Accurate measurement of fuel consumption is very important in engine testing work.

As already mentioned two basic types of fuel measurement methods are :

- Volumetric type
- Gravimetric type.

Volumetric type flowmeter includes Burette method, Automatic Burrette flowmeter and Turbine flowmeter.

Gravimetric Fuel Flow Measurement

The efficiency of an engine is related to the kilograms of fuel which are consumed and not the number of litres. The method of measuring volume flow and then correcting it for specific gravity variations is quite inconvenient and inherently limited in accuracy. Instead if the weight of the fuel consumed is directly measured a great improvement in accuracy and cost can be obtained.

There are three types of gravimetric type systems which are commercially available include Actual weighing of fuel consumed, Four Orifice Flowmeter, etc.

7.3.3 Measurement of Air Consumption

One can say the mixture of air and fuel is the food for an engine. For finding out the performance of the engine accurate measurement of both is essential.

In IC engines, the satisfactory measurement of air consumption is quite difficult because the flow is pulsating, due to the cyclic nature of the engine and because the air a compressible fluid. Therefore, the simple method of using an orifice in the induction pipe is not satisfactory since the reading will be pulsating and unreliable.

All kinetic flow-inferring systems such as nozzles, orifices and venturies have a square law relationship between flow rate and differential pressure which gives rise to severe errors on unsteady flow. Pulsation produced errors are roughly inversely proportional to the pressure across the orifice for a given set of flow conditions. The various methods and meters used for air flow measurement include

(a) Air box method, and

(b) Viscous-flow air meter.

7.3.4 Measurement of Exhaust Smoke

All the three widely used smokemeters, namely, Bosch, Hartridge, and PHS are basically soot density (g/m^3) measuring devices, that is, the meter readings are a function of the mass of carbon in a given volume of exhaust gas.

Hartridge smokemeter works on the light extinction principle.

The basic principles of the Bosch smokemeter is one in which a fixed quantity of exhaust gas is passed through a fixed filter paper and the density of the smoke stains on the paper are evaluated optically. In a recent modification of this type of smokemeter units are used for the measurement of the intensity of smoke stain on filter paper.

In Von Brand smokemeter which can give a continuous reading a filter tape is continuously moved at a uniform rate to which the exhaust from the engine is fed. The smoke stains developed on the filter paper are sensed by a recording head. The single obtained from the recording head is calibrated to give smoke density.

7.4 MEASUREMENT OF EXHAUST EMISSION

Substances which are emitted to the atmosphere from any opening of the exhaust port of the engine are termed as exhaust emissions. If combustion is complete and the mixture is compound can be separately analyzed for concentration. This is the only method by which each component existing in an exhaust sample can be identified and analyzed. However, it is very time consuming and the samples can be taken only in batches. Gas chromatograph is primarily a laboratory tool.

In addition to the above methods such as mass spectroscopy, chemiluminescent analyzers, and electrochemical analyzer are also used for measuring exhaust emissions.

7.5 MEASUREMENT OF BRAKE POWER

The brake power measurement involves the determination of the torque and the angular speed of the engine output shaft. The torque measuring device is called a dynamometer.

Dynamometers can be broadly classified into two main types, power absorption dynamometers and transmission dynamometer.

Figure 7.3 shows the basic principle of a dynamometer. A rotor driven by the engine under test is electrically, hydraulically or magnetically coupled to a stator. For every revolution of the shaft, the rotor periphery moves through a distance 2πr against the coupling force F. Hence, the work done per revolution is .

$$W = 2\,\pi RF$$

The external moment or torque is equal to $S \times L$ where, S is the scale reading and L is the arm. This moment balances the turning moment $R \times F$, i.e.

$$S \times L = R \times F$$

$\therefore$ Work done/revolution $= 2\pi\, SL$

Work done/minute $= 2\pi\, SLN$

where, N is rpm. Hence, power is given by

Brake power $P = 2\pi\, NT$

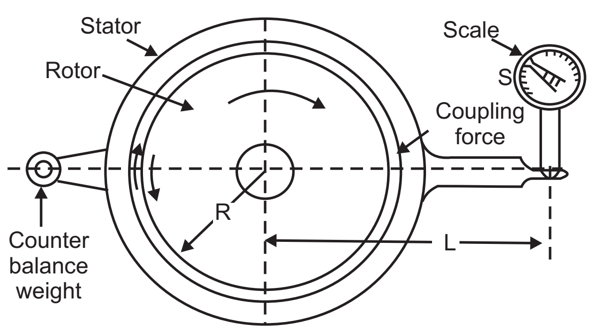

Figure7.3 : Principle of a Dynamometer

Absorption Dynamometers

These dynamometers measure and absorb the power output of the engine to which they are coupled. The power absorbed is usually dissipated as heat by some means. Example of such dynamometers is prony brake, rope brake, hydraulic dynamometer, etc.

Transmission Dynamometers

In transmission dynamometers, the power is transmitted to the load coupled to the engine after it is indicated on some type of scale. These are also called torque-meters.

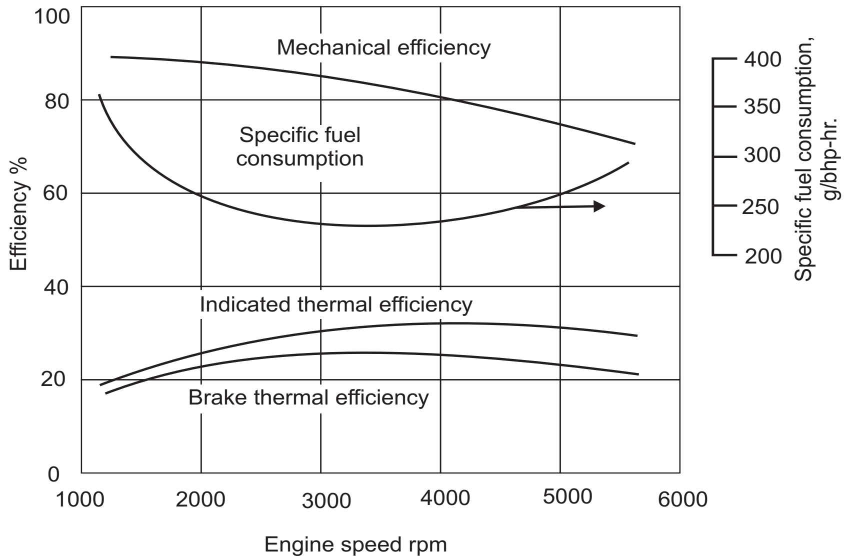

Figure 7.12 : Efficiency and Specific Fuel Consumption Vs.

Figure 7.13 shows the *ip*, *bp*, *fp* (by difference) brake torque, brake mean effective pressure and brake specific fuel consumption of a high compression ratio (9) automotive SI engine at full or Wide Open Throttle (W.O.T.).

Speed for a Petrol Engine at Full Throttle

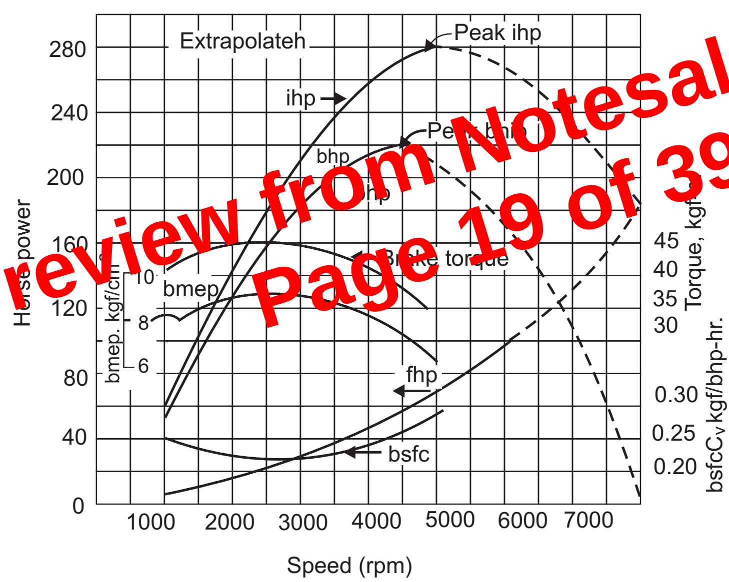

Figure 7.13 : Variable Speed Test of Automotive SI Engine at Full Throttle (*CR* = 9)

Referring to the Figure 7.10 through Figure 7.13 the following conclusions can be drawn :

(a) At full throttle the brake thermal efficiency at various speeds varies from 20 to 27 percent, maximum efficiency being at the middle speed range.

(b) The percentage heat rejected to coolant is more at lower speed (≈ 35 percent) and reduces at higher speeds (≈ 25 percent). Considerably more heat is carried by exhaust at higher speeds.

(c) Torque and mean effective pressure do not strongly depend on the speed of the engine, but depend on the volumetric efficiency and friction losses. Maximum torque position corresponds with the maximum air charge or minimum volumetric efficiency position.

Torque and mep curves peak at about half that of the brake-power.

Solution

$$\text{Brake power } = \frac{2\pi\, NT}{60000} = \frac{2 \times \pi \times 2000 \times 8}{60000}$$

$$= 1.6746 \text{ kW}$$

$$\text{Friction power} = 2.0 - 1.6746$$

$$= 0.3253$$

$$\%\text{ loss } = \frac{0.3253}{2} \times 100$$

$$\%\text{ loss} = 16.2667\%$$

Example 7.3

A diesel engine consumes fuel at the rate of 5.5 gm/sec. and develops a power of 75 kW. If the mechanical efficiency is 85%. Calculate *bsfc* and *isfc*. The lower heating value of the fuel is 44 MJ/kg.

Solution

$$bsec = \frac{\text{kW heat input}}{\text{kW heat output}}$$

$$= \frac{C_v \times m_f}{P} = C_v \times bsfc$$

$$bsfc = \frac{5.55}{75} = 0.074 \text{ g/kWs}$$

$$= 0.074 \times 10^{-3} \text{ kg/kWs}$$

$$C_v = 44 \text{ MJ/kg} = 44 \times 10^3 \text{ kJ/kg}$$

$$bsec = \text{b}sfc \times C_v = 44 \times 10^3 \times 0.074 \times 10^{-3} = 3.256$$

$$isec = bsec \times \eta_n = 3.256 \times 0.85$$

$$isec = 2.7676.$$

Example 7.4

Find the air-fuel ratio of a 4-stroke, 1 cylinder, air cooled engine with fuel consumption time for 10 cc as 20.0 sec. and air consumption time for 0.1 m^3 as 16.3 sec. The load is 16 kg at speed of 3000 rpm. Also find brake specific fuel consumption in g/kWh and thermal brake efficiency. Assume the density of air as 1.175 kg/m^3 and specific gravity of fuel to be 0.7. The lower heating value of fuel is 44 MJ/kg and the dynamometer constant is 5000.

Solution

$$\text{Air consumption } = \frac{0.1}{16.3} \times 1.175 = 7.21 \times 10^{-3} \text{ kg/s}$$

$$\text{Fuel consumption } = \frac{10}{20} \times 0.7 \times \frac{1}{1000} = 0.35 \times 10^{-3} \text{ kg/s}$$

$$\text{Air-fuel ratio } = \frac{7.21 \times 10^{-3}}{0.35 \times 10^{-3}} = 20.6$$

$$\text{Power output } (P) = \frac{WN}{\text{Dynamometer constant}}$$

$$= \frac{16 \times 3000}{5000} = 9.6 \text{ kW}$$

Solution

First we draw a graph of drop in speed versus time taken for the drop.

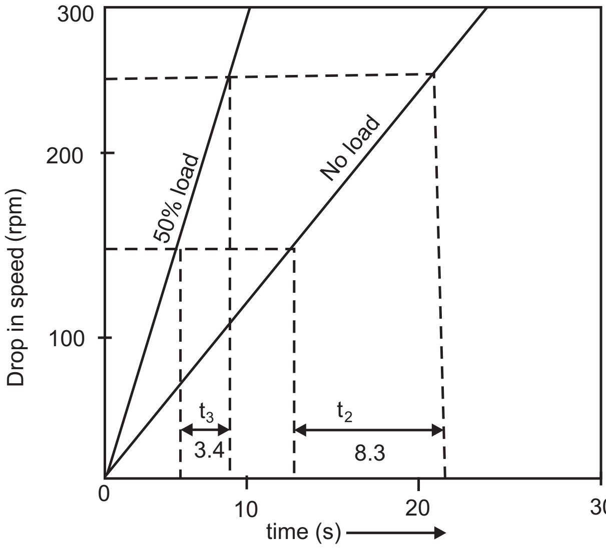

Figure 7.18 : Speed Vs Time

$$P = \frac{2\pi\, NT}{60000}$$

Full load torque, $T = \dfrac{P \times 60000}{2\pi\, N} = \dfrac{10 \times 60000}{2 \times \pi \times 500} = 191.083$ Nm

Torque at half load, $T_{1/2} = 95.5415$ Nm

From graph :

Time for the fall of 100 rpm at no load, $t_2 = 8.3$ sec.

Time for the fall of same 100 rpm at half load, $t_3 = 3.4$ sec.

$$T_f = \frac{t_3}{t_2 - t_3} \times \text{ Torque at 50\% load}$$

$$= \frac{t_3}{t_2 - t_3} \times T_{1/2} = \frac{3.4}{(8.3 - 3.4)} \times 95.5415 = 66.294 \text{ Nm}$$

$$\text{Friction power } = \frac{2\pi N T_f}{60000} = \frac{2\pi \times 500 \times 66.294}{60000} = 3.469 \text{ kW}$$

$$\eta_m = \frac{bp}{bp + fp} = \frac{10}{10 + 3.469} \times 100 = 74.24\%$$

Example 7.9

A 4-cylinder, 4-stroke cycle engine having cylinder diameter 100 mm and stroke 120 mm was tested at 1600 rpm and the following readings were obtained.

Fuel consumption = 0.27 litres/minute, Specific gravity fuel = 0.74, B.P. = 31.4 kW, Mechanical efficiency = 80%, Calorific value of fuel = 44000 kJ/kg.

Determine :

(i) *bsfc*,

(ii) *imep*, and

(iii) Brake thermal efficiency.

(iii) *bsfc*,

(iv) Draw up heat balance sheet on kW basis.

Solution

(i) Brake Power (*b.p.*) :

$$b.p. = 2\pi\ NT = 2 \times \pi \times \frac{1750}{60} \times 327.4 \times 10^{-3} = 60.01 \text{ kW}$$

(ii) Mechanical Efficiency (η_m) :

$$\eta_m = \frac{b.p.}{i.p.}$$

But, $i.p. = b.p. + f.p.$

$f.p. = 10$ kW

Given that power absorbed by non-firing engine when driven by electric motor. This is frictional power.

This type of testing is done in a motoring test which is used to calculate the frictional power of an engine.

Hence, $f.p. = 10$ kW

$\therefore$ $i.p. = b.p. + f.p.$

$= 60.01 + 10$

$\therefore$ $i.p. = 70.01$ kW

$$\therefore \quad \eta_m = \frac{60.01}{70.01} = 0.8571 = 85.71\%$$

(iii) *bsfc* : Brake Specific Fuel Consumption :

$$\therefore \quad bsfc = \frac{m_{f/hr.}}{b.p.} = \frac{15}{60.01} = 0.25 \text{ kg/kW.hr}$$

(iv) Heat Balance Sheet in kW basis :

(i) Power supplied by fuel $= m_f \times C_v$

$$= \frac{15}{3600} \times 42000 = 175 \text{ kW}$$

(ii) Brake power = 60.01 kW

(iii) Power to cooling water $= m_w\ C_{PW}\ \Delta T$

$$= \frac{16}{60} \times 4.19 \times (T_o - T_{in})$$

$T_o = 65.8 + 273 = 338.8$ K

$T_{in} = 20.8 + 273 = 293.8$ K

Power lost to cooling water = 50.28 kW

(iv) Power to exhaust $= m_E\ C_{PE}\ \Delta T$

Here, mass of exhaust gases

$m_E = m_a + m_f$

$$= \frac{4.75}{60} + \frac{15}{3600} = 0.0833 \text{ kg/s}$$