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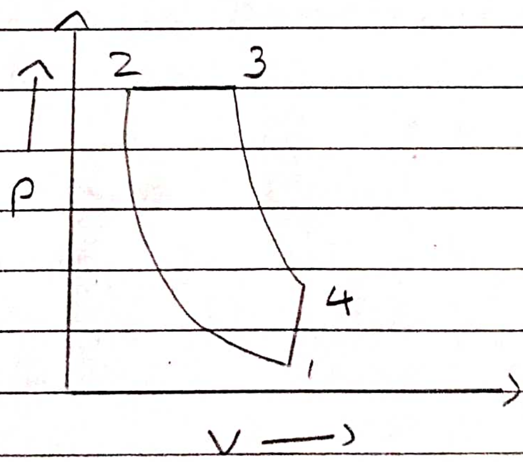
Heat Engine

1 Derive Equation for air standard efficiency of Diesel Cycle.

Diesel Cycle is ideal cycle for compression ignition Engine.

This cycle is working with four reversible processes.

=) This are the Four Processes.



-) For, 1 - 2 -) This is reversible adiabatic compression Processes.

In this processes Air's Pressure and temperature will increase.

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-> For 2 - 3 -> This is Constant Pressure Processes.

During this processes pressure of air remaine constant and volume and temperature will increase.

-> For 3 - 4 -> This is reversible adiabatic expansion processes.

In this processes pressure and temperature will decrease.

-> For 4 - 1 -> This is constant volume Processes.

During this Processes pressure and temperature will decrease.

-> In this cycle,

Heat Supplied $Q_S = C_p(T_3 - T_2)$

Heat Rejected $Q_R = C_v(T_4 - T_1)$

Work done per cycle $= Q_S - Q_R$

Air standard efficiency $\eta_a = \frac{\text{Work done}}{\text{Heat Supplied}}$

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$$\eta_a = \frac{C_p(T_3 - T_2) - C_v(T_4 - T_1)}{C_p(T_3 - T_2)}$$

$$\therefore \eta_a = 1 - \frac{C_v\,(T_4 - T_1)}{C_p\,(T_3 - T_2)}$$

$$= 1 - \frac{1}{\gamma}\frac{(T_4 - T_1)}{(T_3 - T_2)} \quad — (1)$$

Here, we will substitute for T_2, T_3 and T_4 in terms of T_1.

→ Process 1-2: $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$

$$\therefore T_2 = T_1 \cdot (r)^{\gamma-1} \quad — (2)$$

Here, $r = \frac{V_1}{V_2}$ = Compression ratio.

→ For Process 2-3: $\frac{T_3}{T_2} = \frac{V_3}{V_2} = \rho$

$$\therefore T_3 = T_1 \cdot \rho \cdot r^{\gamma-1} \quad (3)$$

Here, $\rho = \frac{V_3}{V_2}$ = cut off ratio.

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→ For Process 3-4: $\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$

$\therefore T_4 = T_3 \cdot \left(\frac{V_3}{V_2} \cdot \frac{V_2}{V_4}\right)^{\gamma-1}$

$\therefore T_4 = T_3 \left(\frac{\rho}{r}\right)^{\gamma-1}$ Here $V_1 = V_4$

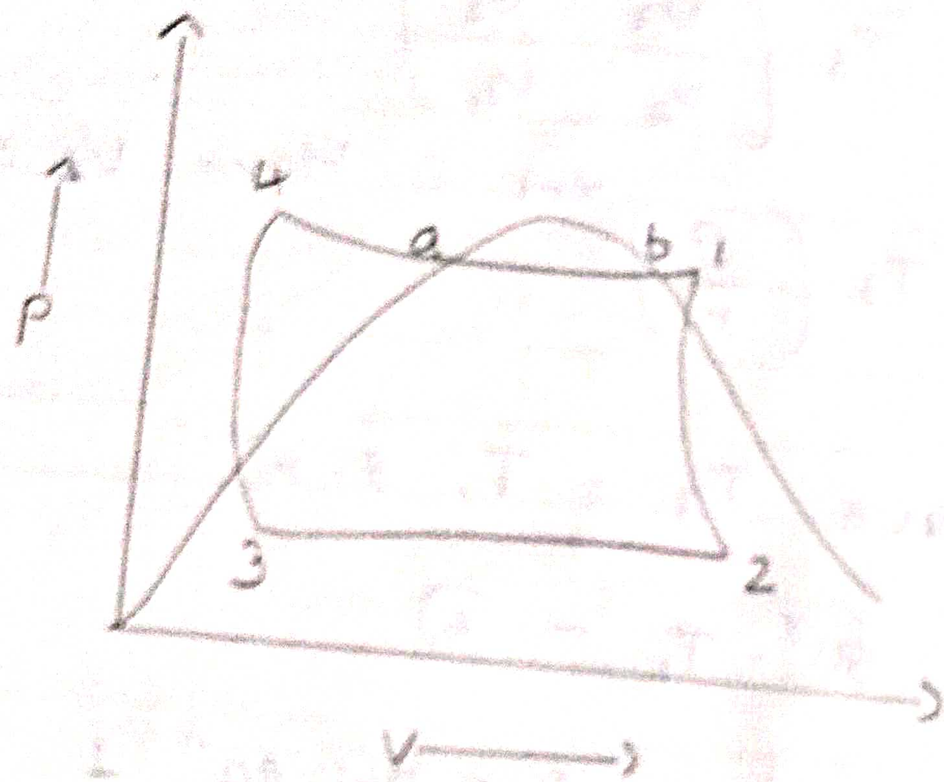
We have $T_3 = T_1 \cdot \rho \cdot r^{\gamma-1}$

$\therefore T_4 = \rho^{\gamma} \cdot T_1$ — (4)

We put all the value of eq^n 1.

$\therefore \eta_a = 1 - \frac{(\rho^{\gamma} \cdot T_1 - T_1)}{\gamma(T_1 \cdot \rho \cdot r^{\gamma-1} - T_1 \cdot r^{\gamma-1})}$

$\therefore \eta_a = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}\right]$



Rankine Cycle

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2 Derive thermal efficiency formula for Rankin cycle.

Rankin cycle is wroking with four Processes
1) Boiler 2) Turbine 3) Condenser 4) Pump.

Thermal Efficiency of rankin cycle can be obtained by applying the steady Flow.

-> Boiler -> Heat is supplied in boiler and no work done.

Heat Supplied $Q_S = h_1 - h_4$

-> Turbine -> For reversible adiabatic expansion for $Q = 0$

$\therefore W_T = h_1 - h_2$

-> Condenser -> Heat is rejected to cooling water but no work done.

Heat Rejected $Q_R = h_2 - h_3$

-> Pump -> For reversible pumping Q is zero.

$\therefore W_P = h_4 - h_3$

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Net work output $= W_T - W_P$

$= (h_1 - h_2) - (h_4 - h_3)$

Thermal Efficiency of Rankine Cycle $\eta = \dfrac{\text{Net work Output}}{\text{Heat Supplied}}$

$$\therefore \eta_R = \frac{(h_1 - h_2) - (h_4 - h_3)}{h_1 - h_4}$$

$$\therefore \eta_R = \frac{h_1 - h_2}{h_1 - h_4}$$

Here, pump work is very small compared to work by turbine hence it is neglected.

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3 Explain the Essential Elements of heat engine.

Heat engine is exeuted by thermodynamic cycle. This cycle is known as heat engine cycle.

A Heat Engine cycle consists of series of Processes.

This are the essential elements of heat engine

1 Heat Source : It is a reservoir of heat for which heat is supplied to working fluid.

Ex. Furnace of Boiler.

2 Heat Sink : It is a low temperature resevoir of heat for which heat is rejected by the working fluid.

3 Working Fluid : It is a substance which can receive and reject heat.

4 Turbine : It is a device in which working fluid is expanded.

5 Pump : It is a device in which pressure of working fluid is increase.

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4. What is an air standard efficiency?

Air standard efficiency is taken as the ideal efficiency of an Internal Combustion engine.

Air standard efficiency is base on an air standard cycle.

The air standard efficiency is used as a base line to provide a standard point.

Thermal efficiency of air standard cycle is also known as air standard efficiency.

Air Standard Efficiency

$$\eta_a = \frac{\text{Work done}}{\text{Heat Supplied}} = \frac{Q_S - Q_R}{Q_S}$$

=> State the Assumption made in air standard efficiency?

This are the assumption made in air standard efficiency.

1 The working Fluid is air and It follows the idel gas law $pV = mRT$.

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2 The working fluid is homogeneous and no chemical reaction take place.

3. Specific heat of air is constant and take $c_p = 1.005$ kJ/kgK and $c_v = 0.718$ kJ/kgK

4. The mass of air in cycle is fixed and cycle is ~~exec~~ executed by closed system.

5. Combustion Process is replaced by equivalent heat transfer Process.

6. Exhaust Process is replaced by equivalent heat rejection.

7. All Process are reversible.

Air standard Efficiency

$$\eta_a = \frac{\text{Work done}}{\text{Heat Supplied}}$$

$$= \frac{Q_S - Q_R}{Q_S}$$

Relative Efficiency $\eta_r = \dfrac{\text{Actual thermal Eff.}}{\text{Air standard Eff.}}$