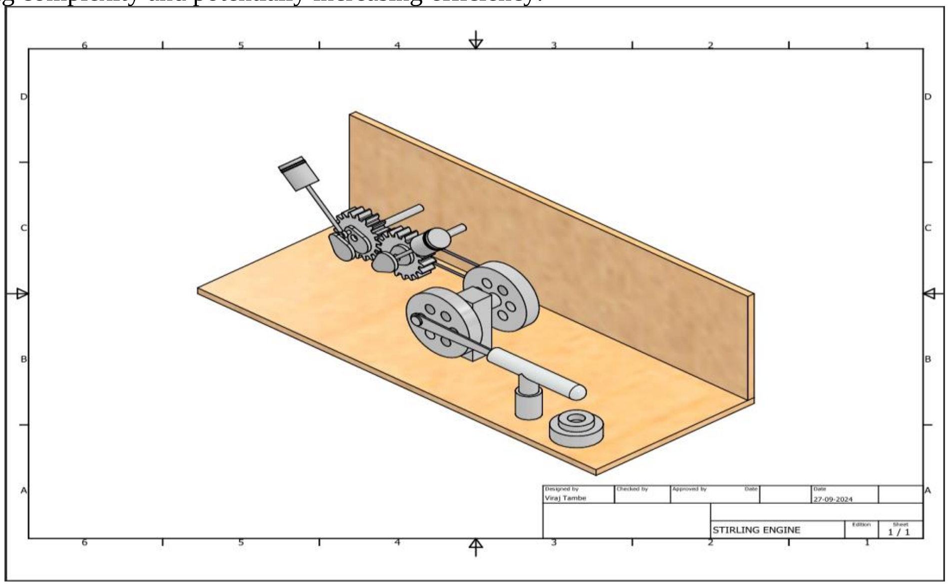


Chart-38: Fig 4.1: Stirling Engine Model

Discussions:

Challenges in Implementation:

According to the literature, while stirling engines are highly efficient and versatile they have not been widely adopted in the automotive sector, The project addresses this gap by suggesting stirling engines could be a future replacement for IC engines.

Renewable Energy Integration:

The engine’s potential to utilize renewable energy sources such as solar power and biomass further supports its application in reducing reliance on fossil fuels and contributing to sustainability goals.

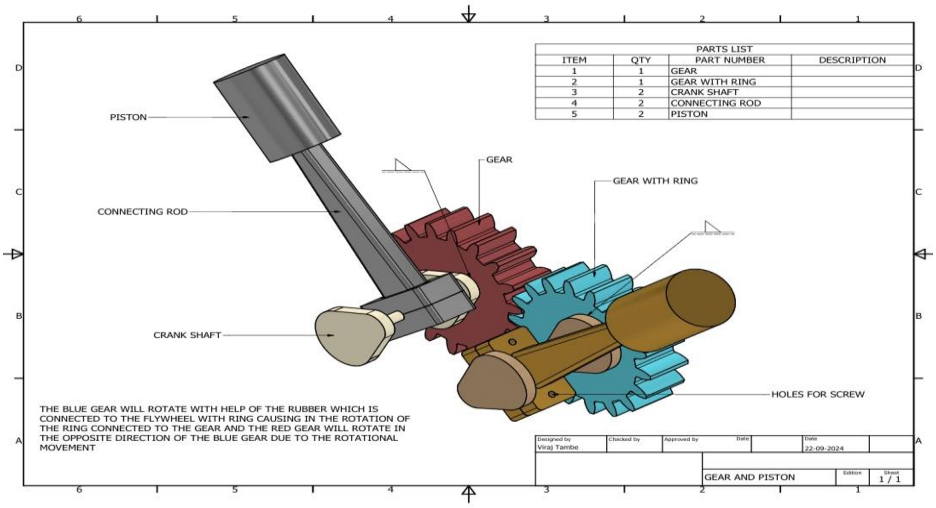


Chart - 39: Fig 4.2: Gear and Piston Mechanism

CONCLUSION

From this project we are able to study and gain knowledge about the Stirling Engine and how a thermal expansion engine works. We also came across the lack of usage of Stirling engines in the automotive world. Stirling engines can be great alternatives to internal combustion engines in the future. Our project aims towards making that happen.

Stirling engines offer a promising alternative to traditional internal combustion engines, particularly in applications where efficiency, reliability, and low emissions are paramount. Here are some key conclusions based on their characteristics and potential:

Advantages:

- i High Efficiency: Stirling engines can achieve higher thermal efficiencies compared to traditional engines, making them more energy-efficient.
- ii Low Emissions: They produce significantly lower emissions of greenhouse gases and pollutants, making them more environmentally friendly.
- iii Quiet Operation: Stirling engines are inherently quieter than internal combustion engines, making them suitable for applications where noise reduction is important.
- iv Sealing Issues: Ensuring proper sealing between the moving parts in a Stirling engine can be challenging, as leaks can reduce efficiency and performance.
- v Start-up Time: Stirling engines may require longer start-up times compared to traditional engines, especially in cold conditions.

ACKNOWLEDGEMENT

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