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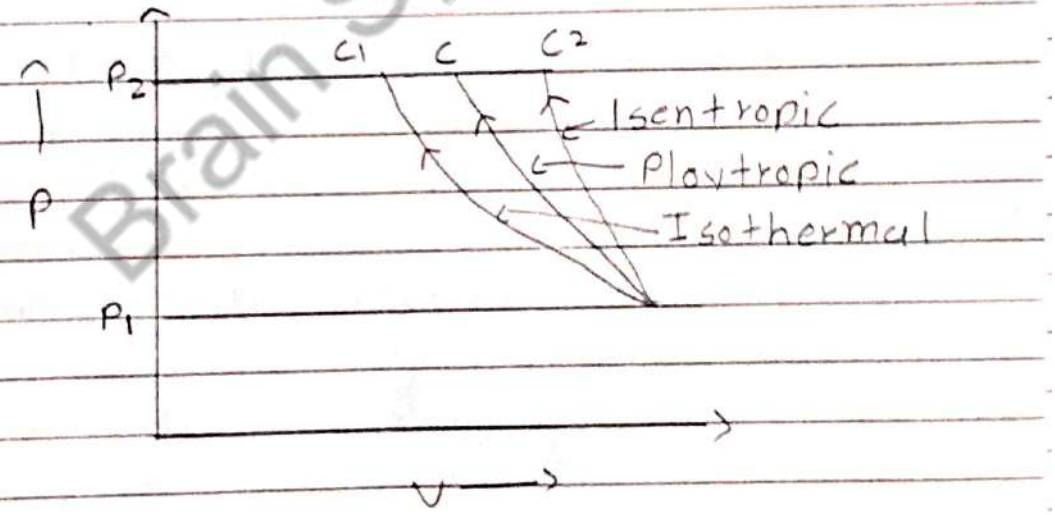
Air Compressor

1 Derive equation for workdone in single stage reciprocating compressor without clearance.

The working of reciprocating compressor includes three operations. 1) Suction
2) Compression
3) discharge of Compressed fluid.



Let P_1 is Suction Pressure,
V_1 is volume suction and
T_1 is Suction Temperature

and P_2 is Compression after Pressure
V_2 is After Compression Volume and
T_2 is After Compression Temperature

r is a compression ratio = P_1 / P_2

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=> Workdone During Isothermal Process.

Workdone during the sunction,

$$W_1 = P_1 V_1$$

Workdone during the Compression,

$$W_2 = P_1 V_1 \log_e \left(\frac{V_1}{V_2}\right)$$

Workdone during the discharge compressed

$$W_3 = P_2 V_2$$

=> Total Workdone $W = W_3 + W_2 - W_1$

$$\therefore W = P_2 V_2 + P_1 V_1 \log_e \left(\frac{V_1}{V_2}\right) - P_1 V_1$$

Since $P_1 V_1 = P_2 V_2$ and
$P_1 V_1 = mRT_1 2.3$

$$\therefore W = mRT_1 2.3 \log_e \left(\frac{V_1}{V_2}\right)$$

$$\frac{P_2}{P_1} = \frac{V_1}{V_2} = r$$

$$\therefore W = mRT_1 2.3 \log r$$

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=> Workdone during Polytropic Process.

Workdone during the suction,

$$W_1 = P_1 V_1$$

Workdone during the compression

$$W_2 = \frac{P_2 V_2 - P_1 V_1}{n-1}$$

Workdone during the discharge

$$\therefore W_3 = P_2 V_2$$

=> Total Workdone $W = W_3 + W_2 - W_1$

$$W = P_2 V_2 + \frac{P_2 V_2 - P_1 V_1}{n-1} - P_1 V_1$$

$$W = \frac{P_2 V_2 (n-1) + P_2 V_2 - P_1 V_1 - P_1 V_1 (n-1)}{n-1}$$

$$W = \frac{n}{n-1} (P_2 V_2 - P_1 V_1)$$

$$W = \frac{n}{n-1} P_1 V_1 \left(\frac{P_2 V_2}{P_1 V_1} - 1 \right)$$

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Polytropic process $P_1 V_1^n = P_2 V_2^n$

$$\therefore \frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1}{n}}$$

$$\therefore W = \frac{n}{n-1} P_1 V_1 \left[\frac{P_2}{P_1}\left(\frac{P_1}{P_2}\right)^{1/n} - 1\right]$$

$$\therefore W = \frac{n}{n-1} mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

Since $\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \frac{T_2}{T_1}$

$$\therefore W = \frac{n}{n-1} mRT_1 \left(\frac{T_2}{T_1} - 1\right)$$

$$\therefore W = \frac{n}{n-1} mR(T_2 - T_1)$$

=> Work done during Isentropic Process.

The workdone equation is similar to that of during polytropic Process

$$\therefore W = \frac{\gamma}{\gamma-1} mR(T_2 - T_1)$$

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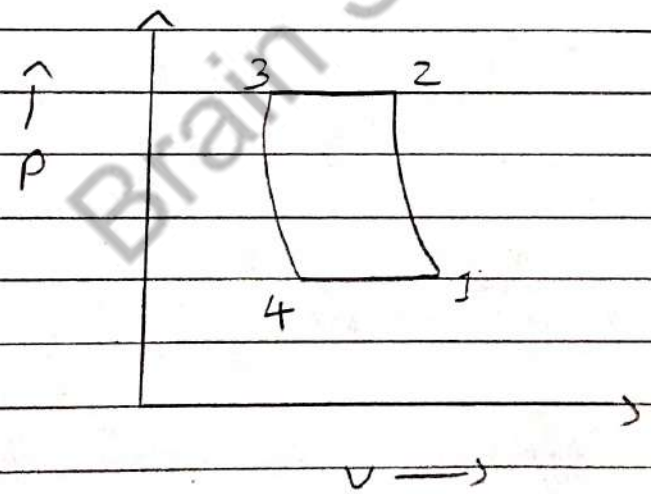
Here $R = C_p - C_v = C_p\left(\frac{\gamma-1}{\gamma}\right)$

$\therefore W = \frac{\gamma}{\gamma-1} m C_p \left(\frac{\gamma-1}{\gamma}\right)(T_2 - T_1)$

$\therefore W = m C_p (T_2 - T_1)$

2 Derive Equation of volumetric Efficiency of a single stage reciprocating air compressor.



Here, V_c = Clearance Volume (V_3)
V_s = Swept Volume ($V_1 - V_3$)

Clearance ratio = $\frac{\text{Clearance Volume}}{\text{Swept Volume}}$

$$C = \frac{V_c}{V_s} = \frac{V_3}{V_1 - V_3}$$

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Volumetric Efficiency

$$\eta_{vol} = \frac{\text{Free air Delivered}}{\text{Swept Volume}}$$

$$\therefore \eta_{vol} = \frac{V_1 - V_4}{V_1 - V_3}$$

$$= \frac{(V_1 - V_3) + (V_3 - V_4)}{V_1 - V_3}$$

$$= 1 + \frac{V_3}{V_1 - V_3} - \frac{V_4}{V_1 - V_3}$$

$$= 1 + \frac{V_c}{V_s} - \frac{V_4 V_3 / V_3}{V_1 - V_3}$$

$$= 1 + \frac{V_c}{V_s} - \frac{V_c}{V_s} \times \frac{V_4}{V_3}$$

For Polytropic Process $\frac{V_4}{V_3} = \left(\frac{P_3}{P_4}\right)^{1/n}$

$$\therefore \eta_{vol} = 1 + C - C\left(\frac{P_3}{P_4}\right)^{1/n}$$

Here $P_3 = P_2$ and $P_4 = P_1$

$$\therefore \eta_{vol} = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}$$

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3 With neat sketch explain Centrifugal Compressor.

Centrifugal Compressor is sometimes called radial Compressor.

Centrifugal Compressor is a type of dynamic Compressor or turbo compressor.

=>

=> Construction:

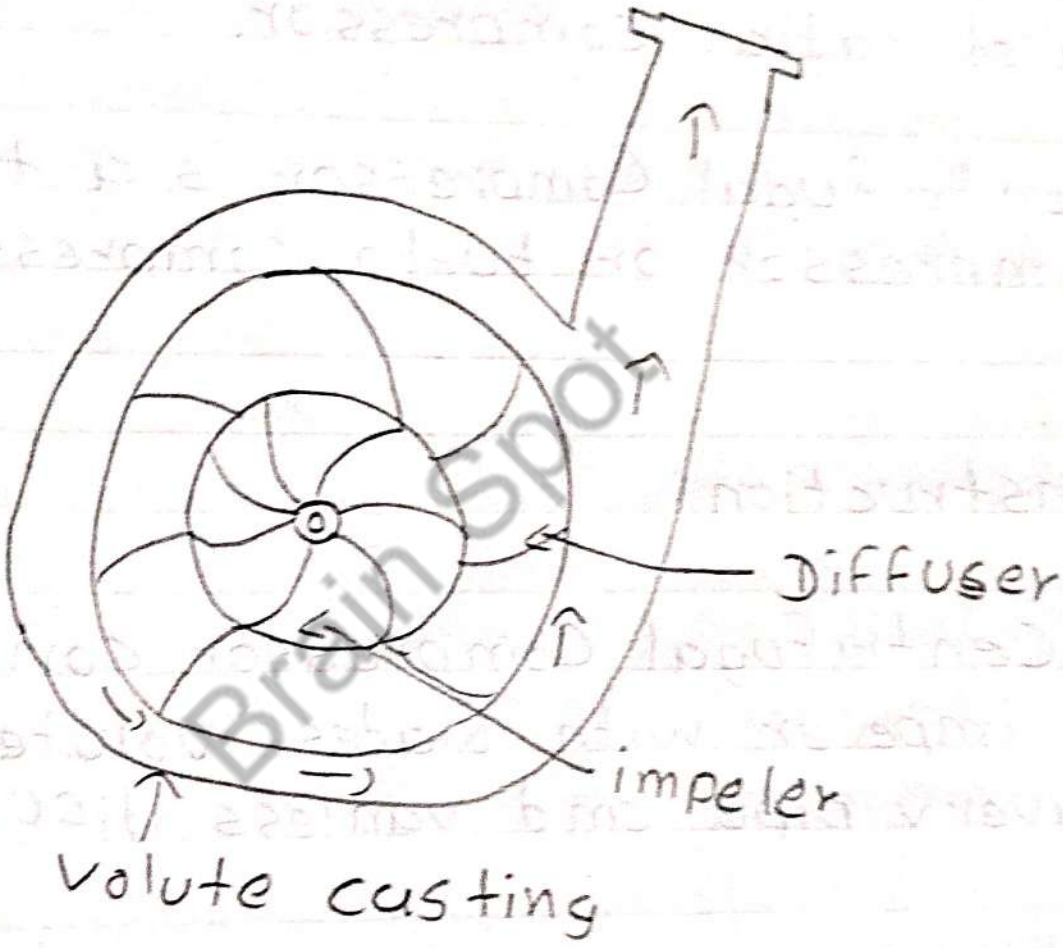
A Centrifugal Compressor consists inlet pipe, an impeler with blades, volute casting, delivery pipe and vanless diffuser.

=> Working:

In Centrifugal Compressor air is drawn into the center of a rotating impeler with blades.

It is pushed toward the center by centrifugal force.

This radial movement of air increase pressure and generation of kinetic energy.



Centrifugal Compressor

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Before the air is led into the center of the impeler, the kinetic energy is converted into pressure.

=> Advantages

Low weight and Easy to design and manufacture

High flow rate than the positive displacement compressor.

=> limit:

Centrifugal Compressors can be sized for an inlet flow of 400000 rpm in a single body.

=> Use: Gas turbines and Automobiles.