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DESIGN AND FABRICATION OF MULTI ENGINE AIR COMPRESSOR

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Abstract: -

A compressor is used to get high pressure air for many industrial and commercial purpose. The triangular air compressor with the common compression chamber is a reciprocating type compressor, which delivers air at high pressure with less vibration and less power consumption than the existing ones. Triangular air compressor with common compression chamber uses three cylinders and the entire cylinder and all the cylinders will have their own connecting red, crank shaft, pistons and chain sprockets and it is driven by a chain drive. During operation the pistons will move in phase from BDC to TDC and hence the air is compressed in the common compression head. This common in the compression chamber will have one inlet and outlet valve. From this valve, air is intake and delivered. The common compression head will be is a triangular shape with angle of 60 from one side to another. The compressor is mechanical equipment which is used to increase the pressure with the help of the piston. Need to improve the performance of compressor by several methods. The main aim of the project is to make tri-cylinder, air compressor to generate large amounts of air with less power and low vibration. In Tri cylinder, air compressor the three cylinders are kept at 120 degrees to each other. The three cylinders are placed radically and equally apart such that the cylinder opening tends to meet on a common triangular compression chamber. The three pistons are made to compress air simultaneously onto the common triangular chamber over shorter stroke and the isothermal efficiency will be better than single cylinder with one piston. The motor is connected to the chain drive to drive the three crankshafts which are used to move the piston. If space is smaller the pressure will be more and bigger lower. If compressor is made to work at 1400 rpm air taken will be147.18 × 1400 = 206052 litters at 7 atmospheres pressure .The advantage with triangular compressor will be low vibration, smaller unit giving more output and so cheaper to make, ideal for air compressor is Airconditioning and Refrigeration, Vacuum pumps and general purpose usage.*

Keywords: - *Air compressor, TDC, BDC, pneumatic cylinder, tri cylinder*

1. INTRODUCTION

The need to improve the performance of compressor by several methods Such as designs, shape and construction are known and screw type compressor is the latest design as on date. The power required to compressor air to a known pressure is given in the attached tables. One cubic root of air equals approximately 28 liters its volume we brought about a novel idea to design the triangular compressor as per the attached sketches or diagrams with this. It is three cylinder compressor placed radially equally apart such that the cylinder openings tend to meet on a common triangular compression chamber that has one inlet and outlet value to a tank for receiving air in the compressed state. As an example, let us take a 100cc displacement single single cylinder compression, e.g. which will have a bore of 50 mm and stroke 50mm. The volume displaced is

$$50^2/4 \times \Pi \times h = 25^2 \times 3.14 \times 50$$

$$= 98.125cc$$

Nearly,

$$= 100cc.$$

To have the identical capacity 3 cylinders for above 100cc capacity each cylinder Displacement must be 100/3 = 33.33cc each. In the market sprayer 2 stroke engine has a displacement of 34cc 3 times that equals 102cc the bore is 35 and stroke 34.

i.e., Swept volume of each $= 35^2 / 4 \times \Pi \times 34 = 32.695$

3 Cylinders $= 98.1cc$

The compressing area of single 100cc compressor as said above is 50 Q or 1962.5 mm². The compressing Area of 35cc piston in 961.625mm for 3 pistons area = 2884.875mm². This is bigger by = 922.375mm²

Now all 3 pistons are made to compress air simultaneously onto the common triangular chamber over shorter stroke and so the isothermal efficiency will be better than the single cylinder one of 50 pistons also there will be no vibration due to triangle force acting towards the center at the same time. Adiabatically also this will be advantages since 3 cylinders displacement is pushed at the same velocity and force on the common chamber because the three piston move at equal velocity driven by one chain to achieve this 3 compressors crank sprockets as teeth. For every rotation of crank each piston will move once from TDC to BDC and BDC to TDC two strokes. Therefore, theoretically 98cc of air will be taken in and compressed to the volume of smaller space is the common compression chamber which we have made use of 15 bore X 70 long = 18.78cc or 7 times the total 98cc volume = 7atmospheres. If space is smaller the pressure will be more and bigger lower. If compressor is made to work at 1400 rpm air taken will be 98 X 1400 = 137.2 liters @ 7 atmospheres pressure the advantage with triangular compressor will be low vibration, smaller unit giving more output and so cheaper to make, ideal for air compressor is Air conditioning and Refrigeration, Vacuum pumps and General purpose usage.

1.1. TYPES OF AIR COMPRESSORS

The usage of compressed air is not limited only to industries, but they are also used in manufacturing, welding, constructions, power plants, ships, automobile plants, painting shops, and for filling breathing apparatus too. Thus there are so many types of air compressors used specifically for the above purposes. Let us discuss on various types of air compressors. Compressors are classified in many ways out of which the common one is the classification based on the principle of operation.

1. Positive Displacement and
2. Roto-Dynamic Compressors.

Positive displacement compressors cab be further divided into Reciprocating and rotary compressors.
Under the classification of reciprocating compressors, we have

a. In-line compressors,
b. “V”-shaped compressors,
c. Tandem Piston compressors.
d. Single-acting compressors,
e. Double-acting compressors,
f. Diaphragm compressors.

The rotary compressors are divided into

1. Screw compressors,
2. Vane type compressors,
3. Lobe and scroll compressors and other types. Under the Roto-dynamic compressors, we have 1. Centrifugal compressors, and the

2. Axial flow compressors.

The compressors are also classified based on other aspects like

1. Number of stages (single-stage, 2-stage and multi-stage),
2. Cooling method and medium (Air cooled, water cooled and oil-cooled),
3. Drive types (Engine driven, Motor driven, Turbine driven, Belt, chain, gear or direct coupling drives),

4. Lubrication method (Splash lubricated or forced lubrication or oil-free compressors).
5. Service Pressure (Low, Medium, High)

The Attached picture shows the clear classification of different types of compressors. (Shown in figure 1.)

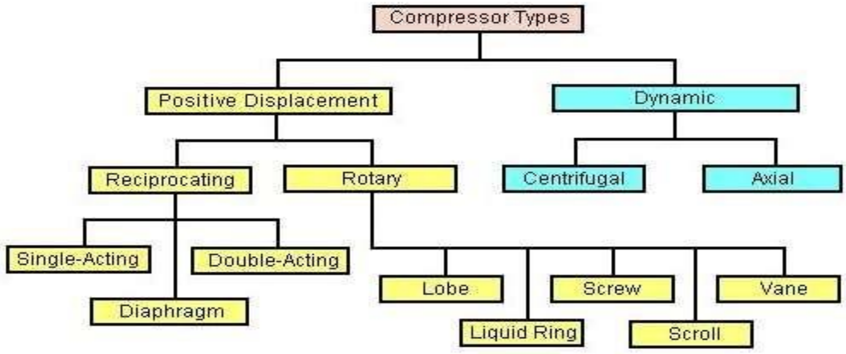

Figure 1: The classification of different types of compressors

2. AIR COMPRESSOR WORKING PRINCIPLE

Air compressors collect and store air in a pressurized tank, and use pistons and valves achieve the appropriate pressure levels within an air storage tank that is attached to the motorized unit. There are a few different types of piston compressors that can deliver even air pressures to the user.

Automotive compressors are combustion engine compressors that use the up-and-down stroke of the piston to allow air in and pressurize the air within the storage tank. Other piston compressors utilize a diaphragm, oil-free piston. These pulls air in, and pressurize it by not allowing air to escape during the collection period. These are the most common types of air compressors that are used today by skilled workers and craftsmen. Before the day of motorized engines, air compressors were not what they are today. Unable to store pressurized air, a type of antique air compressor may be found in the blacksmith's foundry bellows.Multi engine compressor is shown in figure 2.and figure 3.

Now the air compressor is capable of building extreme pressures in storage tanks capable of storing enormous amounts of pressurized gases for industrial use.

Figure 2: Multi engine compressor

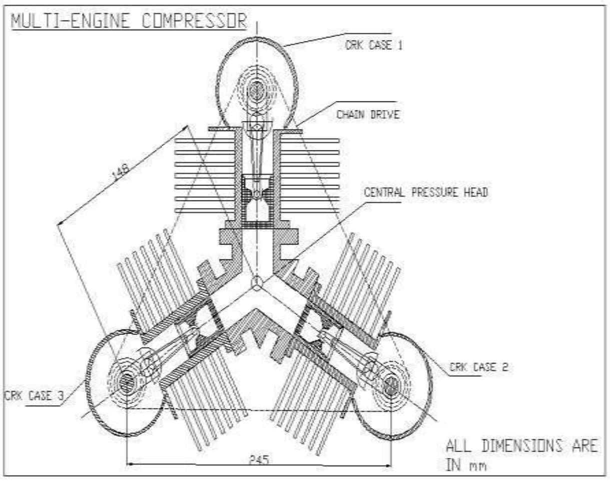

Figure 3: Multi engine compressor

The capacity of an air compressor is determined by the amount of free air (at sea level) that it can compress to a specified pressure, usually 100 psi per minute, under the conditions of 68°F and a relative humidity of 38 percent. This capacity is expressed in cubic feet per minute (cfm) and is usually included in the nomenclature of the compressor.
The number of pneumatic tools that can be operated at one time from an air compressor depends on the air requirements of each tool; for example, a 55-pound class rock drill requires 95 cfm of air at 80 psi. A 210-cfm compressor can supply air to operate two of the drills, because their combined requirement is 190 cfm. However, if a third such drill is added to the compressor, the combined demand is 285 cfm, and this condition overloads the compressor and the tools and results in serious wear.

The three basic types of air compressors are
- Reciprocating rotary
- Screw rotary
- Centrifuga

These types are further specified by:
- The number of compression stages
- cooling method (air, water, oil)
- Drive method (motor, engine, steam, other)
- lubrication (oil, Oil-Free where Oil Free means no lubricating oil contacts the compressed air)
- Packaged or custom-built

2.1. Starting Procedure
The following are to be checked before starting the unit.
- Check the oil level in the oil indicator if the level is the oil level indicator if the level is below the minimum mark; add fresh oil to the correct grade.
- Check the chain tension
- Check the suction pipe air filler
- Check that the unit rotates freely by hard and that there is no mechanical obstructions
- Start the unit and allow itto run for a few minutes

2.2. Checks during operation:
- Check whether the running sound is normal
- Check the pressure developed by opening manometer safety device If all the above preliminary checks are found satisfactory then the unit may be put to regular use

2.3. Merits
- Best suitable for low pressure application.
- Less weight compared to other compressor.
- Production cost is low
- Higher efficiency because of less power required.
- High Durability.
- Compactness of the compressor saves utilization space.
- Easy to use and portable

2.4. Demerits

- Balancing is necessary.
- Frictional loss is high.

2.5. Applications

- Used in laboratories and pharmaceuticals.
- Used for fabrication of plastic structure with hot guess Used for best control fumigation service.
- Used for air agitation of photo film processing tanks, electroplating bath and in chemical plants.
- Used for cooling electronic circuits.
- Used for inflating tyres and air mattresses.
- Used for light duty spray painting.
- Used to operate air driven hand tools such s Die-Polishers, Die-Grinders etc., Used in bore wells to deliver water from the well.

3. Design of major components

3.1. Design of piston

We know the diameter of the piston which is equal to 35 mm

The thickness of the piston head is calculated from flat plate theory

$$t = D \sqrt{(3/16) \times (P/F)}$$

Where,

P- The maximum Compression pressure which is equal to 7 mm

f-The Permissible stress in tension.

Here piston material is aluminum alloy.

So permissible tensile stress =34.6 N/mm²

$$\therefore t = 0.035 \times \sqrt{\{(3/16) \times [7/(34.6 \times 10^6/10^5)]}$$

T = 2.15 mm

t=3 mm

Number of piston Rings = $2\sqrt{D}$

"D" should be in inches

D=35 mm=1.49 inches

∴Number of piston rings=2 x $\sqrt{1.49}$

=2.4

∴Weadopt 2 compression ring and one oil ring.

Thickness of wall under piston ring=3 mm

Thickness of the ring = D/32=35/32

=1.09 mm

Width of the ring = D/20 = 35/20

=1.75 mm

The distance of the first ring from top of the piston equals

= 0.1D = 0.1 x 35

=3.5 mm

Width of piston lands between rings=0.75 x 1.75

=1.312 mm

Say=1.5 mm

Length of piston=1.625 x D

=1.625 x 35

=56.875 mm

Length of the Piston skirt =Total length –Distance of first ring from top of the piston –(Number of landing between rings x width of land) –(No. Of Compression ring x Width of the ring)

=56.875 –3.5 – (2 x 1.5) – (2 x 1.75)

=46.875 mm
Centre of piston pin above the centre of the skirt = 0.02 D
=0.02 x 35
= 0.7
Say = 1 mm
Therefore the distance from the bottom of the
Piston to the centre of the piston pin = ½ x 46.875 –1.5
=24.937 mm
The thickness of the piston walls at open ends = ½ x 3 = 1.5mm

The Bearing area provided by piston skirt = 46.875 x 35
=1640.625 mm²

3.4. Specification of cylinder:

Diameter of Piston	= 35 mm
Thickness of the Piston head	= 3 mm
Number of piston rings	= 2 Nos
Number of compression ring	= 1 No
Number of oil ring	= 1 No.
Thickness of wall under piston ring	= 3 mm
Thickness of ring	= 1.09 mm
Width of the ring	= 1.75 mm
Distance of the first ring from top of the piston	=3.5 mm
Width of piston of land between rings	=1.5 mm
Length of piston	=56.875 mm
Length of Piston skirt	=46.875 mm
The centre of the piston pin above The Centre of the skirt	=1 mm
Distance from the bottom of the piston to The center of the piston pin	=24.934 mm
The thickness of the piston walls at open end	=1.5 mm

3.3. Design of cylinder:-

Considerations:

Required stroke length	=34 mm
Maximum Pressure (P)	=7 kg/cm²
Material used (cost iron)F_t	=1730 kg/cm²
Diameter of the piston d_i	=35 mm

Force acting on cylinder during compression (F) $=\Pi/4 \times di^2 \times P$
$=\Pi / 4 \times 3.5^2 \times 7$
=68 kgf

Length of the cylinder=Stroke length + Length of the piston
=34 + 56.875 mm
=90 mm

3.4. Specification of cylinder: -

Inner diameter	=35 mm
External Diameter	=44 mm
Thickness of the wall	=4.5 mm
Length of the cylinder	=90 mm

3.5. Fin design

As the temperature produced during the compression process is nearly around 200ºC, it is necessary to design the fin to conduct the heat produced during the process. Since the cylinderis made up of cast iron, the fin also made up of cast iron.

∴Thermal conductivity of cast iron (K) $=67.5 \times 10^{-3}$ W/mºK
Heat transfer Co-efficient (h) =25.4 W/m² ºK
Perimeter of the fin (P) =Π (d + Thickness)
=Π (44 + 4.5)
=152.36 mm=0.152 m
Area of the fin (A) $=\Pi \times (d^2/4)$

$=\Pi \times 44^2/4$
$=1936\ mm^2$

Heat transferred (Q) $=hpKA \times (T_0-T_1)$
$=25.4 \times 0.152 \times 67.5 \times 10^{-3} \times 1.936 \times 0.171$
$=86.27$ KW

3.6. Specification of the fin:

Total number of fins	= 6
Type of fin	=Rectangular type
Perimeter of the fin (P)	=0.152 m
Area of the fin (A)	$=1936\ mm^2$
Efficiency of the fin (η)	=79%
Actual heat transferred	=68.15 KW
Therefore diameter of delivery valve	=14.9 mm

3.7. Specification:

Inlet Valve:

Velocity at which air enters	= 7.15 m/sec
Discharge (Q)	= $4.38 \times 10^{-3} m^3/sec$
Diameter of Inlet valve	= 12.7 mm

Outlet Valve

Velocity at which air delivers	= 125.4 m/sec
Diameter of outlet Valve	= 14.9 mm

3.8. Design of Head

As we are doing Triangular air compressor with common compression chamber, the head design plays an important role. The Cylinders are at an angle of 120º to each other. As the breadth of the cylinder Block is about 56mm. Therefore the sides of the head are designed to 56mm.The drill at the centre where the valve should be fitted will be at the size of 12.7mm. Because the dia of the inlet valve is 12./7mm and the outlet valve is about 14.9mm.Then the air from the cylinder should reach the common compression chamber. Hence the drill is done at the diameter of 15mm at exactly centre of the piston to the common compression chamber. Then to fix the cylinder with the Compression chamber the groove of 7mm thickness is taken at the three sides.

3.9. Specifications of the Head:

Length of the Head	= 70mm
Breadth of the Head	= 56mm
Diameter of Central drill	= 12.7mm
Diameter of the drill which connects the piston with central drill	= 15mm
Distance from centre to one side	= 30mm

3.10. Specification of the connecting rod:

Length of connecting rod from centre to centre	=	80 mm
Height of the Connecting rod	=	6.5 mm
Width of the Connecting rod	=	5.2 mm
Thickness of the flange and web	=	1.3 mm
Depth at the big end	=	7.15 mm
Depth at the small end	=	5.90 mm

3.11. Specifications of the bearings

Total load on bearing	=	0.673×10^3 N
Equivalent load	=	0.436×10^3 N
Dynamic Capacity	=	3.119×10^3 N
Bearing Life	=	3 Years
Number of revolutions	=	388.8×10^6
Revolutions Types of Bearing	=	SKF 6202
Code	=	ISI 25 B CO3

3.12. Specifications of the Crank Shaft:

Diameter of the Crank shaft (d)	=	14 mm
Thickness of the Web (t)	=	3 mm
Distance between web	=	5 mm
Width of the Web (W)	=	4.6 mm

3.13. Specifications of piston pin

External Diameter of the piston pin (d_1)	=10 mm
Internal Diameter of the piston pin (d_2)	=5 mm
Length of the piston pin between supports	=17.5 mm

4. Plan of Experiments

4.1 Electrical connection

The electrical power supply must be connected to the motor through starter. Start the unit momentarily and observe the direction of rotating the rotor. The direction should be clockwise. If the direction of rotation is not correct change the direction by interchanging the two places in the starter.

4.2 Adjusting belt tension

The chain tension between the motor and Crankshaft flywheel must be correctly adjusted with proper tension. Otherwise the Compressor will not run of the required speed.

4.3 Starting procedure

The following are to be checked before starting the unit.

- Check the oil level in the oil indicator if the level is the oil level indicator if the level is below the minimum mark; add fresh oil to the correct grade.
- Check the chain tension
- Check the suction pipe air filler
- Check that the unit rotates freely by hard and that there is no mechanical obstructions Start the unit and allow it to run for a few minutes

4.4 Checks during operation

- Check whether the running sound is normal
- Check the pressure developed by opening manometer safety device

If all the above preliminary checks are found satisfactory then the unit may be put to regular use

4.5. Working principle

This triangular air compressor with common compression chamber 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 and with low vibration. For this compressor contain three cylinders having their own piston, connecting rod, crank shaft and their drive. Chain drive was preferred to overcome slipping. When the motor drives the crank shaft all the three piston 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.

4.6. Maintenance procedure

4.6.1 Lubrication

The Crankshaft and Connecting Rod assembly is lubricated by lubricating oils as mentioned in the recommended lubricants charts. Oil should be filled in the oil tank which sprays oil into cylinder during the suction stroke. Care should be taken to see that the oil level is correctly maintained.

4.6.2 Daily

- Check the oil level
- Check the chain tension

4.6.3 Every two hours of operation

- Clean the suction filter, to ensure long life for the values and the piston assembly.

4.6.4 Every 200 hours of operation

- Check and adjust the chain tension.
- Check all the bolts for tightness clean.
- Check the developed pressure clean and adjust the safety valve if necessary.
- Check the bearing sound.

4.6.5 Every 1000 hours

The suction and delivery valves should be removed and the valve seats seating should be inspected for any score or damage. The valves may be lapped if necessary in their respective seats using fine lapping compound. Dismantle the crank shaft bearing and assemble it by new one or by applying grease.

5. Results and Discussions

The performance of the compressor was found to be satisfactory and the output of the compressor is continuous it is up to the level expected. Further improvements can be done on the radial compressor.

5.1. Advantages

- Best suitable for low pressure application.
- Less weight compared to other compressor.
- Production cost is low.
- Higher efficiency because of less power required.
- High Durability.
- Compactness of the compressor saves utilization space. Easy to use and portable.

5.2Applications

- Used in laboratories and pharmaceuticals.
- Used for fabrication of plastic structure with hot gas.
- Used for best control fumigation service.
- Used for air agitation of photo film processing tanks, electroplating bath and in chemical plants.
- Used for cooling electronic circuits.
- Used for inflating tyres and air mattresses.
- Used for light duty spray painting.
- Used to operate air driven hand tools such s Die-Polishers, Die-Grinders etc,

Used in bore wells to deliver water from the well

6. Conclusion

The design and fabrication of Multi engine air compressor in the common compression chamber have been successfully completed and overall assembly of the compressor is drawn in this report. The performance of the compressor was found to be satisfactory and the output of the compressor is Continuous it is up to the level expected. Further improvements can be done on the radial compressor as dealt in the previous chapter.

7. Future scope

The tri cylinder air compressor with common compression chamber can be improved in following areas,

- Lubrication method to be improved to reduce wear and tear.
- Inter cooling can be used to reduce the work done when multistage compression is used.
- Pressure rise can be increased by reducing the clearance volume.
- The production cost can be reduced by casting the cylinder and the head assembly into a Single piece.

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