Program : **B.Tech**

Subject Name: **I C Engines**

Subject Code: **ME-501**

Semester: **5th**

Unit-1 Internal Combustion Engines

At a design and development stage an engineer would design an engine with certain aims in his mind. The aims may include the variables like indicated power, brake power, brake specific fuel consumption, exhaust emissions, cooling of engine, maintenance free operation etc. The other task of the development engineer is to reduce the cost and improve power output and reliability of an engine. In trying to achieve these goals he has to try various design concepts. After the design the parts of the engine are manufactured for the dimensions and surface finish and may be with certain tolerances. In order verify the designed and developed engine one has to go for testing and performance evaluation of the engines.

Thus, in general, a development engineer will have to conduct a wide variety of engine tests starting from simple fuel and air-flow measurements to taking of complicated injector needle lift diagrams, swirl patterns and photographs of the burning process in the combustion chamber. The nature and the type of the tests to be conducted depend upon various factors, some of which are: the degree of development of the particular design, the accuracy required, the funds available, the nature of the manufacturing company, and its design strategy. In this chapter, only certain basic tests and measurements will be considered.

Objectives

After studying this unit, you should be able to

- Understand the performance parameters in evaluation of IC engine performance,
- calculate the speed of IC engine, fuel consumption, air consumption, etc.,
- evaluate the exhaust smoke and exhaust emission, and
- Differentiate between the performance of SI engine and CI engines.

Engine performance is an indication of the degree of success of the engine performs its assigned task, i.e. the conversion of the chemical energy contained in the fuel into the useful mechanical work. The performance of an engine is evaluated on the basis of the following:

(a) Specific Fuel Consumption.
(b) Brake Mean Effective Pressure.
(c) Specific Power Output.
(d) Specific Weight.
(e) Exhaust Smoke and Other Emissions.

The particular application of the engine decides the relative importance of these performance parameters.

For Example: For an aircraft engine specific weight is more important whereas for an industrial engine specific fuel consumption is more important.

For the evaluation of an engine performance few more parameters are chosen and the effect of various operating conditions, design concepts and modifications on these parameters is studied. The basic performance parameters are the following:

(a) Power and Mechanical Efficiency.
(b) Mean Effective Pressure and Torque.
(c) Specific Output.
(d) Volumetric Efficiency.
(e) Fuel-air Ratio.
(f) Specific Fuel Consumption.
(g) Thermal Efficiency and Heat Balance.
(h) Exhaust Smoke and Other Emissions.
(i) Specific Weight.

Power and Mechanical Efficiency

The main purpose of running an engine is to obtain mechanical power.

Power is defined as the rate of doing work and is equal to the product of force and linear velocity or the product of torque and angular velocity.

Thus, the measurement of power involves the measurement of force (or torque) as well as speed. The force or torque is measured with the help of a dynamometer and the speed by a tachometer.

The power developed by an engine and measured at the output shaft is called the brake power.

The total power developed by combustion of fuel in the combustion chamber is, however, more than the *bp* and is called indicated power (*ip*). Of the power developed by the engine, i.e. *ip*, some power is consumed in overcoming the friction between moving parts, some in the process of inducting the air and removing the products of combustion from the engine combustion chamber.

Indicated Power

It is the power developed in the cylinder and thus, forms the basis of evaluation of combustion efficiency or the heat release in the cylinder.

The difference between *ip* and *bp* is called friction power (*fp*).

Mean Effective Pressure

Mean effective pressure is defined as a hypothetical/average pressure which is assumed to be acting on the piston throughout the power stroke. If the mean effective pressure is based on *bp* it is called the brake mean effective pressure and if based on *ihp* it is called indicated mean effective pressure.

Specific Output

Specific output of an engine is defined as the brake power (output) per unit of piston displacement.

Volumetric Efficiency

Volumetric efficiency of an engine is an indication of the measure of the degree to which the engine fills its swept volume. It is defined as the ratio of the mass of air inducted into the engine cylinder during the suction stroke to the mass of the air corresponding to the swept volume of the engine at atmospheric pressure and temperature. Alternatively, it can be defined as the ratio of the actual volume inhaled during suction stroke measured at intake conditions to the swept volume of the piston.

Fuel-Air Ratio (*F/A*)

Fuel-air ratio (*F/A*) is the ratio of the mass of fuel to the mass of air in the fuel-air mixture. Air-fuel ratio (*A/F*) is reciprocal of fuel-air ratio. Fuel-air ratio of the mixture affects the combustion phenomenon in that it determines the flame propagation velocity, the heat release in the combustion chamber, the maximum temperature and the completeness of combustion.

Relative fuel-air ratio is defined as the ratio of the actual fuel-air ratio to that of the stoichiometric fuel-air ratio required to burn the fuel supplied. Stoichiometric fuel-air ratio is the ratio of fuel to air is one in which case fuel is completely burned due to minimum quantity of air supplied.

Brake Specific Fuel Consumption

Specific fuel consumption is defined as the amount of fuel consumed for each unit of brake power developed per hour. It is a clear indication of the efficiency with which the engine develops power from fuel.

Thermal Efficiency and Heat Balance

Thermal efficiency of an engine is defined as the ratio of the output to that of the chemical energy input in the form of fuel supply. It may be based on brake or indicated output. It is the true indication of the efficiency with which the chemical energy of fuel (input) is converted into mechanical work. Thermal efficiency also accounts for combustion efficiency, i.e., for the fact that whole of the chemical energy of the fuel is not converted into heat energy during combustion.

The basic measurements to be undertaken to evaluate the performance of an engine on almost all tests are the following:

(a) Fuel consumption

(b) Air consumption

(c) Smoke density

(d) Brake horse-power

(e) Indicated horse power and friction horse power

(f) Heat going to cooling water

(g) Heat going to exhaust

(h) Exhaust gas analysis.

In addition to above a large number of other measurements may be necessary depending upon the aim of the test.

Firing Order

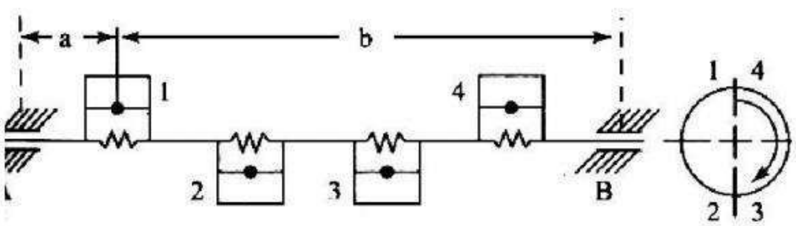
The firing order is the sequence of power delivery of each cylinder in a multi-cylinder reciprocating engine. This is achieved by sparking of the spark plugs in a gasoline engine in the correct order, or by the sequence of fuel injection in a Diesel engine. When designing an engine, choosing an appropriate firing order is critical to minimizing vibration, to improve engine balance and achieving smooth running, for long engine fatigue life and user comfort, and heavily influences crankshaft design.

Further, there are three factors which must be considered before deciding the optimum firing order of an engine. These are:

(i) Engine vibrations

(ii) Engine cooling and

(iii)Development of back pressure



Consider that the cylinder number 1 of the four-cylinder engine, shown in Fig., is fired first. A pressure p, generated in the cylinder number 1 will give rise to a force equal to {pA × [b/(a + b)]} and {pA × [a/(a + b)]} on the two bearings A and B respectively. The load on bearing A is much more than load on bearing B. If the next cylinder fired is cylinder number 2, this imbalance in load on the two bearings would further aggravate the problem of balancing of the crankshaft vibrations & would result in severe engine vibrations. If we fire cylinder number 3 after cylinder number 1, the load may be more or less evenly distributed.

Further, consider the effect of firing sequence on engine cooling. When the first cylinder is fired its temperature increases. If the next cylinder that fires is number 2, the portion of the engine between the cylinder number 1 and 2 gets overheated. If then the third cylinder is fired, overheating is shifted to the portion between the cylinders 2 and 4. Thus we see that the task of the cooling system becomes very difficult because it is then, required to cool more at one place than at other places and this imposes great strain on the cooling system. If the third cylinder is fired after the first the overheating problem can be controlled to a greater extent.

Next, consider the flow of exhaust gases in the exhaust pipe. After firing the first cylinder, exhaust gases flow out to the exhaust pipe. If the next cylinder fired is the cylinder number 2, we find that before the gases exhausted by the first cylinder go out of the exhaust pipe the gases exhausted from the second cylinder try to overtake them. This would require that the exhaust pipe be made bigger. Otherwise the back pressure in it would increase and the possibility of back flow would arise. If instead of firing cylinder number 2, cylinder number 3 is fired. Then by the time the gases exhausted by the cylinder 3 come into the exhaust pipe, the gases from cylinder 1 would have sufficient time to travel the distance between cylinder 1 and cylinder 3 and thus, the development of a high back pressure is avoided.

It should be noted that to some extent all the above three requirements are conflicting and therefore a trade-off is necessary.

Valve timing diagram

The valve timing diagram is defined as the graphical representations of the events of opening & closing of inlet & outlet valves during one complete engine cycle.

Its significance is to optimize valve timing events for a modern high speed internal combustion engine for the purpose of improving fuel economy during idle, high speed performance and allowing for a leaner fuel/air ratio during idle. The method is based on an analytical treatment of the instantaneous relationship between valve flow area and the changes in cylinder volume occurring because of piston motion.

Actual Opening and closing of Inlet Valve:

The inlet valve is made to open 10degree to 30degree before the piston reaches the Top Dead Center (TDC) during Suction Stroke and is allowed to close only after 30degree to 40degree after the piston reaches and leaves the BDC in the beginning of compression stroke.

Reason:

The reason for doing this is to facilitate silent operation of the engine under high speeds. The inlet valves are made to operate slowly to avoid noise and hence sufficient time should be provided for the air-fuel mix to get into the cylinder. Thus valves are made to open before the actual BDC. Since the inlet valve is a small opening sufficient mixture doesn't enter the cylinder in such short time, as the piston reaches BDC. Thus the inlet valve is kept open for some time period of time after BDC, to facilitate sufficient flow of charge into the cylinder.

Actual Opening and closing of Exhaust Valve:

The exhaust valve is made to open 30degree to 60degree before the TDC in the exhaust stroke and allowed to close only after 80 to 10 in0 the beginning of the suction stroke.

Reason:

The gases inside the cylinder posses a higher pressure even after the expansion stroke, this higher pressure enables it to move out of the cylinder through the exhaust valve reducing the work that needs to be done by the engine piston in pushing out these gases. Thus the exhaust valve is made to open before the piston reaches the BDC thus enabling the gases to escape outside on its own and the remaining gases are pushed out by the upward motion of the piston. When the piston reaches the TDC, if the exhaust valve is closed like in actual timing diagram, a certain amount of exhaust gases will get compressed and remain inside the Cylinder and will be carried to the next cycle also. To prevent this, the exhaust valves are allowed to close only a certain time after the piston reaches the TDC.

Heat balance sheet

A heat balance sheet is an account of heat supplied and heat utilized in various ways in the system. Necessary information concerning the performance of the engine is obtained from the heat balance sheet. The heat balance sheet is generally done on second basis or minute basis or hour basis.

The engine should be equipped with suitable loading arrangement to measure the brake power of the engine. Provisions are also made to measure the amount of air intake, amount of fuel consumed, temperature of cooling water at inlet and outlet of the engine amount of cooling water circulated and temperature of exhaust gases.

The heat supplied to the engine is only in the form of fuel – heat and is equal to.

$Qs = mf \times C.V$

Where,

mf = mass of fuel used in kg/min

C.V = Calorific value of fuel in KJ /kg

The various ways in which the heat is utilized are

1. Heat equivalent to break power of the engine.
2. Heat carried away by the cooling water
3. Heat carried away by the exhaust gases
4. Unaccounted heat losses.

Heat equivalent to B.P:

The brake power in KW is converted into KJ/min

$Q_{B.P} = B.P \times 60$ KJ/min

Heat carried away by the cooling water: (Qw)

Heat carried away by the exhaust gases: (Q_g)

Unaccounted heat losses:

Qun = Qs - (Q.B.P + Qw + Qg) in KJ / min

Heat Balance Sheet

S No	Particulars	Credits	
		KJ/min	%
1	Qs		
2	QBP		
3	Q_w		
4	Qg		
5	Qun		
	Total		

