DESIGN AND FABRICATION OF TRI-CYLINDER AIR COMPRESSOR

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Abstract: In this project, the research has been carried out for tri-cylinder air compressor to generate the air pressure of 40-50 Psi in storage tank. All cylinder mounted over frame placed at 120° to each which reciprocated by the eccentric mechanism produces compressed air. D.C. motor gives mechanical power input required to run the assembly to produce compressed air. Output of all cylinders are connected to storage-tank with help of hoses and connectors. An experimental work carried out in this project gives results that increasing number of cylinders reduces time to generate certain amount of pressure. With increase in stroke length of cylinder, compressor gives maximum output. Advantage of this assembly is light weight, portable and easy to manufacture. D.C. power can easily be produced with battery and after run, compressed air can be used for low pressure industrial application such as painting, cleaning and fumigation.

Index Terms – Air pump, Tri-Cylinder, Fumigation.

I. INTRODUCTION

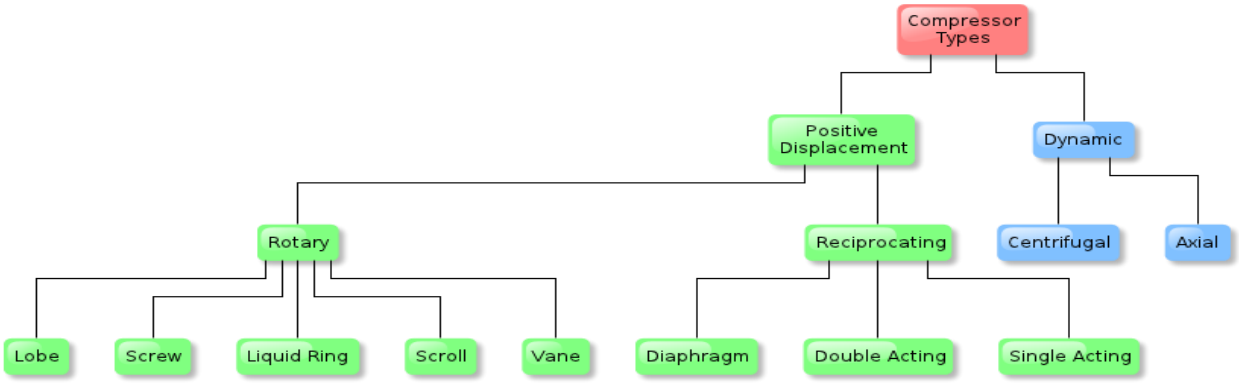
The compressor is mechanical equipment which is used to increase the pressure with the help of the piston. In other words, a compressor is a mechanical device that increases the pressure of a gas by reducing its volume. An air compressor is a specific type of gas compressor. Compressors are similar to pumps; both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible; while some can be compressed, the main action of a pump is to pressurize and transport liquids.

- **Types of air compressor**
  According to the design and principle of operation
  1. Positive displacement type air compressor
  2. Dynamic type air compressor
- **Positive displacement**
  It is also sub divided in following two main type:
  1. Rotary type air compressor
  2. Reciprocating type air compressor

Positive-displacement air compressors are the type of compressor executed by forcing air into a chamber whose volume is decreased to compress the air. Piston-type air compressors use this principle by pumping air into an air chamber through the use of the same motion of pistons. This type of compressor uses one-way valves to guide air into a chamber, where the air is compressed. Rotary screw compressors also utilize positive-displacement compression by matching two helical screws that, when turned, guide air into a chamber, whose volume is increased as the screws turn.

- **Dynamic air compressor**

When you need lots of horse power dynamic type air compressor is a ideal choice. They are available in both axial and radial designs. They are frequently called 'turbo-compressor'. Those with radial design called centrifugal air compressors. A dynamic compressor works at constant pressures unlike, for example displacement compressors which works with constant flow. Inlet



temperature may affect the performance of it. which results in change in capacity.

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Figure 1.1 Types of compressors

II. PROBLEM STATEMENT

The primary complication of conventional compressor is it uses AC power supply and consumes more energy. In case of breakdown due to power-cut in industry compressed air can't be produced without AC power supply. Some operations i.e. painting, cleaning and spraying can't be done without compressed air which causes delay in work. These operations require compressed air at 20-30 psi which can be generated with tri-cylinder air compressor. Single cylinder and double cylinder compressor needs to be balanced while in tri-cylinder, cylinders are placed at 120° to each other, thus they do not need to be balanced.

III. LITREATURE REVIEW

1. Bhaumik Patel and Ashwin Bhabhor had done thermal analysis of piston of reciprocating air compressor This literature contains research on temperature distribution over the piston head. With the help of this research we can predict that if the piston head is going to damage due to thermal stresses generated in operating conditions. These parts are not easy to repair and generally too expensive to manufacture. To reduce the chances for thermal elongations of piston head and produce safe components researchers makes 3D CAD model of piston and make ANSYS alaysis of this model with different material at different working conditions. This study concluded that design of piston should has to be safe from the prescribed temperature stresses.
2. Mahmood Faezaneh-gord and Amir Niamand has done analysis on optimizing reciprocating air compressor design parameter. Reciprocating air compressor has modelled based on mass and energy conservation law. Based on that we can find out in-cylinder pressure, in-cylinder temperature, mass flow rate of air at inlet and outlet and better understanding of suction and discharge pressure. Various position of inlet and discharge valve at different crank angle. Effects of clearance volume and crank speed may affect the performance of compressor. For that optimum value of suction and dis charge valve value has been concluded.

IV. WORKING PRINCIPLE

This tri-cylinder air compressor consists of three cylinders placed at 120 to each other cylinder. The main aim if this compressor is to generate large amount of air compared with existing compressor with less power input. For this compressor contain three cylinders having their own piston, piston rod with eccentric mechanism and drive. Chain drive was preferred to overcome slipping. When the motor drives the mechanism and all the three pistons will move in phase from BDC to TDC, when the piston reaching TDC compression takes place and discharge is done and when reaches the BDC suction condition are obtained and suction takes place.

V. DESIGN & CALCULATION

- Some Assumptions taken from the standard data available for calculation: –

1. Single acting Air pump intakes air at 27°C temperature, at 1 bar pressure and suction pressure is 0.97 bar
2. During compression process, increase in temperature is negligible so it can be eliminated.
3. Transmission efficiency is 85% and mechanical efficiency is 80%
4. For polytrophic process polytropic index(n) is 1< n < 1.4. we are assuming 1.3 in our case.

- According to above assumption calculation are listed below: -

- Volume of surge tank = $V = \pi \frac{D^2}{4} H$
  V= 3.1416(25.4)*(50.8)/4 cm^3
  V= 25,740.8 cm^3
  V = 25.74 liter

- Volume of 1 cylinder = $\pi \frac{d^2}{4} h$
  v = $3.1416(4.5)^2(45)/4$ cm^3
  v = 715.69 cm^3

- Volume of air intake during suction
  $V_{suction} = V_{clearence} + V_{stroke}$
  $V_{suction} = \pi \frac{d^2}{4} (6 + 28)$
  $V_{suction} = 3.1416\ (4.5)^2/4\ (34)$
  $V_{suction} = 540.74\ cm^3$

- Volume of Air at compression

$$(V_{compression})^n = \frac{(P \times V^n)_{suction}}{P_{compression}}$$

$$(V_{compression})^n = \frac{(0.97 \times 540.74^n)}{1.5}$$

$$(V_{compression})^n = 381.34 \text{ cm}^3$$

- Thickness of cylinder wall to sustain pressure of working to make safe design P_{max} = 300 psi = 20.68 bar

$\sigma_w = \sigma_t / K$

K = Factor of safety = 6

σ_w = working stress =270 / 6 = 45 MPa σ_t = tensile stress = 270 MPa

$t = \left(\frac{P \times b}{2\sigma_w}\right)$+ allowance in mm

$t = \left(\frac{20.68 \times 45.67}{2 \times (40 \times 10^6)}\right)$+ 0.5

t = 1.180 + 0.5 = 1.68 mm

- Force acting on air pump piston

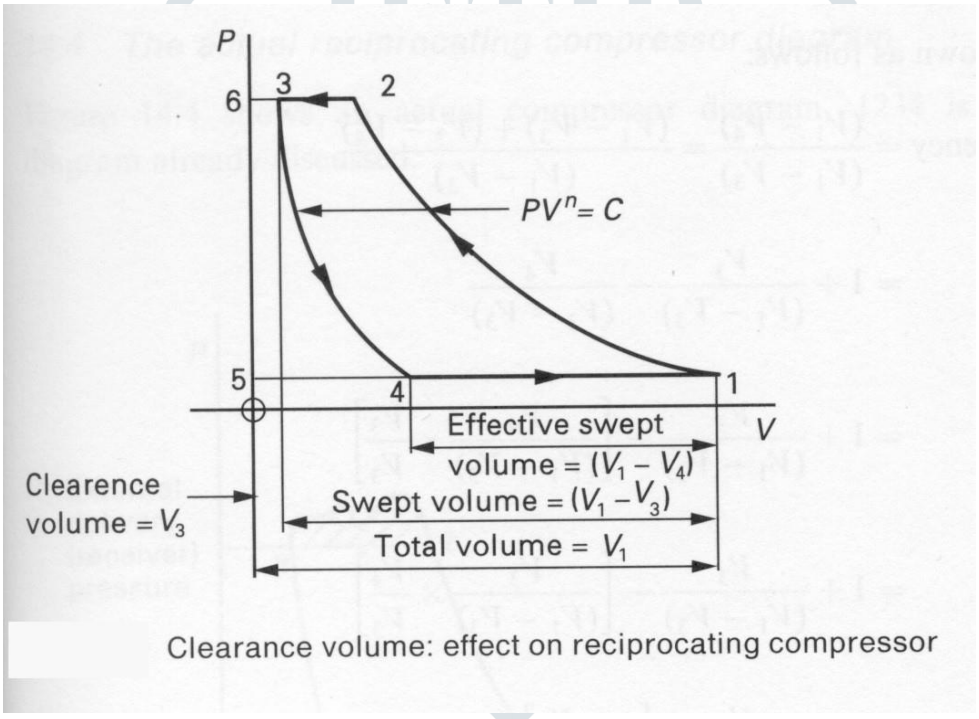
F = PA

$F = \left(\frac{3.5 \times 3 \times 3.1416 \times 45 \times 45}{4}\right)$

F = 1.669N

- Torque required

T_r = 1.669×0.3 = 0.5 Nm



Clearance volume: effect on reciprocating compressor

P-V Diagram of reciprocating compressor

- Free air delivery per cycle is

V_{free} = 3×540.74 cm^3

V_{free} = 1622.22 cm^3

- Effective swept volume

$$V_{swept} = V_{total} - V_{clearance}$$

$$V_{swept} = \frac{P_{free} \times V_{free} \times T_1}{T_{free} \times P_{suction}}$$

$$V_{swept} = \frac{1 \times 16622.22 \times (273+35)}{0.97 \times (273+50)}$$

$$V_{swept} = 1594.7 \text{ cm}^3$$

- Expanded clearance volume

$$V_{expanded} = V_{clearence} \left(\frac{P_1}{P_{suction}}\right)^{\frac{1}{n}}$$

$$V_{expanded} = 95.42 \left(\frac{1}{0.97}\right)^{\frac{1}{1.3}}$$

$V_{expanded}$ = 97.62 cm^3

- Free air mass density

$$\rho = \frac{P_{free}}{R \times T_{free}}$$

$$\rho = \frac{1 \times 10^5}{287 \times (273+35)}$$

ρ = 1.1614 kg/m^3

- Motor power required

$P_{required}$= F×V

$P_{required}$= 1.669× V

$$V = \left[\frac{2 \times \pi \times n}{60} \times T\right]$$

$$V = \left[\frac{2 \times \pi \times 45}{60} \times 0.35\right] = 1.64 \text{ m/s}$$

$P_{required}$= 1.669×1.64

$P_{required}$= 5.46 watts

Note: -

Here to consider that Air pump and Motor will be available as per standard size and specifications.

- Available air pump dimensions
  b = 45 mm l = 500 mm
- Available Motor specifications
  N = 45 RPM, Torque = 20Nm, Power = 150W
  Input voltage - 24 V and Power – 500 watts.

VI. DESIGN OF COMPONENT

1. **Frame** :- It is basic requirement for any mechanical equipment. We have used box section channels in the design of our mechanical device. This box channels provides proper structure for compressor's different components. Circular disc is welded to the motor shaft at centre of the frame as we can see in the figure. All cylinders are mounted to the arms of the frame. The main functions of the frame in this compressor is to provide support for cylinder, motor and whole eccentric mechanism. Another function is to damp the vibration produced during working conditions.

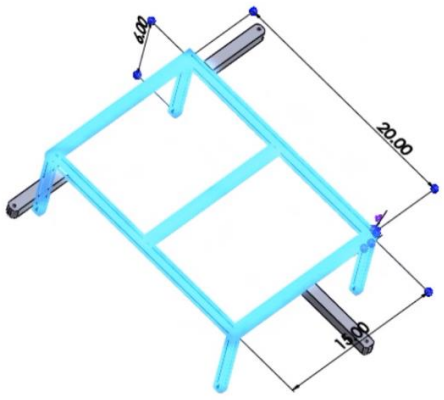


Figure 4.1 Frame

2. **Motor** :- The motor we have used is Viper motor of truck which work on DC supply. It works on 24V DC supply and it require 150W power. The motor has nominal torque of 20Nm but it has starting torque of 120Nm. It's speed varies from 45 RPM at high speed to 30 RPM at low speed.

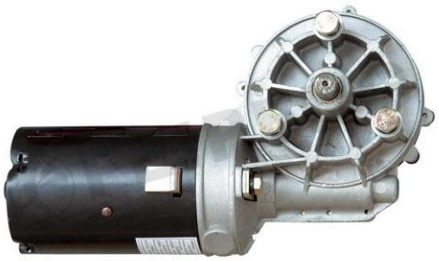


Figure 4.2 DC Motor

3. **Air-pumps** :- Air pumps are the main components of this compressor. In reciprocating type of air compressor, the air intake in suction and will get compressed in compression strokes. In our case suction take place through hole in piston of the piston-rod of the air pump which gets open in suction and closed in compression. Pumps gets its motions from the eccentric mechanism. pumps has the maximum stroke length of 450 mm and its bore is 48 mm. it is made of stainless steel which provides corrosion resistance to the cylinder wall. Pump intakes the air at 0.97bar suction pressure and compresses the air to 25 psi(1.78 bar). By varying the stroke length this pressure can also change.

Figure 4.3 Air-pump

4. **Hoses** :- Hoses are the small connecting pipes which carries air or any fluids. This small diameter pipes are made of polymers material and very flexible. The main function of this pipes is to carry the compressed air form all air pumps to the surge-tank. Generally this pipes comes in various internal diameters from 2mm to 25mm. our pipe has internal diameter of 6mm.

Figure 4.4 Actual image of Hoses

5. **Disc** :- Circular disc in centre of the frame provides the eccentric mechanism. Disc is welded from the bottom with the shaft of the motor. And at upper face of the disc a bolt is welded near edge of the disc. This bolt is which all connecting piston rods gets mounted. With motion of the shaft, disc will start rotating. And with disc rotation all 3 piston rod starts reciprocating motions. Disc is made of 2 mm thick mild steel sheet.and diameter is 360mm.

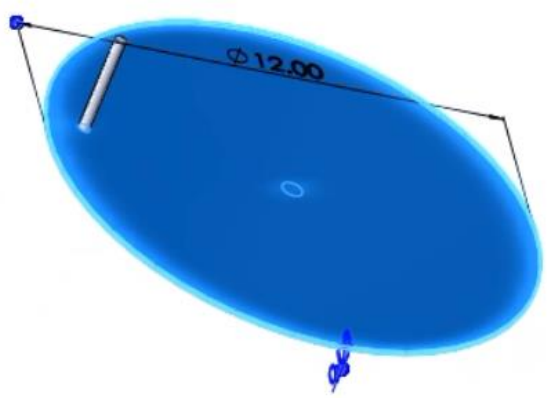


Figure 4.5 Disk

6. **Connectors** :- Connectors are the small attachments to connect hoses with cylinders, no-return valves and surge tanks. It also provides common output of 3 different inputs. They are made of plastic materials.

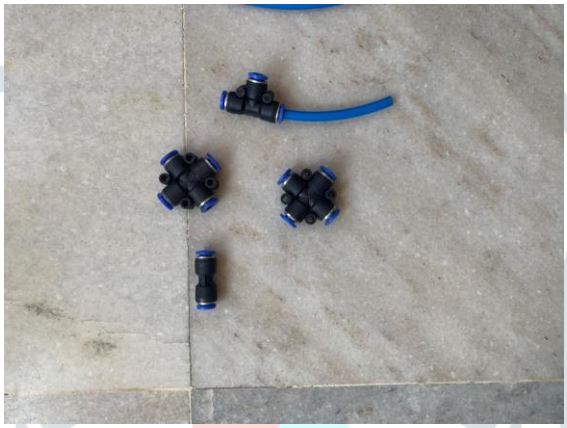


Figure 4.6 Actual image of Connectors

7. **No-return valve** :-No-return valve are type of valve that fluid can flow in only one direction and does not come back from other side. It helps to keep the flow of compressed air in one direction. It does not let return the compressed air from surge tank to back to cylinder.

Figure 4.7 Actual image of No-Return Valve

8. **Surge tank**:- Surge tank is the storage tank for compressed air. Air from cylinder after being compressed are comes to the surge tank where it can be used for any useful purpose. It is made of mild steel sheet. It has storage capacity of 24.74 liters. Length and diameter are 18×10 inches. It can sustain the pressure above 100psi. pressure gauge is mounted over it which shows the pressure of air inside. Safety valve is also provided that helps to maintain the pressure of compressed air at safe pressure that tank can sustain.

Figure 4.8 Actual image of Surge tank

9. **Transformer_**:- Transformer is electromagnetic static electrical equipment (with no moving parts) which transforms magnetic energy to electrical energy. It consists of a magnetic iron core serving as a magnetic transformer part and transformer cooper winding serving as electrical part. The transformer is high-efficiency equipment, and its losses are very low because there isn't any mechanical friction inside. Transformers are used in almost all electrical systems from low voltage up to the highest voltage level. It operates only with alternating current(AC), because the direct current (DC) does not create any electromagnetic induction. Depending on the electrical network where the transformer is installed, there are two transformer types, three-phase transformers and **single-phase transformers**. The operation principle of the single-phase transformer is: the AC voltage source injects the AC current through the transformer primary winding. A bridge rectifier circuit which convert AC supply into DC supply.

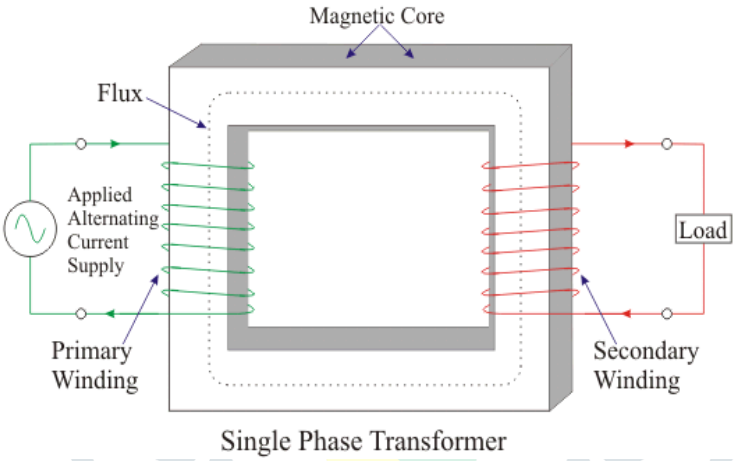


Figure 4.9 Transformer

- **Final assembly of project**

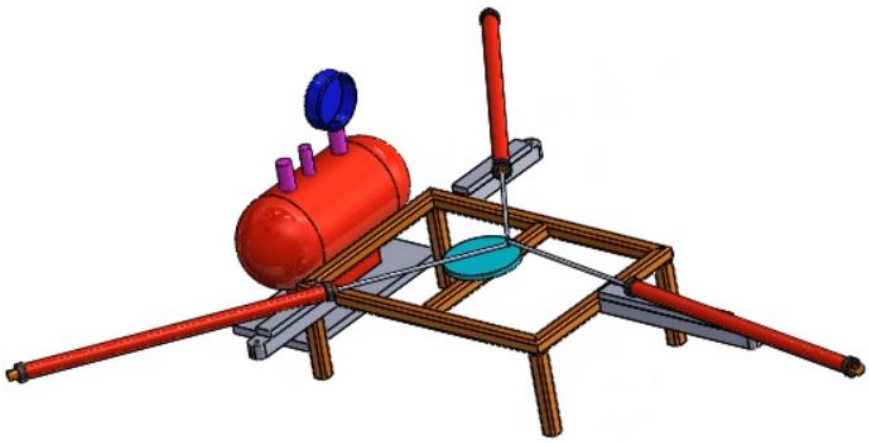
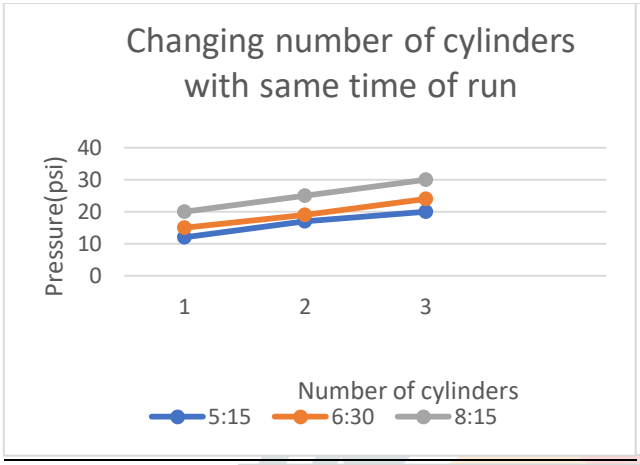
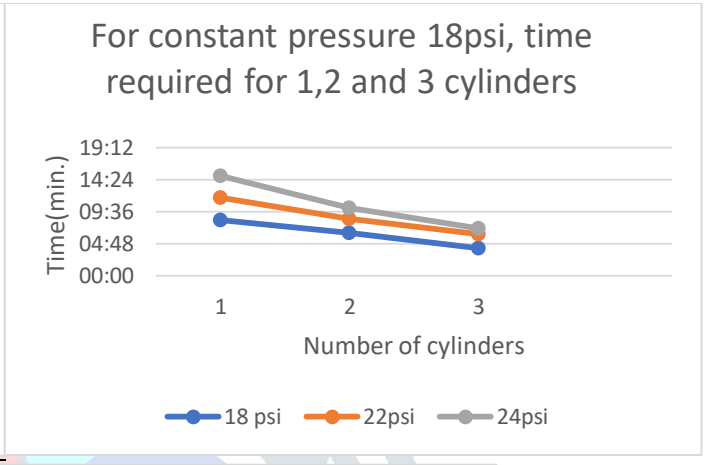


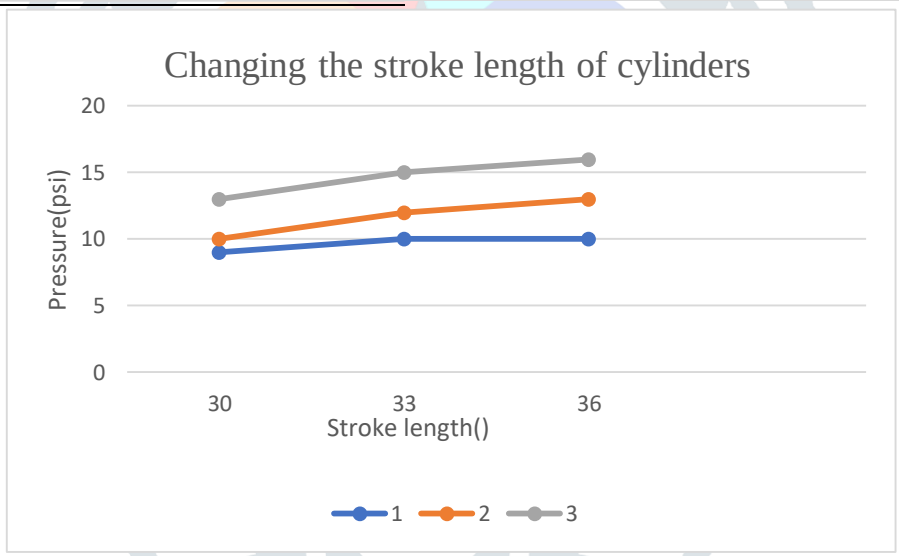
Figure 4.10 Final Assembly

VII. RESULT AND DISCUSSION

After completion of our experimental work the maximum pressure generated by three, two- and single-cylinder arrangement and their respective best stroke length is concluded by our readings. First test conducted on above arrangement to justify that three-cylinder arrangement is giving the better output in comparison to other arrangement. Second tests are conducted to find optimal stroke length and the final output give us value of 38cm for all cylinder arrangement. After that there are some tests to find which arrangement is taking how much time to attain value of 18psi. However, again the three-cylinder arrangement prove to be efficient compare to other arrangement.







VIII. CONCLUSION

- After completion of designing and fabrication of tri-cylinder air compressor is able to generate 30 Psi pressure at 45 RPM
- In tri-cylinder air compressor working with single cylinder is able to generate 14 psi of pressure within 5 minutes of runtime.
- In tri-cylinder air compressor working with two cylinders is able to generate 17psi of pressure within 5 minutes of runtime.
- In tri-cylinder air compressor working with all three-cylinder assembled is able to generate 20 psi of pressure within 5 minutes of runtime.
- By this experimental work we found that at 38cm stroke length, the compressor gives maximum pressure output.

VIII. ACKNOWLEDGEMENTS

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