Lecture 6

Engine Performance Tests

INTERNAL COMBUSTION ENGINES

By

Lecturer

Dr. Hyder H. Abd Balla

Automobile Department
Engineering Technical College / Najaf
Al-furat Al-awsat Technical University

2.10 Performance tests:

The modern I.C engines have; higher ratios of power /weight than earlier types, increased values of (bmep) and thermal efficiency, and lower (s.f.c). At present time in the automotive field; the petrol engine is highly developed and flexible, but there is an increasing competition from the diesel engine. Brake thermal efficiencies of 25 to 35% are usual with S.I. engines and may reach 50% in diesel engines.
For comparing the performance of engines, a number of standards are available:

1. 1-Specific fuel consumption (kg/kW.h).
2. 2-Brake means effective pressure, bmep (kPa).
3. 3-Specific weight (Weight of engine per kW, kg/kW)
4. 4-Output per unit displacement kW per m3)

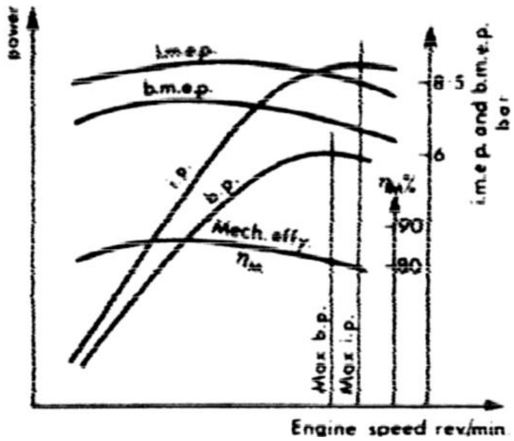
Most of the performance factors are directly related to atmospheric conditions, so comparison between engines should be performed at similar atmospheric conditions. The tests on I.C. engines can be divided into two types: *Variable speed test* and *Constant speed test.*

1-Variable – speed test:

Variable – speed tests can be divided into full – load tests, where maximum power and minimum s.f.c at each different speed are the objectives, and part – load tests to determine variation in the s.f.c.

a) Full – load test with SI engine:

The throttle is fully opened and the lowest desired speed is maintained by brake load adjustment. The spark is adjusted to give maximum power at this speed. The test is started by the watch governing the fuel consumption, the test ended at the time the fuel- consumption test has been completed. During this interval of time, the average speed, brake load, temperatures, fuel weight … etc., are recorded, then load is adjusted for the next run at different speed.
After the completion of the test, the required results are calculated, and performance curves are drawn and a typical example is shown in figures. The variation of volumetric efficiency with speed is indicated in fig. 2.4, and the mechanical efficiency with speed in fig. 2.3.



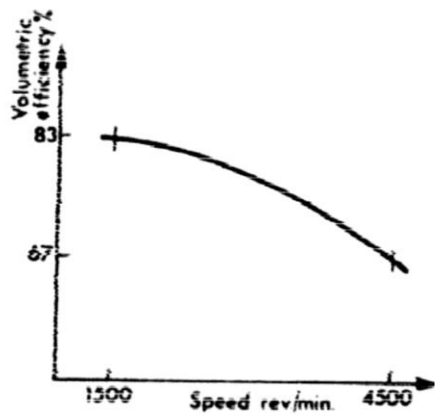


Figure 2.3 *Figure 2.4*

b) Part – load test:

To run a part – load test at variable speed, say half load, power reading of half the maximum power at each speed is obtained by varying the throttle and brake setting.

2.Constant – speed test:

Constant – speed test is run with variable throttle from no load to full load in suitable steps of load to give smooth curves. Starting at zero load, the throttle is opened to give the desired speed. Then a load is put on the engine and the throttle is opened wider to maintain the same constant speed as before, and the second run is ready to start. The last run of the test is made at wide-open throttle. In a CI-engine test the last run would show smoke in the exhaust gas.

2.1 Consumption loop test:

This test is carried out at constant speed, constant throttle opening, and constant ignition setting. The specific fuel consumption is plotted to a base of "bmep" and a "hook curve" is obtained. For a Single cylinder at full throttle the curve is defined as in fig.2. 5

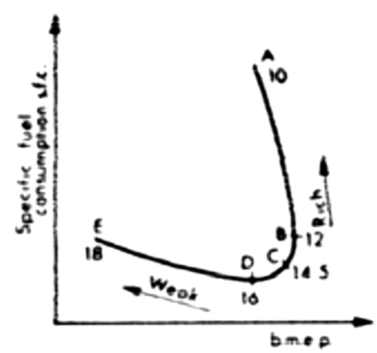
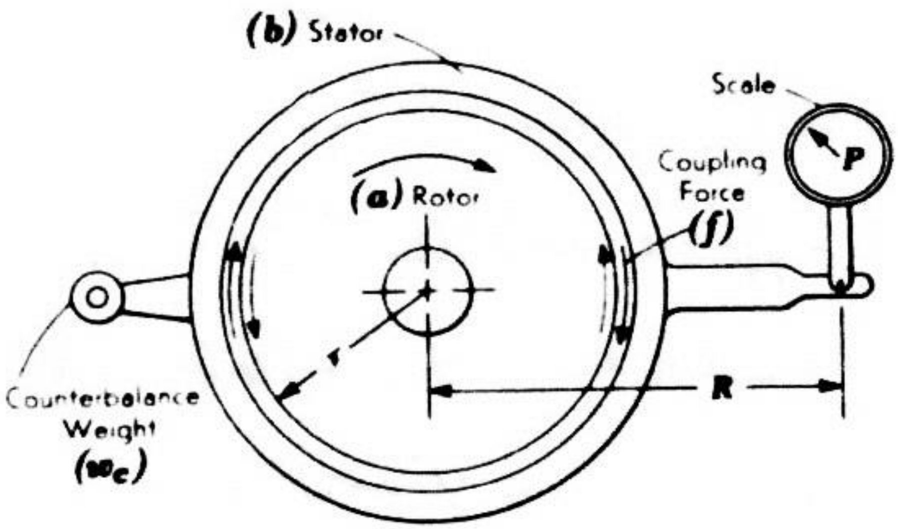


Figure 2.5

2-11 Measurement of engine torque and power:

Any apparatus that permits the measurement of torque and power of the engine is called a "***dynamometer***". They do this by using various methods to absorb the energy output of the engine, There are many types of dynamometers. (Fluid **or hydraulic dynamometers, Eddy current dynamometers, electric dynamometer)** ; all operate on the principle illustrated in fig. (6-5). Here the rotor (a), driven by the engine to be tested, is couple (electrically, magnetically, hydraulically or by friction) to the stator (b). In one revolution of the shaft, the peripherally of the rotor moves through a distance ($2\pi r$) against the coupling force f (drag force).



Thus the work per revolution is:

Work = $2\pi r$ f

The external moment, which is the product of the reading p of the scale (could be a beam balance or weights) and the arm R, must just balance the turning moment, which is (r*f**)**

$$r \times f = R \times P$$

$$\text{Work} = 2\,\pi R P$$

Power is defined as the time rate of doing work, i.e.

Power = $2\,\pi RPN$

where R in meters and P in Newton, (N is engine speed in rpm)

$$\text{power} = \frac{2\,\pi RPN}{1000*60} \quad \textbf{(kw)}$$

2-12 Measurement of friction power (f.p):

The friction power is nearly constant at a given engine speed. Friction has a dominating effect on the performance of the engine. Frictional losses are dissipated to the cooling system as they appear in the form of heat.
Measurement of friction power is important for having better understanding on how the engine output can be increased. Methods of measuring the friction power are as follows:

i-Measurement of the i.p. and b.p. by the methods described previously for the engine at identical working conditions.

ii-Motoring test:
In this test; the engine is first run to measure the b.p at a given speed, then the fuel supply (or the spark) is cut-off and the dynamometer is converted to run as motor to drive the engine (motoring) at the same speed and keeping other parameters the same. The power supplied to the motor is measured which is a measure of the friction power (f.p).

The main objection to this method is that the engine is not firing, which leads to make running conditions are not similar. The pressure and temperature of cylinder contents, cylinder and piston surfaces are not the same.

iii-Morse test:

This test is only applicable to multi-cylinder engines. The engine is run at the required speed and the torque is measured. One cylinder is cut out, the speed falls because of the loss of power with one cylinder cut out, but is restored by reducing the load. The torque is measured again when the speed has reached its original value. If the values of i.p. of cylinders are denoted by I1,I2,I3, and I4(considering a four – cylinder engine), and the power losses in each cylinder are denoted by L1,L2, L3 and L4, then the value of b.p, B, at the test speed with all cylinders firing is given by:

$$B = (I1-L1) + (I2-L2) + (I3-L3) + (I4-L4)$$

If number 1 cylinder is cut out, then the contribution I1 is lost; and if the losses due to that cylinder remain the same as when it is firing, then the b.p B1 now obtained at the same speed is:

$B1= (0 -L1)+(I2-L2)+(I3-L3)+(I4-L4)$

Subtracting the second equation from the first given

$B – B1=I1$

By cutting out each cylinder in turn the values I2, I3 and I4 can be obtained, then:

$I=I1+I2+I3+I4$

iv- Willan's line:

In this method gross fuel consumption versus b.p at a constant speed is plotted.
The graph drawn is called the "Willan's line" and extrapolated back to cut the b.p axis at the point A. OA represent the power loss of the engine at this speed. The fuel consumption at zero b.p is given by OB; this would be equivalent to the power loss OA. This test is applicable to CI engines only.

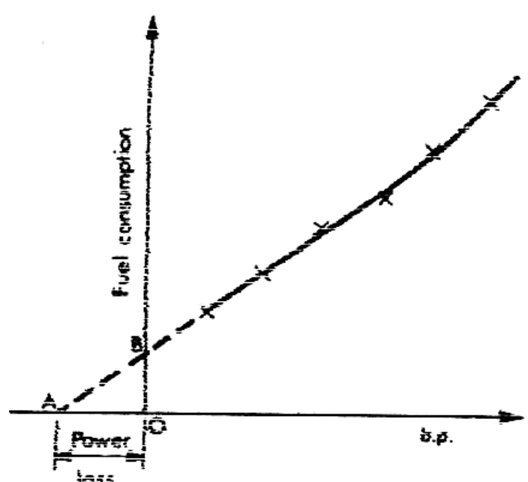


Figure (6-15): *Willan's line*

Example 2-4:
A four – cylinder petrol engine has a bore of 57mm and a stroke of 90mm. its rated speed is 2800 rpm and it is tested at this speed against a brake which has a torque arm of 0.356m. The net brake load is 155N and the fuel consumption is 6.74 L/h. The specific gravity of the petrol used is 0.735kg/L and it has a lower calorific value of; 44200 kJ/kg. A Morse test is carried out and the cylinders are cut out in the order 1,2,3,4, with corresponding brake load of 111,106.5, 104.2 and 111 N, respectively. Calculate for this speed, the engine torque, the bmep, the brake thermal efficiency, the specific fuel consumption, the mechanical efficiency and the imep.

Solution:

$$\tau = R * P = 0.356 * 155 = 55.2\ N.m$$

$$\dot{\boldsymbol{W}}_{\boldsymbol{b}} = \boldsymbol{2\pi N\tau} = \frac{\boldsymbol{2\pi * 2800 * 55.2}}{\boldsymbol{60 * 10^3}} = \boldsymbol{16.2\ Kw}$$

$$\boldsymbol{W_b} = bmep.A_p.\bar{U}_p\ /4$$

$$\bar{U}_p = 2 * 0.09 * \frac{2800}{60} = 8.4\ m/s$$

$$A_p = \frac{\pi(0.057)^2}{4} = 2.5517 * 10^{-3}$$

$$bmep = \frac{4\,\dot{W}_b}{A_p.\bar{U}_p} = 30.231\ bar$$

$$\eta_{BT} = \frac{b.p}{\dot{m}_f \times C.V} = \frac{16.2}{0.001377 \times 44200} = 0.266 \quad \text{or} \quad 26.6\%$$

$$\text{Where } \dot{m}_f = \frac{6.74}{3600} \times 1 \times 0.735 = 0.001377 \quad \text{kg/s}$$

$$\text{sfc} = \frac{\dot{m}_f}{\text{b.p}} = \frac{0.001377 \times 3600}{16.2} = 0.306 \quad \text{kg/kW.h}$$

The indicated load for the engine is calculated by the Morse test method as:

$I = I_1 + I_2 + I_3 + I_4$

and: $I_1 = B - B_1 = 155 - 111 = 44$ N

$I_2 = B - B_2 = 155 - 106.5 = 48.5$ N

$I_3 = B - B_3 = 155 - 104.2 = 50.8$ N

$I_4 = B - B_4 = 155 - 111 = 44$ N

$I = 44 + 48.5 + 50.8 + 44 = 187.3$ N

$$\eta_M = \frac{b.p}{i.p} = \frac{155}{187.3} = 0.828 \quad \text{or} \quad 82.8\%$$

$$i.p = \frac{16.2}{0.828} = 19.57 \quad \text{kw}$$

$$\text{bmep} = \eta_M \times imep$$

$$imep = \frac{30.231}{0.828} = 36.51\ bar$$

2 – 13 Heat balance of Engine:

The main components of the heat balance are:
1- Heat equivalent to the b.p of the engine.
2- Heat rejected to the cooling medium.
3- Heat carried away from the engine with the exhaust gases.
4- Unaccounted losses.

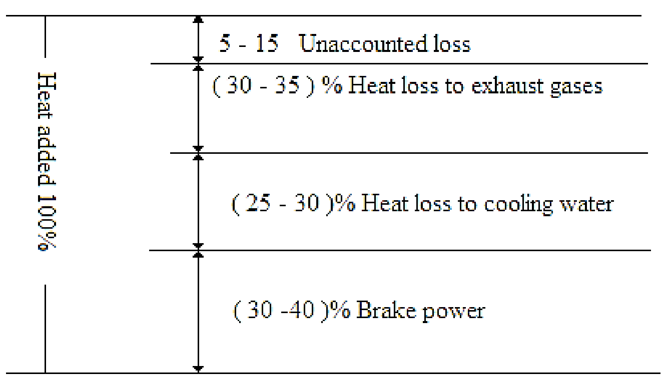


Figure (6-16) Heat balance diagram

<u>Table gives the approximate percentage values of various losses in SI and CI engines:</u>

Engine	% b.p	% heat to cooling water	% heat to exhaust gases	% unaccounted loss
S.I.	21-28	12-27	30-55	0-15
C.I.	29-42	15-35	25-45	10-20