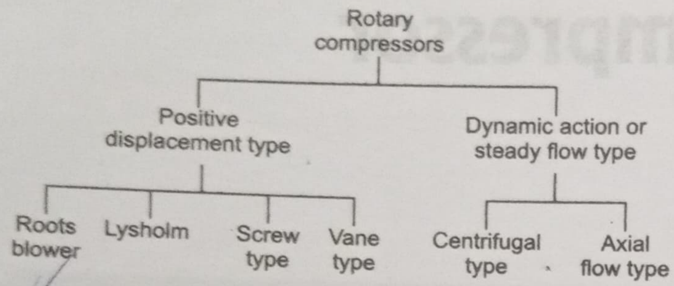
6.1 CLASSIFICATION OF ROTARY COMPRESSORS

The air compressors are either reciprocating type or rotary type. The rotary air compressors can broadly be classified as



In a rotary *positive displacement* type of air compressor, the air is compressed by being trapped in the reduced space formed by two sets of engaging surfaces. In a *non-positive displacement* or steady flow type of compressor, the air flows continuously and pressure is increased due to dynamic action.

The rotary compressors have adiabatic compression. They have high speed and no cooling arrangement is provided during compression. Comparison of reciprocating type and rotary type compressor is presented in Table 6.1.

Table 6.1 *Comparison between Reciprocating and Rotary Compressors*

S. No.	*Aspect*	*Reciprocating compressor*	*Rotary compressor*
1.	Pressure ratio	Discharge pressure of air is high. The pressure ratio per stage may be in order of 4 to 7.	Discharge pressure of air is low. The pressure ratio per stage is limited to 5.
2.	Handled volume	Quantity of air handled is low and is limited to 50 m^3/s.	Larger quantity of air can be handled and it is about 500 m^3/s or more.
3.	Speed of compressor	Low speed of compressor.	High speed of compressor.
4.	Ideal compression process	Isothermal process	Isentropic process
5.	Cooling arrangement	Effective cooling is required	No cooling is required
6.	Vibrational Problem	Due to reciprocating action, greater vibrational problem, the parts of machine are poorly balanced.	Rotary parts of machine, thus it has less vibrational problems. The machine parts are fairly balanced.
7.	Size	Size of compressor is bulky for given discharge volume.	Compressor size is small for given discharge volume.
8.	Air supply	Air supply is intermittent.	Air supply is steady and continuous.
9.	Purity of compressed air	Air delivered from the compressor is dirty, since it comes in contact with lubricating oil and cylinder surfaces.	Air delivered from the compressor is clean and free from dirt.
10.	Compression efficiency	Higher with pressure ratio more than 2.	Higher with compression ratio less than 2.
11.	Maintanance	Higher due to reciprocating parts.	Lower due to balanced rotary parts.
12.	Mechanical efficiency	Lower due to several sliding parts.	Higher due to less sliding parts.
13.	Lubrication	Complicated lubrication system.	Simple lubrication system.
14.	Initial cost	Higher.	Lower.
15.	Flexibility	Greater flexibility in capacity and pressure range.	No flexibility in capacity and pressure range.
16.	Suitability	For medium and high pressure ratio and low and medium gas volume.	For low and medium pressures and large volumes.

6.2 ROOTS BLOWER COMPRESSOR

Roots blower is a positive dispacement compressor. It is also called *lobe compressor.* The roots blower is essentially a low-pressure blower and is limited to a discharge pressure of 1 bar in single-stage design and up to 2.2 bar in a two-stage design. Its discharge capacity is limited to 1500 m^3/min and it can run up to 7000 rpm.

Construction This type of rotary compressor consists of two or more lobed rotors in the casing with inlet and outlet passage of air. The lobed rotors rotate in an air tight casing with the help of gears in external housing. The compressor inlet is open to atmospheric air at one side and it is open to delivery side at the other side. The two lobed roots blower is shown in Fig. 6.1(a).

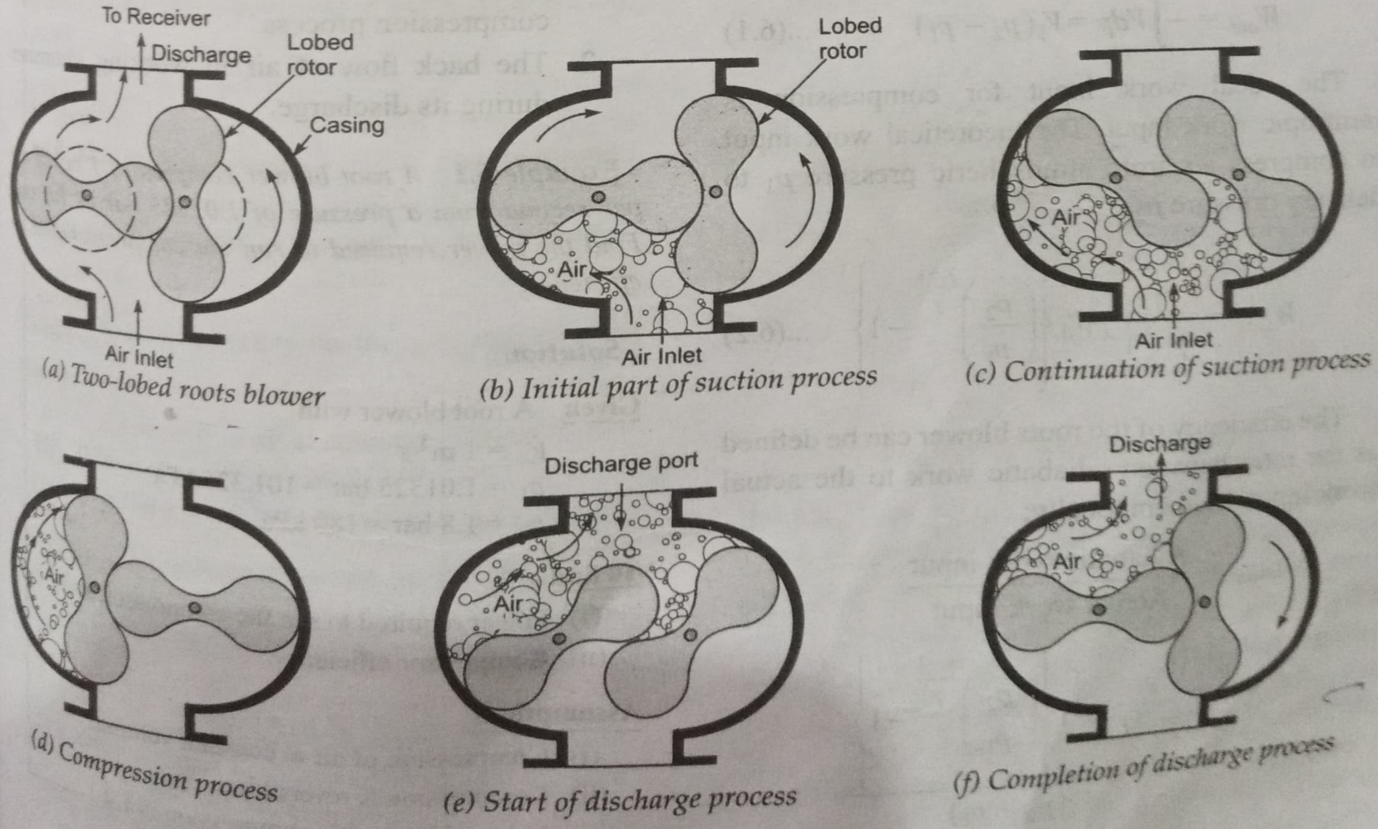
One lobed rotor is connected to drive. The second lobed rotor is gear driven from the first. Thus, both rotors rotate with the same speed. The profile of the lobes is made cycloidal or involute in order to seal the inlet side from the delivery side.

Working The rotation of rotors creates space in the casing at the entry port as shown in Fig. 6.1(b). The air is drawn into the casing to fill the space. The flow of gas in the casing space continues till both rotors change their position as shown in Fig. 26(c).

With further movement of the lobed rotor, the air is trapped between one rotor, when its tip tuches the casing as shown in Fig. 26(d). The air flows into the space created by rotation of other rotor. This rotor is also carrying out the same cycle as first rotor after 90°.

The trapped volume of air is not internally compressed, it is only displaced at high speed from suction side to delivery side. Continued rotation of lobes opens the discharge port as shown in Fig. 26(e).

Since the compressed air at higher pressure is present at the delivery side, when the rotor lobe uncovers the exit port, some pressurised air enters into the space between the rotor and casing of the compressor. This flow of air is called *back flow* of



(a) *Two-lobed roots blower* (b) *Initial part of suction process* (c) *Continuation of suction process*

(d) *Compression process* (e) *Start of discharge process* (f) *Completion of discharge process*

Fig. 6.1

air. This back flow of air continues until the pressure in the blower gets equalised. After back flow, the air is compressed irreversibly at constant volume. Finally, at higher pressure, the air is delivered from the blower to receiver as shown in Fig. 6.1(f). The process of compression can be represented by constant volume line on p–V plane as shown in Fig. 6.2.

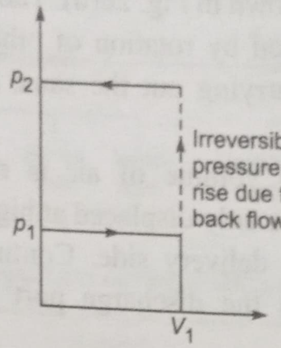


Fig. 6.2 *p-V diagram for roots blower*

Consider a volume of V_1 is trapped between the lobe and casing at atmospheric pressure p_1. The air is compressed to delivery pressure p_2. The actual work done on air;

$$W_{act} = -\int V dp = V_1(p_2 - p_1) \quad \text{...(6.1)}$$

The ideal work input for compression is isentropic work input. The theoretical work input to compress air from atmospheric pressure p_1 to delivery pressure p_2.

$$W_{isen} = \frac{\gamma}{\gamma - 1} p_1 V_1 \left\{ \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right\} \quad \text{...(6.2)}$$

The efficiency of the roots blower can be defined as the ratio between adiabatic work to the actual work input. Mathematically;

$$\eta_{roots} = \frac{\text{Adiabatic work input}}{\text{Actual work input}}$$

$$= \frac{\frac{\gamma}{\gamma - 1} p_1 V_1 \left\{ \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right\}}{V_1(p_2 - p_1)}$$

Let $\frac{p_2}{p_1} = r_p$, pressure ratio. Dividing numerator and denominator by p_1V_1, we get

$$\eta_{roots} = \frac{\gamma}{\gamma - 1} \times \frac{\left\{(r_p)^{\frac{\gamma-1}{\gamma}} - 1\right\}}{(r_p - 1)} \quad ...(6.3)$$

The efficiency of roots blower decreases with increase in pressure ratio. However, the compressor is suitable to give a pressure ratio between range of 1 to 2.2.

η_{mech} 0.8

6.3 VANE-TYPE COMPRESSOR

Construction An arrangement of a typical vane-type compressor is shown in Fig. 6.3. It consists of an air-tight circular casing, in which a drum rotates about an eccentric centre of casing. The drum consists of a set of spring-loaded vanes. The slots are cut in the drum to accomodate the vanes. The drum rotates in anticlockwise direction. During the rotation of the drum, the vanes remain in contact with the casing. Size of inlet passage is larger than the size of outlet in the compressor.

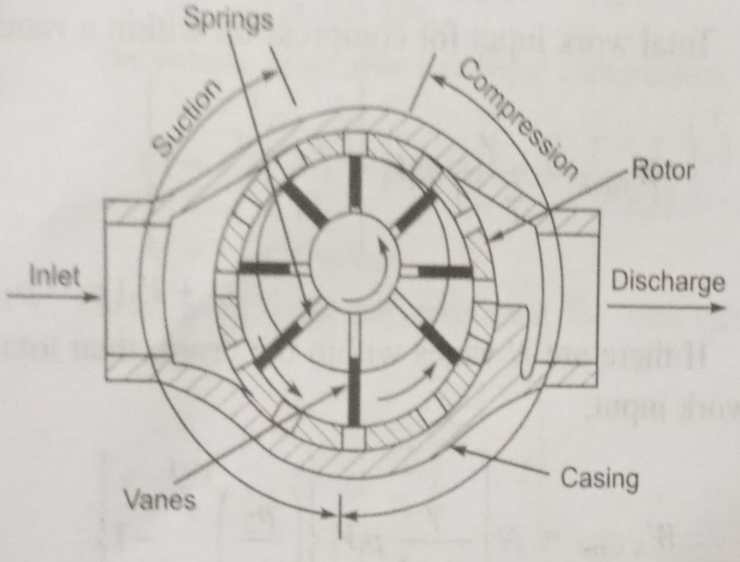


Fig. 6.3 *Vane-type compressor*

Working As the drum rotates, the volume of air V_1 at atmospheric pressure p_1 is trapped between the vanes, drum and casing. Air gets compressed due to two operations performed on air. First the compression begins due to decreasing volume between the drum and casing. The volume is reduced to V_2 and pressure increases to p_2. Secondly, the air is compressed due to back flow of compressed air in the receiver. Then the air is compressed at constant volume to a pressure p_3. The first part of compression follows adiabatic compression process and the second part follows constant-volume process. The process of compression is shown on the p–V diagram in Fig. 6.4

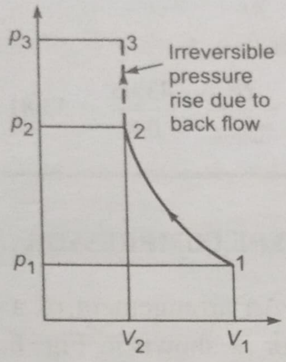


Fig. 6.4 *p-V diagram for Vane type compressor*

Work input for adiabatic compression;

$$W_{1-2} = \frac{\gamma}{\gamma-1} p_1 V_1 \left\{ \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right\}$$

Work input for constant volume compression;

$$W_{2-3} = V_2 (p_3 - p_2)$$

Total work input for compression within a vane;

$$W_{vane} = \frac{\gamma}{\gamma-1} p_1 V_1 \left\{ \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right\} + V_2 (p_3 - p_2)$$

If there are N vanes within the drum, then total work input;

$$W_{N\,vane} = N \left[\frac{\gamma}{\gamma-1} p_1 V_1 \left\{ \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right\} + V_2 (p_3 - p_2) \right] \quad \text{...(6.4)}$$

The efficiency of a vane compressor can be expressed as

$$\eta_{vane,\,comp} = \frac{\text{Work input for constant-volume compression}}{\text{Total work input for compression}}$$

$$= \frac{V_2(p_3 - p_2)}{\frac{\gamma}{\gamma - 1} p_1 V_1 \left[\left(\frac{p_2}{p_1} \right)^{\frac{\gamma - 1}{\gamma}} - 1 \right] + V_2(p_3 - p_2)} \quad \text{...(6.5)}$$

1. The vane-type compressor requires less work input compared to roots blower for same capacity and pressure ratio.
2. Vane-type compressors are commonly used to deliver air up to 150 m^3/min at a pressure ratio up to 8.5.
3. Vane-type compressors can run up to 3000 rpm.
4. Vane-type compressors are used for supercharging of IC engines and supply of air to cupola.
5. These are portable compressors used for construction purpose.

6.5 CENTRIFUGAL COMPRESSOR

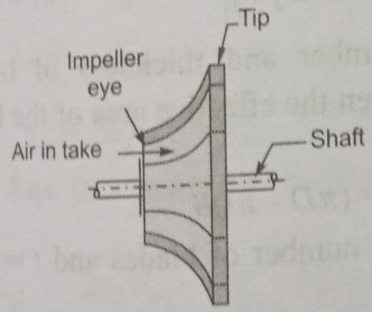
The centrifugal compressors are dynamic action compressors. These compressors have appreciably different characteristics as compared to reciprocating machines. A small change in compression ratio produces a marked change in compressor output and efficiency. Centrifugal machines are better suited for applications requiring very high capacities, typically above 3000 m^3/min and a moderate pressure ratio of 4 to 5. They are preferred due to their simplicity, light weight and ruggedness.

The centrifugal air compressor is an oil-free compressor by design. The oil-lubricated running gear is separated from the air by shaft seals and atmospheric vents. It is a continuous duty compressor with few moving parts, and is particularly suited to high volume applications, especially where oil-free air is required.

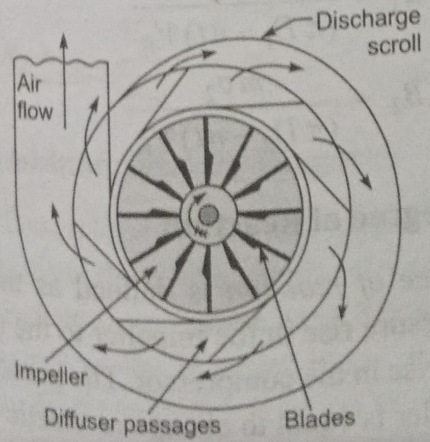
The centrifugal compressors find their applications in oil refineries, gas turbines, refrigeration and air conditioning, HVAC, turbochargers and superchargers of automobiles etc.

6.5.1 Construction

The basic components of a typical centrifugal compressor includes an impeller, diffuser and casing as shown in Fig. 6.6. The impeller is a radial disc with a series of radial blades (vanes). The



(a) Impeller eye



(b) Sectional view of centrifugal compressor

6.5.13 Comparison between Reciprocating and Centrifugal Compressors

Sr. No.	*Reciprocating Compressor*	*Centrifugal Compressor*
1.	Geater noise and vibrations	Compratively salient operation
2.	Poor mechanical efficiency due to large sliding parts	Better mechanical efficiency due to absence of sliding parts
3.	Installation cost is higher	Installation cost is lower
4.	Pressure ratio up to 5 to 8	Pressure ratio up to 4
5.	Higher pressure ratio up to 500 atm. is possible with multistaging of compressor	It is not suitable for multistaging
6.	It runs intermittantly and delivers pulsating air	It runs continuously and delivers steady and pulsating free air
7.	Less volume is handled	Large volume is handled
8.	More maintenance is required	Less maintenance is required
9.	Weight of compressor is more	Comparatively less weight
10.	It operates at low speed	It operates at high speed

Contd.

6.6 AXIAL COMPRESSOR

Axial compressors are aerofoil (blade) based rotary compressors. The gas flows parallel to the axis of rotation in axial flow compressors and gas is continuously compressed. The several rows of aerofoil blades are used to achieve large pressure rise in the compressor.

The axial compressors are generally multi-stage machines; each stage can give a pressure ratio of 1.2 to 1.3. The axial flow compressors are suitable for higher pressure ratios and are generally more efficient than radial compressors.

Axial compressors are widely used in gas turbine plants and small power stations. They are also used in industrial applications such as blast-furnace, large-volume air-separation plants, and propane dehydrogenation. Axial compressors are also used for supercharging. They are also used to boost the power of automotive reciprocating engines by compressing the intake air.

6.8 DIFFERENCE BETWEEN CENTRIFUGAL AND AXIAL FLOW COMPRESSORS

Sr. No.	*Centrifugal Compressor*	*Axial-flow Compressor*
1.	Air flows radially in the compressor.	Air flows parallel to axis of shaft.
2.	Low maintenance and running cost.	High maintenance and running cost.
3.	Low starting torque required.	Requires high starting torque.
4.	Not suitable for multistaging.	Suitable for only multistaging.
5.	Suitable for low pressure ratios up to 4.	Suitable up to a pressure ratio of 10.
6.	For given mass-flow rate, it requires, larger frontal area.	It requires less frontal area.
7.	Isentropic efficiency 80 to 82%.	Isentropic efficiency 86 to 88%.
8.	Better performance at part load.	Poor performance at part load.