MODULE III

TESTING OF IC ENGINES

Trials

The test conducted on engine to judge the performance is called trials

The measurements which are used in engine trials are

1. INDICATED POWER(IP)

It is the power developed inside the engine cylinder

$$IP = \frac{PmLANK}{60}$$

Where,

P_m =Indicated mean effective pressure in KN/m^2

A = Area of piston in m^2

L = Length of stroke in m

n = Number of power strokes

In case of four stroke engines n = N/2

In case of two stroke engines n = N

Where N = Engine speed in Rpm

2. BRAKE POWER (BP)

It is the amount of use full work available from an engine ,ie it is the output of an engine

$$BP = \frac{2\pi NT}{60}$$

Where, N = speed in Rpm

T = Engine torque in KNm

BP = FP – IP

Where, FP = Frictional power

IP = Indicated power

For Rope Brake system

$$BP = \frac{\pi D1N\ (W-S)}{60}$$

Where, D_1 = Effective diameter of brake wheel

= (D + d) in m

d = diameter of rope in m

D = Diameter of brake drum in m

N = Speed of engine in Rpm

W = Dead weight in KN

3. FRICTIONAL POWER

It is defined as the power required to overcome the frictional resistance of the engine parts.

FP = IP – BP

EFFICIENCY OF IC ENGINE

1. MECHANICAL EFFICIENCY

It is the ratio of brake power to indicated power.

μ_m = BP/IP

2. INDICATED THERMAL EFFICIENCY

It is the ratio of energy equalent of "IP" (ie, work done by gases in cylinder) to total energy compression of fuel

$$\mu_i = \frac{IP}{FC\ X\ C}$$

Where, IP= Indicated power in KW

FC = Fuel consumption in kg/s

C = Calorific value in KJ/Kg

3. BRAKE THERMAL EFFICIENCY

It is the ratio of energy equivalent of BP to total energy supplied by fuel at same time

$$\mu_b = \frac{BP}{FC\ X\ C}$$

4. RELATIVE EFFICIENCY

It is the ratio of indicated thermal efficiency of air standard efficiency

$$\mu_R = \frac{\mu i}{\mu air} \text{ and } \mu_R = \frac{\mu b}{\mu air}$$

where, μ_i = Indicated thermal efficiency

μ_b = Brake thermal efficiency

μ_{air} = Air standard efficiency

SPECIFIC FUEL CONSUPTION (SFC)

It is the amount of fuel used in KG in a given hour. it is denoted by Mf or SFC

HEAT BALANCE SHEET/ENERGY BALANCE SHEET

Complete record of heat supplied and heat rejected during a certain time.(eg:- 1 minute) by an IC engine is tabulated and is called heat balance sheet.
->following terms are considered in a heat balance sheet.

(i) heat supplied by fuel:-
Heat supplied by fuel is given by,

$$Q = Mf \times Cv$$

(Cv=calorific value)
Unit=KJ/min

(ii)heat absorbed in IP production:-

$$IP = \frac{Pm \times A \times L \times K \times (10^5)}{60}$$

(iii)heat rejected by cooling water:-
Some heat is rejected to cooling water and is

= =Mw Cw (t2-t1)

Where, Mw=mass of cooling water supplied in Kg/min
Cw=specific heat of water
t1=inlet temperature
t2=outlet temperature

(iv) Heat carried by exhaust gas:-

=Mg Cg t KJ/min

Mg=mass of exhaust gas
Cg=specific heat of exhaust gas
t=rise in temperature

(v) Un accounted heat:-

- Some heat is always loss by friction leakage, radiation
- It is measured by difference of heat supplied by fuel and heat absorbed in IP , cooling water & exhaust gas

Ie**, un accounted heat= (total heat supplied)-(heat absorbed in IP +heat absorbed by cooling water +heat carried always by exhaust gas)**

MORSE TEST

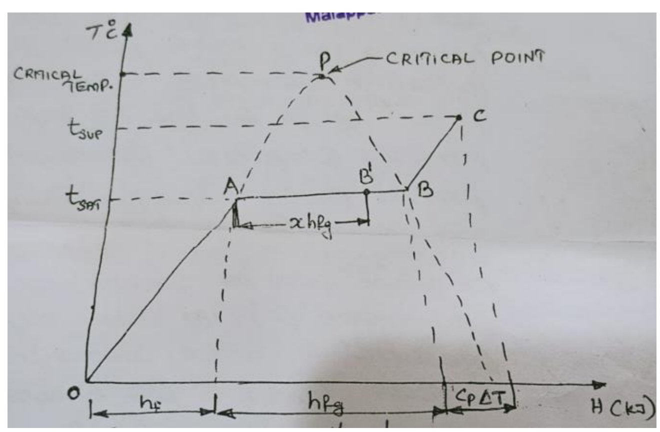
- It is used to find indicated power of an IC engine without indicator diagram.
- Consider a four cylinder engine, first the brake power of engine when all cylinders are working is measured at constant speed and load.
- Now cylinder 1 is cut off by short circuiting spark plug in SI engine and cutting off individual fuel supply in CI engine .when one cylinder is cut off speed reduced and load will be reduced to make increase in speed
- Then indicated power of remaining 3- cylinder is measured in the same way each cylinder is cut off one by one and BP in remaining cylinder is measured.

STEAM AND ITS PROPERTIES

Gas is the state of a substance of which evaporation from the liquid is complete.

Vapour is a partially evaporated liquid containing pure gaseous state together with liquid particles is suspension.

FORMATION OF STEAM



STAGE 1 (OA)

This is the warming phase in which temperature of water increases upto saturation temperature $t_{sat.}$ Saturation temperature corresponds with the boiling point of water is heated. Higher the pressure higher is the temperature. The heat supplied to produce this temperature. The heat supplied to produce this temperature rise is called sensible heat or liquid heat or liquid enthalpy (h_f)

STAGE 2 (AB)

It is an evaporation stage. Water evaporated at constant temperature (t_{sat}) and transfer into dry saturated steam. Point 'B' represent this stage of steam.Line Ab represents evaporation of water at constant temperature. The stste of stage between the extreme points A and B is wet indicating incomplete evaporation. For example Point 'B' on the line AB indicates such a state partially evaporated steam will have water particles under suspension in it and hence called wet steam. The heat energy supplied during evaporation is called enthalpy of evaporation or latent heat of steam or latent heat of evaporation (L).

Enthalpy of evaporation or latent heat is defined as the heat required to convert 1 kg of water at given pressure and temperature into steam at the same temperature and pressure.

STAGE 3 (BC)

This phase begins only when evaporation water is complete and all dry saturated steam is formed. further supply of heat producing superheated steam which is accompanied by a rise in temperature. The amount of heat supplied in the superheat phase is called super heat enthalpy.

DRYNESSFRACTION

It is defined as the ratio of mass of dry saturated steam to the mass of wet steam containing it.

Let, M = Mass of wet steam in kg.

m = Mass of water particles in suspension in kg.

Then (M-m) = mass of pure dry saturated steam in kg.

Dryness fraction, $x = \frac{M-m}{M}$

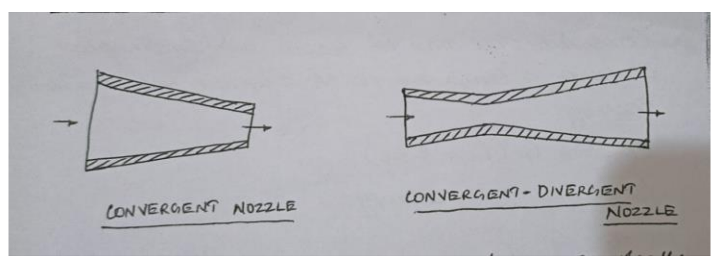
Enthalpy Formulae

1. Liquid enthalpy or sensible heat = h_f kj/kg
2. Enthalpy of dry saturated steam,
   H_g = liquid enthalpy + Enthalpy of evaporation
   $H_g = h_f + h_{fg}$ Kj/kg
3. Enthalpy of wet steam,
   $h = hf + xhfg$
4. Enthalpy of superheated steam,
   H_{sup} = enthalpy odf dry saturated steam + Suerheat enthalpy
   $H_{sup} = h_f + h_{fg} + C_p\Delta T$
   $= h_g + C_p (t_{sup} – t_{sat})$

STEAM NOZZLES

A Nozzle is a passage of varying cross-section in which a fluid is accelerated to a high velocity. Steam nozzle, in particular, converts heat energy into kinetic energy (work energy). Its chief use is to produce high velocity jet of steam which impinges on the turbine blades and drives it at higher speeds. As steam flows it expands and pressure drop produces a high velocity and hence the kinetic energy.

TYPES OF NOZZLES



A Convergent nozzle tapers gradually from point of energy to the exit. The exit of a nozzle can be called a mouth of the turbine.

A nozzle which first converges to the smallest section and then diverges towards exit end is called convergent – divergent nozzle. The smallest section is called throat of the nozzle.

Expression for velocity steam leaving a nozzle

Let V_1 = Velocity of steam at entry (m/s)

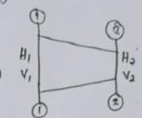
V_2 = Velocity of steam at any given section (m/s)

H_1 = Enthalpy of steam at entry (J/kg)

H_2 = Enthalpy of steam at given section (J/kg)

$\Delta H = H_1 - H_2$

= Enthalpy (Heat) drop (J/kg)



Considering unit mass (m = 1 kg) of steam,

Increase in kinetic energy $= \frac{1}{2}V_2^2 - \frac{1}{2}V_1^2$

$= \frac{1}{2}(V_2^2 - V_1^2)$

But gain in K.E = Enthalpy drop.

ie $\frac{1}{2}(V_2^2 - V_1^2) = \Delta H$.

$V_2^2 - V_1^2 = 2\Delta H$

$V_2^2 = 2\Delta H + V_1^2$ → ΔH in J/kg.

$V_2 = \sqrt{2\Delta H + V_1^2}$ m/s

Usually V_1 is negligible compared to V_2.

$\therefore V_2 = \sqrt{2\Delta H}$ m/s.

$\boxed{V_2 = 1.414\sqrt{\Delta H}}$

We read usually enthalpy values in kJ/kg.

Hence, if ΔH is in kJ/kg.

Then, $V_2 = \sqrt{2 \times 1000 \times \Delta H}$

$\therefore \boxed{V_2 = 44.72\sqrt{\Delta H}}$ m/s.

In practice, friction will occur which is a loss in the nozzle. Effect of friction will reduce ΔH value. If frictional loss is 10% of heat drop.

$V_2 = 44.7\sqrt{k\Delta H}$ where $k = 0.9$.

Generally we have, $\boxed{V_2 = 44.7\sqrt{k\Delta H} \text{ m/s}}$ where k is called friction factor, nozzle coefficient or nozzle efficiency.