UNIT 10 INTERNAL COMBUSTION ENGINES

Structure

10.1 INTRODUCTION

Construction equipment work on a variety of power sources. Internal combustion engines are invariably employed except when the drive is electric or steam. However, steam power is almost obsolete nowadays. In this unit, you will learn about the various aspects of IC engines.

Objectives

By the end of this unit, you will be able to describe

- IC engines,
- the ratings and performance of IC engines,
- the characteristics of IC engines for heavy construction equipment,
- auxiliary apparatus that go with IC engines,
- pressure-time fuel injection,
- inlet and outlet manifolds,
- the purpose of an air cleaner,
- diesel filters,
- lube filters,

- a lubrication system,
- a cooling system,
- what is turbocharging,
- fuels supplied,
- lubricants used,
- performance of IC engines at high altitudes,
- regulation of IC engines,
- starting of IC engines, and
- types of governors provided.

10.2 CLASSIFICATION

There are two ways by which IC engines may be classified:

a) the spark ignition engine using volatile oils like petrol or power kerosene, and

b) the compression ignition engine, using diesel fuel or furnace oil.

Spark ignition engines have low initial cost, low weight to power ratio, low cranking effort and large variable speeds and loads. At high compression ratios and with throttle wide open, the specific fuel consumption is fairly low.

On the other hand, the compression ignition engine, has higher thermal efficiency, good part load performance, cheaper fuel, absence of pre-ignition and better suitability for 2-stroke operation.

SAQ 1

i) How are IC engines classified?

ii) What are the advantages of spark plug ignition engines?

iii) What are the advantages of compression ignition engines?

10.3 RATINGS AND PERFORMANCE OF IC ENGINES

IC engines are rated in terms of brake horse power, BHP (or flywheel horse power, FHP), measured in a dynamometer test at full throttle opening. The test is performed with power being supplied to all the equipment to be driven by the engine. As much as 8% to 10% of the rated BHP may be consumed by the equipment. The Peak HP or the maximum power available is obtained by performing the test for at least 60 secs. Continuous HP which is less than the Peak HP is obtained by performing a 24-hour test at full load operation. Equipment such as pumps, generators and others which are required to work fairly steadily for long periods are rated by the Continuous HP. The ratings of shovels, excavators and such other machines that are subject to wide load and torque fluctuations are rated slightly lower than the ratings for tractors, trucks and hauling equipment which are rated at power available at specified speed under good operating conditions.

Performance curves for petrol and diesel engines are relations between the variation of BHP, fuel consumption and torque against engine speed (Figure 10.1). The curves show that the torque and BHP of the engine increase as the speed rises upto a certain maximum value and thereafter they decrease. Since capacity loads are more important than the speed of engines used on construction equipment, the speed is usually governed at or lower than for producing maximum power.

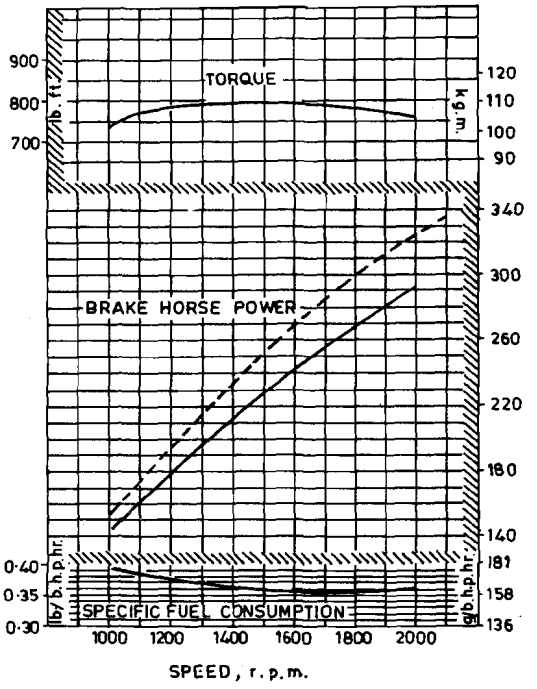

Figure 10.1 : Performance Curves for a Diesel Engine

SAQ 2

i) How are IC engines rated?

ii) How is the performance of an IC engine tested?

iii) What are performance curves of an IC engine?

10.4 CHARACTERISTICS OF IC ENGINES FOR HEAVY CONSTRUCTION EQUIPMENT

Construction equipment work under severe conditions related to topography, environment and climate and they have to deliver high power output intermittently. The prime movers provided on such equipment should meet certain specific requirements. The more important ones include:

a) There is a wide variation of load and so the engine should be able to provide smooth load variation without any trouble. Under sudden load applications, the engine should not stall. Torque converter is necessary for construction equipment.

b) Load capability is more important than economy. Thus, governed speed is the one that delivers maximum horse power.

c) The engine should provide high torque while starting and whenever the load is applied.

d) The engine should work efficiently at high altitudes for which turbochargers are used.

e) The engine should be able to start quickly under varying altitudes and weather conditions.

f) Suitable and properly selected devices for filtering air, oil and fuel should be provided. On a construction engine 15 or even more filtering devices may be provided.

g) A fuel tank of adequate capacity should be provided.

h) The weight to horse power ratio should be small. This may be about 6.13 kg/kW or less.

i) Parts to be maintained should be easily accessible.

SAQ 3

i) What are the conditions under which construction equipment function?

ii) What are the characteristics of IC engines needed for heavy construction equipment?

10.5 AUXILIARY APPARATUS

The auxiliary apparatus on an IC engine include: the fuel system; the ignition system; the lubrication system and the cooling system. The systems are different for petrol and diesel engines.

Petrol Engines

In spark ignition engines using petrol fuel, the fuel system comprises the fuel storage tank, filter, lift pump, carburettor and intake manifold with the required pipework (Figure 10.2). Air cleaner, exhaust manifold and silencer or muffler are accessories of the system. Petrol is drawn from the tank through the filter by the engine operated fuel lift pump and fed into the carburettor.

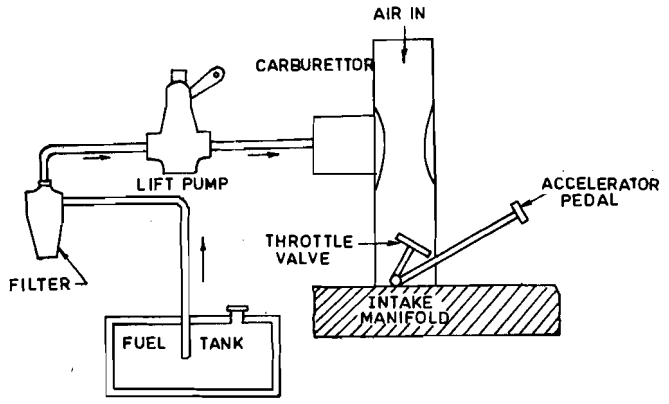

Figure 10.2 : Fuel System of a Spark Ignition Engine

The ignition system provides an electric spark for igniting the combustible mixture in the combustion chamber. The main requirement of the system is to produce an electric spark of sufficient intensity at the correct instant. A battery type ignition system (Figure 10.3) includes the battery, the ignition coil, the distributor and the spark plug.

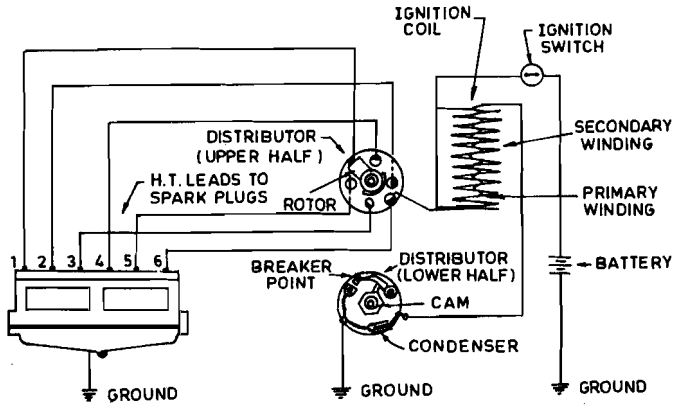

Figure 10.3 : Battery Type Ignition System for a Petrol Engine

Diesel Engines

In a diesel engine (Figure 10.4) the fuel system consists of a fuel tank, fuel lift pump, fuel filter, fuel injection pump, high pressure fuel lines, engine cylinder and an overflow pipeline. Air filter, intake and exhaust manifolds and muffler are accessories of the system. Diesel is drawn from the tank by the engine operated fuel lift pump, passed through the filter and fed into the fuel injection pump which forces the diesel through high pressure lines to the engine cylinder. An overflow pipeline leads the excess diesel back into the fuel tank.

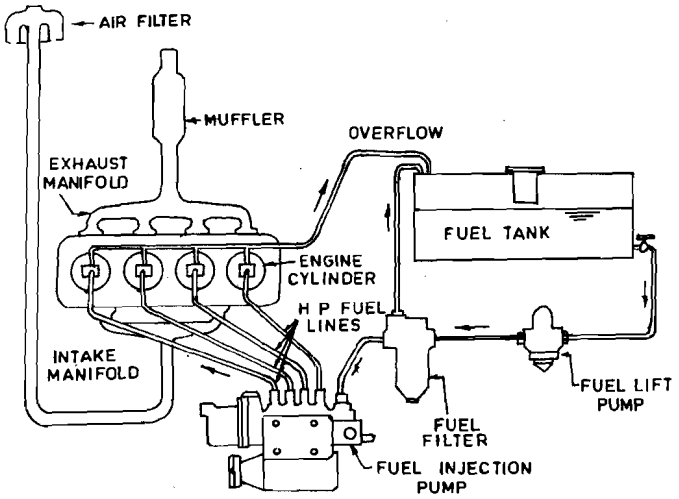

Figure 10.4 : Fuel System for a Diesel Engine

SAQ 4

i) Describe the auxiliary apparatus on petrol engines.

ii) What are the functions and requirements of the ignition system on petrol engines?

iii) Describe the auxiliary apparatus on diesel engines.

10.6 PRESSURE-TIME FUEL INJECTION

The pressure time fuel injection is based on the principle that by changing the pressure of a liquid flowing through a pipe, the amount of liquid coming at the open end, if changed within a given time, an increase in pressure increases the amount of liquid delivered and vice-versa. In such a system the fuel keeps on circulating constantly except during a short period following the injection into the combustion chamber. Since a bulk of the fuel in circulation is returned to the tank, it absorbs enough heat in passing through the injector, ensuring that the fuel will not freeze during cold weather.

SAQ 5

i) What is the principle of the pressure-time fuel injection?

ii) How is the fuel prevented from freezing during cold weather?

10.7 INLET AND OUTLET MANIFOLDS

The inlet manifold is the connection between the carburettor on one side and the inlet valves on the other. There is no carburettor in a diesel engine, and the inlet manifold has the air cleaner on one side and the combustion chamber on the other. It must provide, as

far as possible, an equal distribution of the charge (air in case of a diesel engine) to each cylinder. In some constructions, the inlet manifolds have the provision to heat the charge (or air), with heat of exhaust gases passing round the charge.

The exhaust manifold is the connection between the cylinder exhaust outlets and the pipe to the muffler.

The function of the muffler is to reduce pressure in the exhaust lines and to eliminate most of the noise which may result if gases are discharged directly into the atmosphere. These are possible by the muffler causing the gases to expand gradually and to cool them before they are discharged. The power loss due to back pressure rise in a clogged or damaged muffler or in one with poor design may sometimes become fairly large and should be guarded against. Mufflers have volumes of 6 to 8 times the piston displacement for mobile engines, while it may be 20 times the piston displacement in large stationary engines and made as concrete pits.

SAQ 6

i) What is an inlet manifold?

ii) What is an outlet manifold?

iii) What are the functions of a muffler?

10.8 AIR CLEANER

An IC engine consumes large volumes of air for combustion which is 14–15 kg of air for every kg of fuel burnt. The volume of air used is about 1,000 litres for every litre of fuel. Unfiltered air may contain abrasive dust which would cause rapid engine wear and clogging of small passages, such as those in the carburettor system. Thus a suitable air cleaner is provided. A good air cleaner should be able to extract dust and impurities from air, and should cause least resistance to the flow of air. It should also be easily serviced.

During servicing care should be taken to ensure leakproof joints. A small leak in the inlet pipe may admit enough unfiltered air to materially shorten engine life. Unfiltered air may leak through loose, improperly tightened connections at damaged or improperly installed seats or gaskets or through the clearances around bolt and stud threads. Special primers and retaining compounds may be used on threaded parts, and these should be well tightened.

The three common types of air cleaners are: the oil wetted copper mesh, the oil bath type and the dry type.

The oil wetted copper mesh air cleaner has a copper mesh wetted with oil to catch the dust particles from air which is made to pass through it. This type is, however, clogged with dust rather quickly, seriously affecting air flow through it, and is not efficient in removing fine dust particles from the air.

The oil bath type air filter is highly efficient in performance and is preferred on most engines. Construction equipment which work generally under dusty conditions are usually provided with such an air cleaner.

The dry air filter consists of elements made of resin impregnated cellulose material made in sheets folded into a ring shaped unit. The filter removes even the smallest dust particles and offers minimum resistance to air flow.

For efficient engine performance, servicing of the air cleaner is important. In the oil bath type cleaner, a proper level of clean oil should be maintained in the bath. The great advantage of the dry air cleaner is its easy servicing.

SAQ 7

i) What are the functions of an air cleaner?

ii) What are the characteristics of a good air cleaner?

iii) What do you check in an air cleaner during servicing?

10.9 DIESEL FILTER

The fuel nozzles being very small even fine particles of dirt may clog the openings thereby obstructing the flow of fuel into the engine cylinder. Thus, it is essential to supply diesel free from inert substances. A typical diesel fuel system of a diesel engine is shown in Figure 10.4. The fuel is supplied from a diesel tank through a lift pump and passes through a set of filters before entering the fuel injection pump. The filters remove all dust and dirt particles that may find their way into the fuel tank.

SAQ 8

What is the purpose of a diesel filter in a fuel system?

10.10 LUBRICATION OIL FILTER

It is a common practice to include an oil filter in the pressure lubrication system of an IC engine in addition to the pump strainer, and this filter is provided on the delivery side of the pump. It may be full flow type, the entire quantity of oil discharged by the pump being passed through it, or a part flow type in which only a part of the oil passes through the filter. The sump strainer is sometimes mounted on a hinged float so that the strainer always stays on top of the oil in the sump where the oil is relatively cleaner (Figure 10.5).

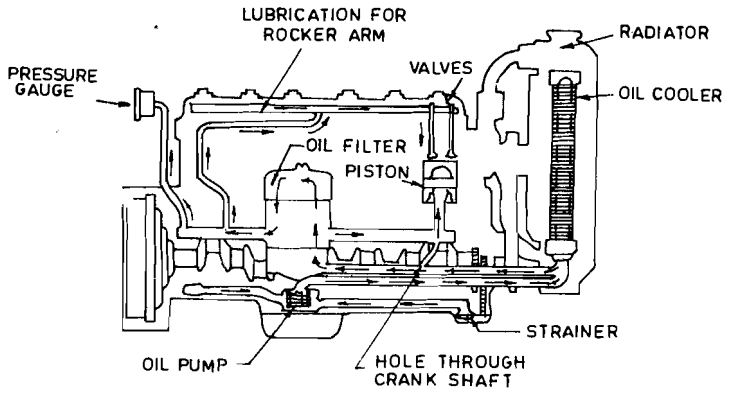

Figure 10.5 : Pressure Lubrication System of an IC Engine

SAQ 9

Why is a lubrication oil filter necessary in an IC engine and where is it provided?

10.11 LUBRICATION SYSTEM

Proper lubrication of equipment reduces breakdowns and improves performance. For construction machines in particular, the lubrication requirements are exacting since these machines work under highly adverse job and management conditions operating in dirt, mud, water, extremes of weather conditions and for long hours during the day. The increased speeds and load capacity, the close tolerances and clearances make proper lubrication a vital necessity for the successful and efficient operation of modern construction machines.

The lubricating system in an engine reduces the amount of friction between moving parts, and at the same time keeps them cool. Reduced friction decreases wear and saves in power

consumption. It also prevents leakage between piston, rings and cylinders, and washes away abrasive material from friction surfaces.

The two principal methods of lubricating IC engines are the splash and the pressure systems. Sometimes, a combination of the two methods is employed.

The splash method is used in lubricating moving parts of slow speed engines and the system needs little special attention.

In the pressure system, oil is distributed under a pressure of 3.5 kg/sq cm to various parts with the help of an oil pump which draws it from the sump through a coarse mesh filter (Figure 10.5).

SAQ 10

i) What does the lubrication system do in an IC engine?

ii) What are the splash method and pressure system of lubrication?

10.12 COOLING SYSTEM

A considerable part of the heat released by the combustion of fuel in an IC engine is not utilised to develop power, and has to be rejected to the atmosphere. On large diesel engines, 15–20 % of the total heat input is thus rejected. Inside the combustion chamber of an IC engine, temperatures normally exceed 550°C and at times may develop as high as 2750°C momentarily. If the extra heat which is not used for producing useful work is not removed from the engine, some parts of the engine may melt due to excessive rise in temperature. Also, the lubricating film on the cylinder walls would disappear if the temperature is very high. Abnormally high engine temperatures would result in heating up the lubricating oil and changing its viscosity and thus render it unfit for effective lubrication. In large high speed engines, it may be necessary to cool the lubricating oil separately, apart from the usual engine cooling.

All engine cooling methods (Figure 10.6) depend on the ultimate dissipation of heat to the atmosphere. The direct air cooling (Figure 10.6(a)) is employed in small industrial engines, in motor bicycle engines, and aircraft engines. Long, closely spaced fins depending on the cylinder size help in dissipating heat effectively due to increase in effective area of the heated surface.

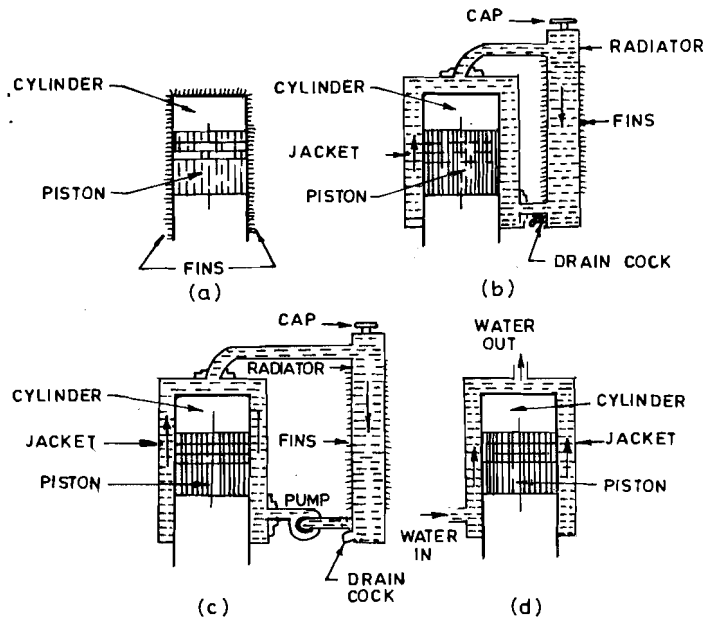

Figure 10.6 : Methods of Engine Cooling
(a) Direct Air Cooling (b) Indirect System with Natural Circulation of Water (c) Indirect Cooling System with Forced Circulation of Water (d) Non Circulating System with Water

The indirect cooling system uses natural circulation (Figure 10.6(b)) or forced circulation of water (Figure 10.6(c)). In the natural circulation method the change in density of water due to a change in temperature causes it to circulate in the system. As the water is cooled in the radiator, it descends while hot water in the jacket rises and flows to the radiator at the top. This system is simple, but the force to circulate water is small and can only provide a slow rate of circulation, necessitating larger cooling elements. Sometimes, a water tank of sufficient capacity may be used instead of the radiator to provide cooling by natural circulation.

The indirect cooling system with forced circulation of water is mostly used in large and medium sized units, fitted on mobile machines used on construction jobs. It employs a small centrifugal type water pump usually mounted on the same spindle as the radiator fan and driven from the engine through a V-belt.

In the non-circulating system (Figure 10.6(d)), cold water is supplied to the jacket and, after circulation, allowed to go to waste without being recirculated. This is a water cooled system as no aid of atmospheric air is taken for heat dissipation. The arrangement is adaptable where a large volume of clean water is available, as from a natural source of water. The requirement of water depends upon the temperature of available water and the final engine temperature to be attained after cooling. For a temperature rise of 6 - 12 °C about 127 - 255 litre/kW/hr of water may be needed.

SAQ 11

i) Why is a cooling system required on an IC engine?

ii) What are the different methods of cooling an IC engine?

iii) What is the direct method of cooling?

10.13 TURBOCHARGING

The power developed by an IC engine depends upon the fuel effectively burnt in the cylinder of the engine. The greater the fuel burnt, the greater would be the engine power. For good combustion of fuel the requisite amount of air must be supplied to the engine cylinders. If a greater volume of air is supplied to an engine, it would be able to develop more power for the same size and conversely, a smaller sized engine, fed with extra air would produce the same power as a larger one supplied with its normal air feed. This increasing of air charge (air-fuel mixture) in an IC engine is called supercharging or turbocharging and is accomplished by installing a blower or compressor called supercharger or turbocharger, between the engine intake and the air inlet past the air cleaner. The supercharger forces air into the cylinders at a pressure higher than atmospheric, the usual range of pressure being 0.28 - 1.4 kg/sq cm. In heavy construction equipment, the supercharger is employed on large sized diesel engines and may be essential in case the equipment is required to work at high altitudes.

SAQ 12

i) What do you understand by supercharging or turbocharging?

ii) How does a supercharger function and where is it used?

iii) Where and why is supercharging necessary?

10.14 FUELS AND THEIR CONSUMPTION

IC engines used on construction equipment are largely designed to run on gasoline, vaporizing oil or diesel as fuel. All the fuels which are petroleum products are blended with alcohols and hydrocarbons to give them certain desirable characteristics.

The high speed spark ignition engines most commonly use petrol or motor spirit called gasoline.

Some engines use vaporizing oil or power kerosene which is somewhat less volatile than gasoline and is intermediate between gasoline and diesel oil as a fuel. Many spark plug ignition engines are started on gasoline and then run on vaporizing oil. Vaporizing oil is different from illuminating kerosene, commonly known as paraffin. Due to less volatility the engine using this fuel cannot be started from cold without special arrangement. It is cheaper than gasoline. The specific fuel consumption is about the same for gasoline and vaporizing oil fuels and is about 2.36–2.75 kW/hr/litre.

High speed compression ignition engines use diesel as fuel. It is cheaper than most other fuels and the specific fuel consumption is around 3.34 kW/hr/litre. Cold running of engines should be avoided, the jacket water temperature being above 70°C.

Fuel consumption for gasoline engines may be estimated at 0.307 litre/kW/hr, and for diesel engines at 0.205 litre/kW/hr. These figures are based on 100% load factor and for engines working at full throttle. In actual operation the load factor may be in the range of 0.6–0.7, and the requirement of fuel should be reduced accordingly.

SAQ 13

i) What are the different fuels used in an IC engine?

ii) What are the consumption of various fuels and the load factors at which IC engines work?

10.15 LUBRICANTS

There are a few basic types of lubricants which can satisfy the lubrication requirements of nearly all construction machines. These include: engine oils, gear oils of EP (extreme pressure) type and those of the adhesive type, hydraulic oils, and heavy duty greases.

Engine crank case oils provide anti-wear properties, rust protection, corrosion resistance, oxidation stability, foam prevention and detergent dispersal characteristics.

Gear oils of the EP type may be used where there is sliding contact between the gear faces. These oils absorb shock loads and prevent scoring under heavy load. They also counter thickening, foaming, oxidation and corrosion. Gear oils of the adhesive type cling to the tooth surfaces even at high pressures, temperatures and peripheral speeds.

Hydraulic oils act as a medium for transmitting power, and also provide for lubrication and cooling of the system components. They are light mineral oils fortified to prevent wear and rust and resist oxidation, sludging and foaming.

Multipurpose heavy greases are used for most lubrication needs of bearings and gears.

SAQ 14

What are the various lubricants used in a construction machine?

10.16 PERFORMANCE OF IC ENGINES AT HIGH ALTITUDES

Horsepower rating of an engine is usually specified at sea level and at 15.5°C atmospheric temperature. The actual hp under varying conditions of temperature and pressure would be different from this value. Power losses due to fall in atmospheric pressure at higher altitudes are lesser in 2-stroke engines due to a partial pre-compression of air before it is charged into the cylinder. About 1% of power under standard conditions may be added for every 5.5°C drop in temperature, and the same amount deducted for every 5.5°C rise in atmospheric temperature. Similarly, 3% of the rated power may be deducted for each 330 m of altitude above sea level for a stroke engine, and 1% for a 2-stroke engine. Usually, no correction is needed for the first 500 m above sea level.

SAQ 15

How does weather and altitude affect the performance of an IC engine?

10.17 REGULATION OF IC ENGINES

In spark ignition engines speed and load regulation are attained by throttling the charge through a butterfly valve in the throat of the carburettor. This is a quantitative method of governing, i.e., the quantity of the charge passing into the cylinder is controlled by restricting its passage in the carburettor throat. The throttling results in decreasing the suction pressure and in increasing the pumping work with a consequent reduction in the engine efficiency at partial loads. This is the simplest method of governing and commonly used.

Compression ignition engines are governed by altering the amount of fuel injected into the cylinder, usually arranged by the movement of the control rod in a variable delivery, multi-plunger pump. These engines are designed to give most economical operation at about 80% of the rated load. Part load operation of these engines is generally better than that of spark ignition engines.

The regulating mechanism in all engines is actuated by governors. In heavy tractors and most construction equipment, the governor controls the fuel supply, and the engine speed is varied by the operator by movement of the governor control lever which is sometimes misnamed as throttle. In vehicles, the fuel supply is usually under the direct control of the accelerator pedal. This is necessary as the operator is well occupied in operating the implements and steering the machine, and the governor relieves him of the duty of regulating the throttle for the entire time of operation.

SAQ 16

i) How are speed and load regulation achieved in a spark ignition engine?

ii) How is governing achieved in compression ignition engines?

iii) What is the function of a governor in heavy tractors?

10.18 STARTING

Starting of small engines is by cranking them by hand, with an arrangement to relieve compression in the cylinder during cranking. Larger sizes of engines need mechanical devices to start them. Spark ignition engines are most commonly started by electrical self-starter. Compression ignition engines use many methods of starting as, apart from the weight of the moving parts, cold weather effects also increase the difficulty of starting.

Cold weather affects fuel-air mixture temperature, the rate of vaporisation of fuel, and the drag of thick cold lubricating oil on bearing parts; and all these effects add to the starting difficulties in engines.

The most popular method of starting diesel engines is through electric motor driven by a storage battery of 12–32 V as done in case of petrol engines.

A second method of starting large sized diesel engines is by auxiliary gasoline engine mounted close to the main engine and driving it through clutch and gears.

A third method consists of starting the engine as a gasoline engine, and when it has warmed up, changing it over to diesel operation.

SAQ 17

i) How are small and spark ignition engines started?

ii) What are the different methods of starting compression engines?

10.19 TYPES OF GOVERNORS

There are two common types of governors, the centrifugal type and the pneumatic type.

In the centrifugal type, used on petrol engines, one or more weights are pivoted on a spindle which moves at the engine speed or at a lesser speed. As the governor weights spin, centrifugal force tends to make them fly outwards and this action of the weights is conveyed through a moving sleeve to the throttle valve of the carburettor or to the control rod of the fuel injection pump. This reduces the flow of fuel into the cylinder and thus decreases the speed of the engine.

The pneumatic governor, used on diesel engines, has a diaphragm attached to the control rod of the fuel pump and a spring which tends to hold this rod in the full-load position. A small air tight chamber is provided on one side of the diaphragm. The movement of the diaphragm is transmitted to the fuel injection pump. As the load on the engine increases the movement of the diaphragm increases the amount of fuel injected.

SAQ 18

i) What is a centrifugal type of governor?

ii) What is a pneumatic type of governor?

10.20 SUMMARY

In this unit you learnt about the various components of IC engines and their characteristics, which are used for heavy construction equipment. The various auxiliary apparatus that go with an IC engine, the types of manifolds, lubrication and cooling systems have been elaborated. Different kinds of lubricants used in an IC engine have also been discussed. The various methods of starting small and large engines, their regulation and governing have been described; as well as the performance of IC engines at high altitudes has been explained.

10.21 ANSWERS TO SAQs

Read through the various sections and find the answers.