mep = Mean effective pressure kPa

V_d = Displacement volume (m^3)

$V_d \times mep = W$ W = Work output, kJ

$$mep = \frac{W}{V_d}$$

bmep = brake mean effective pressure

imep = indicated " " "

$$bmep = \frac{W_b}{V_d}, \quad imep = \frac{W_i}{V_d}$$

fmep = friction mean effective pressure

friction power, $\dot{W}_f = \dot{W}_i - \dot{W}_b$

" work, $W_f = W_i - W_b$

$$\therefore \; fmep = \frac{W_f}{V_d}$$

~~Mep~~ Mean effective pressure is an indicator how the engine is loaded. or stressed.

sfc = specific fuel consumption $\frac{\text{gm of fuel}}{\text{KWh}}$

$$= \frac{\dot{m}_f}{\dot{W}}$$

$\dot{m}_f$ = mass flow rate of fuel burned.

$\dot{m}_f$ = kg/sec

bsfc = brake specific fuel consumption

isfc = indicated " " "

$$A/F \text{ ratio} = \frac{\dot{m}_a}{\dot{m}_f}$$

$$A/F \text{ ratio, stoichiometric} = \left(\frac{\dot{m}_a}{\dot{m}_f}\right)_{stoich}$$

$$A/F \text{ " , actual} = \left(\frac{\dot{m}_a}{\dot{m}_f}\right)_{actual}$$

$$(F/A)_{ratio} = \frac{1}{\cancel{AF}(A/F)_{ratio}}$$

ϕ = equivalence ratio

$$= \frac{(F/A)_{act}}{(F/A)_{stoich}}$$

>1 rich mixture

<1 lean " .

<u>Torque</u> (N-m)

$$\omega \tau = \dot{W}$$

$$\tau = \frac{\dot{W}}{\omega}$$

$$\cancel{\omega = \frac{2\pi(N/2)}{60}}$$

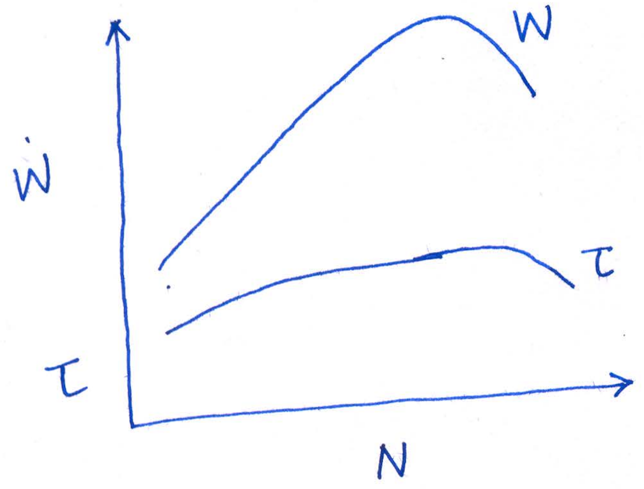
N = rpm.

$$\omega = \frac{2\pi N}{60} \text{ rad/sec}$$

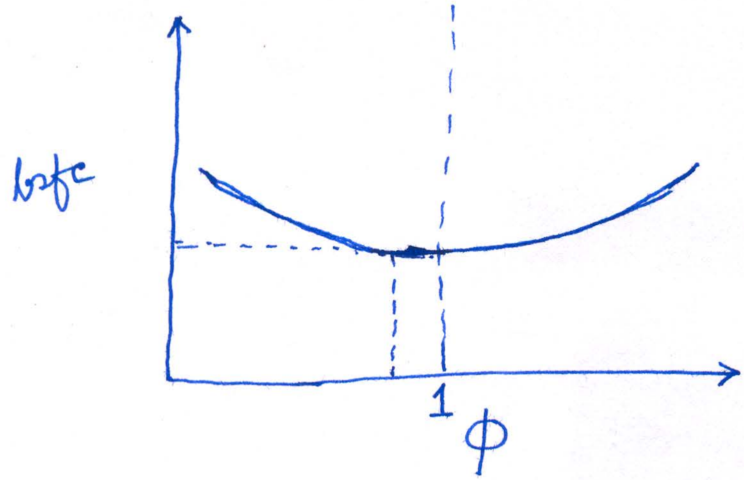
W = Energy from each cycle.

$$\dot{W} = W \times \frac{N}{60} \times \frac{1}{2}$$

$$\dot{W} = W \times \frac{N}{60}$$



ϕ = equivalence ratio



lower ~~bs~~ bsfc means better engine fuel economy

$\phi < 1$ lean mixture

$\phi > 1$ rich mixture

lean mixture is kept at the engine cruising speed ~ 55 km/hr

$\phi > 1$ for accelerating

for idling

Volumetric efficiency

$$\eta_v = \frac{m_a}{\rho_a V_d}$$

m_a = mass of air inducted kg

ρ_a = Density at standard pressure and temperature 101 kPa and 27°C

V_d = Stroke volume

η_v = an ~~d~~ indication of how much air that can be inducted inside the cylinder in the suction stroke.

A 1500-cm³, four-stroke cycle, four-cylinder CI engine, operating at 3000 RPM, produces 48 kW of brake power. Volumetric efficiency is 0.92 and A/F ratio = 21:1. Calculate: (a) Rate of air flow into engine [kg/sec]
(b) Brake specific fuel consumption [gm/kW-hr],
(c) Mass rate of exhaust flow [kg/hr]

A 1500-cm^3, four-stroke cycle, four-cylinder CI engine, operating at 3000 RPM, produces 48 kW of brake power. Volumetric efficiency is 0.92 and air-fuel ratio AF=21:1.

Calculate:

(a) Rate of air flow into engine. [~~kW~~ kg/sec]

(b) Brake specific fuel consumption. [gm/kW-hr]

(c) Mass rate of exhaust flow. [kg/hr]

(d) Brake output per displacement. [kW/L]

Ans: $\eta_v = 0.92 = \dfrac{\dot{m}_a}{\rho_a V_d \frac{N}{120}}$

$\rho_a = \dfrac{P_a}{RT_a} = \dfrac{101 \times 10^3}{287 \times 300}$

$= 1.173 \ kg/m^3$.

Here, P_a = Atm. pressure $= 101$ kPa

T_a = Atm. temp. $= 27°c = 300K$

ρ_a = Density at atm. condition.

$0.92 = \dfrac{\dot{m}_a}{1.173 \times 1500 \times 10^{-6} \times \frac{3000}{120}}$

where $\dot{m}_a$ = mass flow rate of air in kg/sec

$\dot{m}_a = 0.04$ kg/sec. ←

$A/F = \dfrac{\dot{m}_a}{\dot{m}_f}$ where $\dot{m}_f$ = mass flow rate of fuel in kg/sec.

$\dot{m}_f = \dfrac{\dot{m}_a}{21} = \dfrac{0.04}{21} = 1.93 \times 10^{-3}$ kg/sec.

$bsfc = \dfrac{\dot{m}_f \times \frac{1000}{\cancel{3600}} \times 3600}{kW} \left(\dfrac{gm}{kWhr}\right)$

$= \dfrac{1.93 \times 10^{-3} \times \frac{1000}{\cancel{3600}} \times 3600}{48}$

$= 144.75 \ \dfrac{gm}{kWhr}$. ←

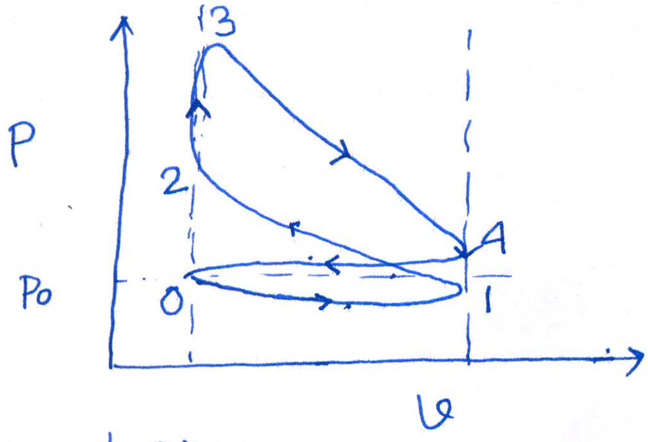
Exhaust flow $= (\dot{m}_a + \dot{m}_f) = (0.04 + 1.93 \times 10^{-3}) \times 3600 \ \dfrac{kg}{hr}$

$= 151$ kg/hr. ←

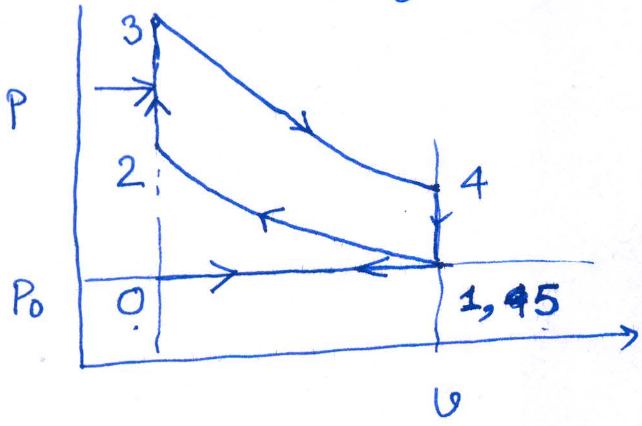
brake output per displacement $= \dfrac{48}{1500 \times 10^{-3}}$ kW/L $= 32$ ←

AIR STANDARD CYCLE

17/1/17



01 - Suction stroke
12 - Compression "
23 - Heat addition
34 - Expansion stroke
40 - Exhaust stroke



Suction and exhaust stroke are removed.

WOT.

Part load or supercharge.

12 - isentropic process
reversible, adiabatic
friction is very small.
heat transfer " " "

2-3 Heat transfer
Pure air cannot combust
Temperature rise will be very high

3-4 Expansion stroke
Isentropic
reversible, adiabatic

4-1 Heat rejection Exhaust Blow-down process

Air is working fluid.

- Ideal gas equation
- Pv^{γ} = constant

where P = Pressure
v = specific volume
γ = ratio of specific heat.

• Working fluid is air.

air + fuel + 7% exhaust gas in CV SI

air + " CI

only air specific heat constant

$c_p = 1.005$ kJ/kgK

$c_v = 0.718$ "

$R = 0.287$ "

$\gamma = 1.4$

$\gamma = 1.3$ at ~ 3000-3200 K

$c_p = \frac{\gamma R}{\gamma - 1}$

$c_v = \frac{R}{\gamma - 1}$

$\gamma = 1.35$

$\cancel{\int_1 \delta q} - \int_1 \delta w = \int_1 du$

17/1/17 (5)

$- {}_1w_2 = u_2 - u_1$

$= c_v(T_2 - T_1)$

$$\boxed{- {}_1w_2 = \frac{R}{\gamma-1}(T_2 - T_1)}$$

$T_2 > T_1$

negative work

$- {}_1w_2 = \frac{(RT_2 - RT_1)}{\gamma - 1}$

$= \frac{(P_2 v_2 - P_1 v_1)}{\gamma-1}$

${}_1w_2 = \cancel{P_0} \int_1^2 P\,dv$

$\cancel{P_2, v}$ P_2, T_2

P_3, T_3

P_4, T_4

$c_p - c_v = R$

$c_v\left(\frac{c_p}{c_v} - 1\right) = R$

$c_v(\gamma - 1) = R$

$c_v = \frac{R}{\gamma - 1}$

$$\boxed{q_{in} = \frac{Q_{in}}{m_m} = \frac{m_m c_v (T_3 - T_2)}{m_m} = \frac{m_f Q_{cv} \eta_c}{m_m}}$$

${}_2q_3 = \frac{m_f}{m_m} Q_{cv} \eta_c$

$Pv = RT$

$P_2 v_2 = RT_2$

$P_1 v_1 = RT_1$

$Q_{cv} =$ kJ/kg of fuel

$m_f =$ kg of fuel

${}_3w_4 = c_v(T_3 - T_4)$

${}_4q_1 = c_v(T_4 - T_1)$

$\eta = \frac{w_{net}}{q_{in}}$

$= \frac{q_{in} - q_{out}}{q_{in}}$

$= 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{T_1}{T_2} \frac{\left(\frac{T_4}{T_1} - 1\right)}{\left(\frac{T_3}{T_2} - 1\right)}$

$$\boxed{\eta_{ith} = 1 - \frac{T_1}{T_2} = 1 - \left(\frac{1}{r_c}\right)^{\gamma-1}}$$

$$\boxed{\eta_{bth} / \eta_{ith} = \eta_m}$$

$Pv^\gamma = C$, $Pv = RT$

$Tv^{\gamma-1} = C$

$T_2 v_2^{\gamma-1} = T_1 v_1^{\gamma-1}$

$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = \cancel{\left(\frac{1}{r_c}\right)^{\gamma-1}} \; r_c^{\gamma-1}$, $\frac{T_1}{T_2} = \left(\frac{1}{r_c}\right)^{\gamma-1}$

$T_3 v_3^{\gamma-1} = T_4 v_4^{\gamma-1}$

$\cancel{\frac{T_3}{T_4}}$; $\frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{\gamma-1} = \left(\frac{v_2}{v_1}\right)^{\gamma-1} = \left(\frac{1}{r_c}\right)^{\gamma-1}$

$\cancel{\frac{T_2}{T_1} = \frac{T_4}{T_3}}$ $\frac{T_1}{T_2} = \frac{T_4}{T_3} \Rightarrow \frac{T_3}{T_2} = \frac{T_4}{T_1}$