B.tech M. E. 4th sem Applied Thermodynamics notes by Yogesh Kumar

Topic – Compressors and its classification.

Compressor - An **air compressor** is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When the tank's pressure reaches its engineered upper limit, the air compressor shuts off. The compressed air, then, is held in the tank until called into use.[1] The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank. An air compressor must be differentiated from a pump because it works for any gas/air, while pumps work on a liquid.

Classification of compressors-

Compressors can be classified according to the pressure delivered

1. Low-pressure air compressors (LPACs), which have a discharge pressure of 150 psi or less
2. Medium-pressure compressors which have a discharge pressure of 151 psi to 1,000
3. High-pressure air compressors (HPACs), which have a discharge pressure above 1,000

They can also be classified according to the design and principle of operation:

1. Single-stage reciprocating compressor
2. Two-stage reciprocating compressor
3. Compound compressor
4. Rotary-screw compressor
5. Rotary vane pump
6. Scroll compressor
7. Turbo compressor
8. Centrifugal compressor

Positive displacement-

Positive-displacement compressors work by forcing air in a chamber whose volume is decreased to compress the air. Once the maximum pressure is reached, a port or valve opens and air is discharged into the outlet system from the compression chamber.[4] Common types of positive displacement compressors are-

- Piston-type: air compressors use this principle by pumping air into an air chamber through the use of the constant motion of pistons. They use one-way valves to guide air into and out of a chamber whose base consists of a moving piston. When the piston is on its down stroke, it draws air into the chamber. When it is on

  its up stroke, the charge of air is forced out and into a storage tank. Piston compressors generally fall into two basic categories, single-stage and two-stage. Single stage compressors usually fall into the fractional through 5 horsepower range. Two-stage compressors normally fall

  into the 5 through 30 horsepower range. Two-stage compressors provide greater efficiency than their single-stage counterparts. For this reason, these compressors are the most common units within the small business community. The capacities for both single-stage and two-stage compressors is generally provided in horsepower (HP), Standard Cubic feet per Minute (SCFM)* and Pounds per Square Inch (PSI). *To a lesser extent, some compressors are rated in Actual Cubic Feet per Minute (ACFM). Still others are rated in Cubic Feet per Minute (CFM). Using CFM to rate a compressor is incorrect because it represents a flow rate that is independent of a pressure reference. i.e. 20 CFM *at 60 PSI.*

- Rotary screw compressors: use positive-displacement compression by matching two helical screws that, when turned, guide air into a chamber, whose volume is decreased as the screws turn.
- Vane compressors: use a slotted rotor with varied blade placement to guide air into a chamber and compress the volume. This type of compressor delivers a fixed volume of air at high pressures.

Dynamic displacement-

Dynamic displacement air compressors include centrifugal compressors and axial compressors. In these types, a rotating component imparts its kinetic energy to the air which is eventually converted

into pressure energy. These use centrifugal force generated by a spinning impeller to accelerate and then decelerate captured air, which pressurizes it.

Applications-

Air compressors have many uses, including: supplying high-pressure clean air to fill gas cylinders, supplying moderate-pressure clean air to a submerged surface supplied diver, supplying moderate-pressure clean air for driving some office and school building pneumatic HVAC control system valves, supplying a large amount of moderate-pressure air to power pneumatic tools, such as jackhammers, filling high pressure air tanks (HPA), for filling tires, and to produce large volumes of moderate-pressure air for large-scale industrial processes (such as oxidation for petroleum coking or cement plant bag house purge systems).[6]

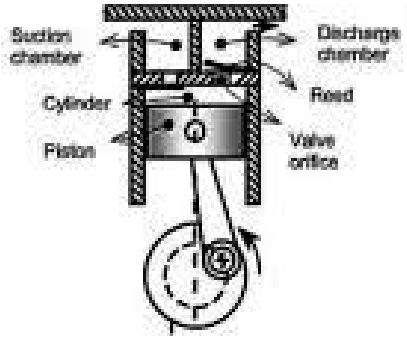
Most air compressors either are reciprocating piston type, rotary vane or rotary screw. Centrifugal compressors are common in very large applications, while rotary screw, scroll,[7] and reciprocating air compressors are favored for smaller, portable applications.

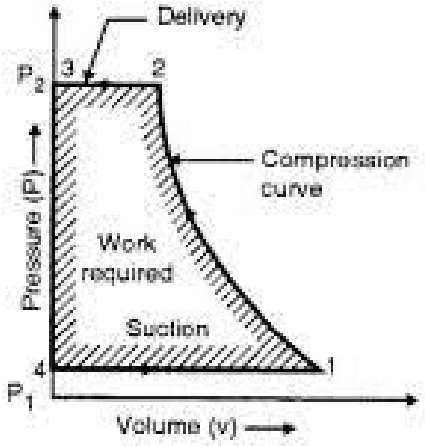
There are two main types of air-compressor pumps: oil-injected and oil-less. The oil-less system has more technical development, but is more expensive, louder and lasts for less time than oil-lubed pumps. The oil-less system also delivers air of better quality.

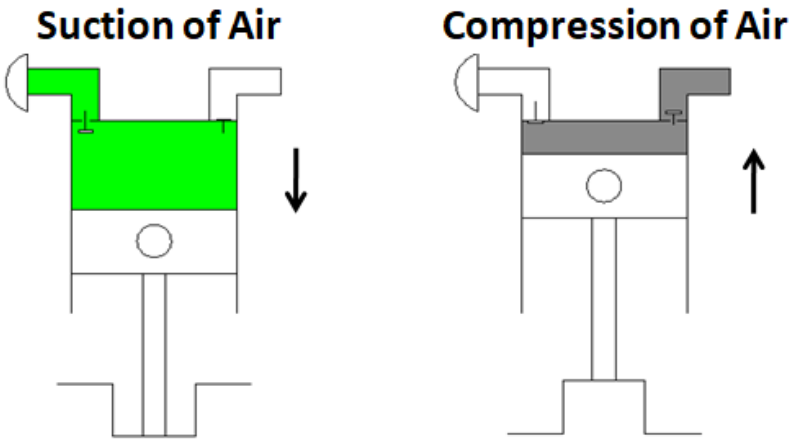
Air compressors are designed to utilize a variety of power sources. While gas/diesel-powered and electric air compressors are among the most popular, air compressors that utilize vehicle engines, power-take-off, or hydraulic ports are also commonly used in mobile applications.[8]

The power of a compressor is measured in HP (horsepower) and CFM (cubic feet per minute of intake air).[9] The gallon size of the tank specifies the volume of compressed air (in reserve) available. Gas/diesel powered compressors are widely used in remote areas with problematic access to electricity. They are noisy and require ventilation for exhaust gases. Electric powered compressors are widely used in production, workshops and garages with permanent access to electricity. Common workshop/garage compressors are 110-120 Volt or 230-240 Volt. Compressor tank shapes are: "pancake", "twin tank", "horizontal", and "vertical". Depending on a size and purpose compressors can be stationary or portable.

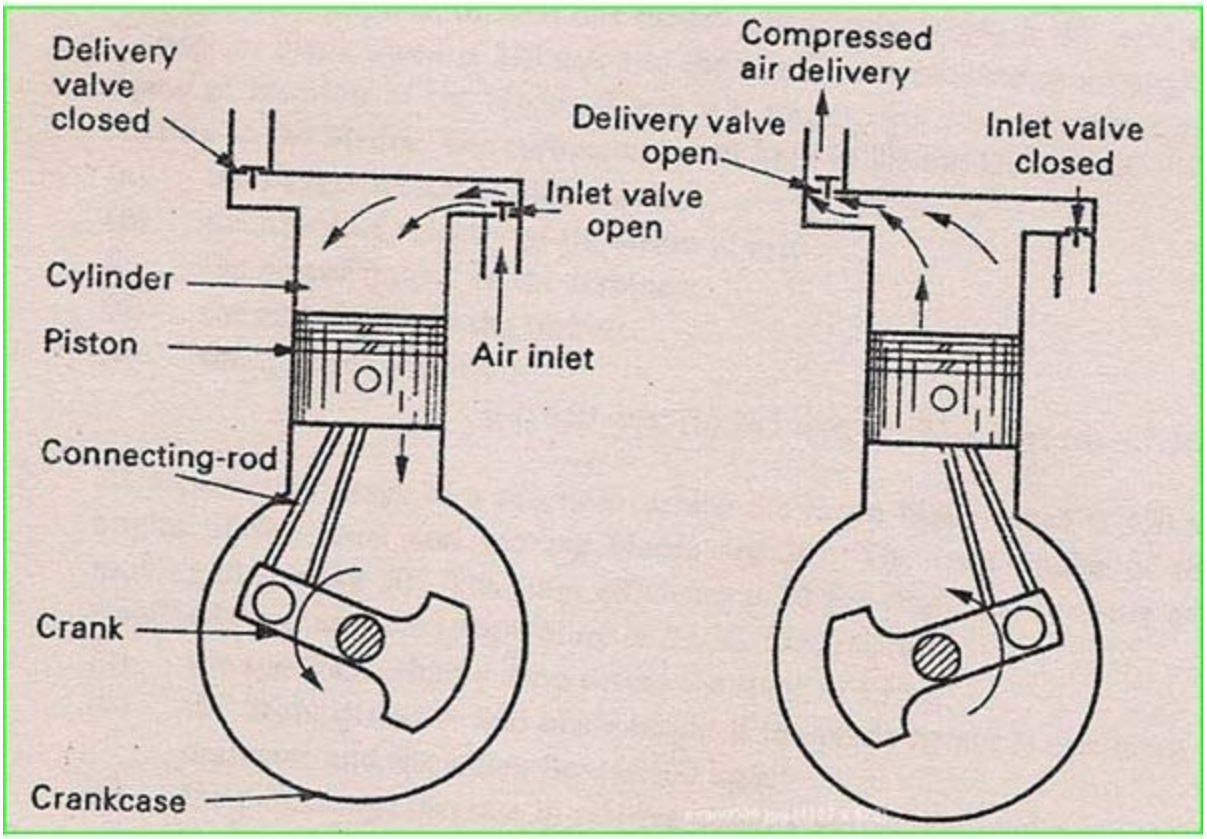
Single stage Reciprocating Air Compressor Construction and Working Principle-







Single Stage Reciprocating Air Compressor



Reciprocating Air Compressor has also classified according to its stages. So, Classification will help you better understand the working of the reciprocating air compressor.

The principle of operation is same in each type. But according to stages, the building of discharge pressure is different in each compressor.

The reciprocating type compressor consists of a piston which is enclosed within the cylinder & equipped with suction & discharge valves.

The piston receives power from the main shaft through the crankshaft and connecting rod. A flywheel/belt wheel is fitted on the crankshaft which is driven by electric motor or diesel engine.

It supplies uniform motion throughout the cycle of operations.

The compression of air is done by first drawing a volume of air into its cylinder through suction valves during suction stroke by the piston & then compressing & discharging it on the return stroke of the piston through delivery valves.

This simple working is used in every Reciprocating Air Compressor. You will easily understand compressor *engineering* from below description.

- *How Single Stage Reciprocating Air Compressor Works*
- In single stage reciprocating air compressor, the entire compression is carried out in a single cylinder.
- If the compression is affected in one end of the piston & cylinder then it is known as single acting & if the compression is affected in both ends of piston & cylinder then it is known as a double acting reciprocating air compressor.
- The opening & closing of a simple check valve (plate or spring valve) depends upon the difference in pressure, if mechanically operated valves are used for suction & discharge then their functioning is controlled by cams.
- The weight of air in the cylinder will be zero when the piston is at top dead centre. At this position, you have to neglect clearance volume.
- When piston starts moving downwards, the pressure inside the cylinder falls below atmospheric pressure& suction valve/inlet valve opens.
- The air is drawn into the cylinder through a suction filter element. This operation is known as suction stroke.
- When the piston moves upwards, compresses the air in cylinder & inlet valve closes when the pressure reaches atmospheric pressure.
- Further compression follows as the piston moves towards the top of its stroke. Until when the pressure in the cylinder exceeds that in the receiver.
- This is compression stroke of a compressor. At the end of this stroke discharge/delivery valve opens & air is delivered to a receiver.
- When it is a double acting reciprocating air compressor, suction stroke is in process at one end of the piston. While at same time discharge stroke is in process at another end of the piston.
- In simple word, we can say that suction & compression took place on both ends of piston & cylinder in double acting reciprocating air compressor.

How Double Stage Reciprocating Air Compressor Works-

Double stage or two stage reciprocating air compressors consists of two cylinders. One is called low-pressure cylinder and another is called high-pressure cylinder.

When piston in a low-pressure cylinder is at its outer dead centre (ODC) the weight of air inside a cylinder is zero (neglecting clearance volume), as piston moves towards inner dead centre (IDC) pressure falls below atmospheric pressure & suction valves open due to a pressure difference.

The fresh air is drawn into the low-pressure cylinder through air suction filter. This air is further compressed by piston and pressure inside & outside the cylinder is equal, at this point suction valves closed.

As the piston moves towards ODC compression of air took place and when the pressure of air is in a range of 1.5 kg/cm² to 2.5 kg/cm² delivery valves opens & this compressed air is then entered into a high-pressure cylinder through the intercooler. This called low-pressure compression.

If suction & discharge stroke took place on both sides of the piston then it is called Double Acting Low-pressure compression.

Suction valves of a high-pressure cylinder open when the air pressure in a high-pressure side is below to the receiver pressure & air from low-pressure cylinder drawn into the high-pressure cylinder.

As piston moves towards the ODC, first stage air is further compressed. When air pressure from the low-pressure cylinder and inside the high-pressure cylinder is equal, suction valves closed.

Now the air is further compressed by piston until the pressure in the High-Pressure Cylinder exceeds that of the receiver & discharge valves open. This desired high-pressure air is then delivered to a receiver.

The Same procedure is repeated in every cycle of operation. If suction & discharge stroke took place on both sides of the piston then it is called double-acting high-pressure compression.

In double stage, reciprocating air compressor air pressure can be developed in a range of 5.5 kg/cm² to 35 kg/cm².

Normally where we required air pressure above 7.0 kg/cm² & delivery of air above 100 cubic feet/min. this double stage reciprocating air compressor is used.

This is the most common model used in various engineering plants. If we required air pressure above 35 kg/cm², this double stage reciprocating air compressor is not useful.

There you have to use three-stage air compressors.

Working Principle of Multi-Stage Air Compressor-

Some industries required air pressure more than 35 kg/cm² to produce their product. For example, mineral water bottle (pet blowing) requires air pressure more than 40 kg/cm². To produce the desired shape of a bottle at the bottom side.

Here Two Stage Reciprocating Air Compressor is not useful; we required the air compressor, who generates air pressure above 35 kg/cm².

This discharge air pressure is achieved by a multi-stage air compressor. We normally use three stage reciprocating air compressors as a multi-stage air compressor.

If we required discharge air pressure above 85 kg/cm² then four-stage air compressors are useful.

The working principle of multistage air compressor is same as double stage air compressor.

In three stage air compressor, fresh air from the atmosphere enters in a first stage (low pressure) cylinder. Air enters through a suction filter.

This air is compressed by piston up to 4 kg/cm² & then delivered to the second stage (middle pressure) cylinder through intercooler for further compression. In this stage suction and compression took place on both sides of the piston.

In the second stage cylinder low-pressure air is compressed up to 14 kg/cm² & discharge to the third stage (high pressure) cylinder through the second intercooler to achieve air pressure up to desired delivery pressure.

During this stage suction and compression took place on one side of the piston.

At high-pressure cylinder, the 14 kg/cm² air pressure is increased up to desired discharge range. It is from 35 kg/cm² to 85 kg/cm² by the piston reciprocating inside the high-pressure cylinder.

In this stage suction and compression took place on both sides of the piston.

The multistage reciprocating air compressor is used in few industries like Pet Blowing, CNG (Compressed Natural Gas) Center etc.