THE GATE COACH

Revised Study Material

For

GATE – PSU

Mechanical Engineering

IC Engine and Power Plant

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IC ENGINE
&
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STEAM NOZZLE WITH COMPRESIBLE FLOW		

CHAPTER 10ENGINE FRICTION AND LUBRICATION

INTRODUCTION

Engine friction is defined as the difference between the indicated horse-power (power at piston top as produced by the combustion gases) and the brake horse-power (useful power) available at the output shaft, Itof the engine.

Engine friction is also greatly affected by engine speed. The mechanical efficiency, which is defined as the ratio of bhp and ihp can be as high as 85 per cent for a carefully designed low speed engine having a piston speed of up to about 600 m/min. But it is very difficult to get a mechanical efficiency figure better than 75 per cent *for* a high speed engine having a piston speed of about 800 m/min. Thus a definite limit is imposed on the30 maximum output which can be obtained from an engine by increasing engine speed and it becomes very important to give careful attention to engine friction at all steps in engine design.

Usually an appreciable difference in the specific fuel consumption between two engines of almost identical size operating under very similar conditions results due to effect of engine friction.

TOTAL ENGINE FRICTION

Total engine friction, defined as the difference between ihp and bhp, includes the power required to drive the compressor or a scavenging pump and the power required to drive engine auxiliaries such as oil pump, coolant pump and fan, etc.

If the power to drive the compressor and auxiliaries is neglected, the total engine friction can be divided into five main components. These are:

Crankcase mechanical friction.

Blowby losses (compression-expansion pumping loss).

Exhaust and inlet system throttling losses.

Combustion chamber pumping loop losses.

Piston mechanical friction.

Crankcase Mechanical Friction

Crankcase mechanical friction can further be sub-divided into:

Bearing friction,

Valve gear friction, and

Pump and miscellaneous friction.

The bearing friction includes the friction due to main bearing, connecting rod bearing and other bearings. Bearing friction is viscous in nature and depends upon the oil viscosity, the speed, size and geometry of the journal.

The mep lost in journal bearing can be approximated by equation

$$mep = \frac{B}{S} \times \frac{N}{100} \times K$$

Where B/S is the bore-stroke ratio of the engine. N the rpm, and A is a constant whose value is generally about 0.85 for petrol engines and 1.76 tor diesel engine.

The valve gear friction losses vary with the engine design variables and general equation is available for predicting them.

All crankcase friction losses other than bearing and valve gear losses vary roughly in proportion to engine displacement and speed.

The bearing losses are affected vary little by the loading of the bearing but they rise rapidly with increase in speed because these losses are primarily the result of continuous shear of the oil film in the bearing clearance.

Crankcase mechanical friction is about 15 to 20 per cent of total engine friction.

Blow by Losses

Blowby is the phenomenon of leakage of combustion products past the piston and piston rings from the cylinder to the crankcase.

These losses depend upon the inlet pressure and compression ratio. These losses vary as the square root of inlet pressure, and increase as the compression ratio is increased.

Blowby losses are reduced as the engine speed is increased.

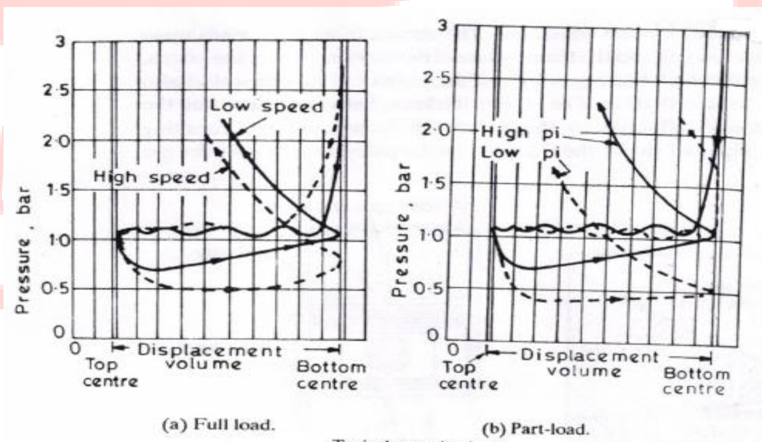
Exhaust and Inlet Throttling Loss

The standard practice for sizing the exhaust valve is to make them a certain percentage smaller than the inlet valves. This usually results in an insufficiently sized exhaust valve and hence, results in exhaust pumping loss.

As the speed increases, the curve rises steeply and may result in substantial loss if the valve size, valve timing and valve flow coefficients are not given due attention.

The inlet throttling loss occurs due to the restrictions imposed by the air cleaner, carburettor venturi, throttle valve, inlet manifold and inlet valve. All these restrictions result in pressure loss.

Similarly, some pressure loss is necessary to exhaust the products of combustion. The work required to inhail fresh charge during the suction stroke and to exhaust the combustion products during the exhaust stroke is called the pumping friction work.



(a) Full load. (b) Part-load.
Typical pumping loops.

Combustion Chamber Pumping Loop Losses

In the case of pre-combustion chamber engines an additional loss occurs. This is the loss occurring due to the pumping work required to pump gases into and out of the pre-combustion chamber.

The exact value of this would depend upon the orifice size connecting the pre-combustion chamber and the main chamber, and the speed. Higher the speed greater is the loss and smaller the orifice size greater is the loss.

Piston Mechanical Friction

Piston mechanical friction can be sub-divided into:

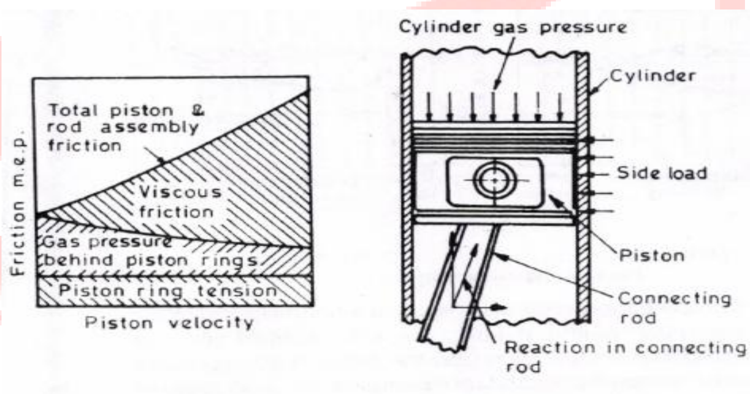
Viscous friction

Non-viscous friction

friction due to ring tension

friction due to gas pressure forces behind the ring.

Figure shows break-up of total piston mechanical friction into its component for a C.F.R. engine. Lower part of the piston works more or less under viscous friction conditions. The viscous friction depends upon the viscosity of the oil and the temperature of the various parts of the piston. The degree to which the upper part of the piston can be lubricated also affects the viscous friction. The oil film thickness between piston and the cylinder is also affected by the piston side-thrust and the resulting vibrations.



Break-up of total piston mechanical friction.

Side load on piston due to gas pressure.

EFFECT OF ENGINE *VARIABLES* ON ENGINE FRICTION

Effect of stroke/bore ratio

The effect of stroke/bore ratio on engine friction and economy is very small. High stroke/bore ratio engines have equally good friction mep values as that for low stroke/bore ratio engine. Indications are that at high speeds the higher stroke/bore ratio engine may be at some disadvantage.

Effect of cylinder size and number of cylinders

The friction and economy improves as a smaller number of larger cylinders are used. Thisis because the proportion between the working piston area and its friction producing area, i.e. circumference is reduced.

Effect of number of piston rings

The effect of number of piston ring is not very critical and this number is usually chosen on the basis of cost, size and other requirements rather than on the basis of their effect on friction.

Effect of compression ratio

As already discussed the friction mean effective pressure increases as the compression ratio is increased. But the mechanical efficiency either remains constantor improves as the compression ratio is increased. If the displacement is varied to keep the maximum engine torque constant, this results in better part load friction characteristics. For example at 1600 rpm, an increase in compress*ion ratio from 9 to 12 results in a 5 per cent increase in fuel economy becomes 10 per cent.*

Effect of engine speed

As already discussed engine friction increases rapidly as the speed increases. The best way to improve mechanical efficiency at high speed is to increase the number of cylinders.

Effect of oil viscosity

*Higher the oil viscosity greater is the friction loss. The temperature of the oil in the crankcase significantly affects the friction losses, wear and service life of an engine. As the oil temperature*increases, *the viscosity decreases and friction losses arc reduced* owing *certain temperature range. If the temperature goes higher than at a certain value the local oil film is* destroyed resulting in metal to metal contact.

Effect of cooling water temperature

A rise in temperature *reduces* engine friction through its effect *on oil viscosity.* During starting operation the temperature of both the oil and the wateris low, hence, the viscosity is high. This results in high starting friction losses and rapid engine wear.

Effect of engine load

As the load increases the maximum pressure in the cylinder has a tendency to increase slightly. This results in slightly higher friction values. However, this increase in friction loss is more than compensated by the decrease in oil viscosity due to higher temperatures resulting from increased load. Further in case of petrol engines the throttling losses reduce as the throttle is opened more and moreto supply more fuel for allowing an increase in engine load. Both these effects combine to reduce frictional losses of a petrol engine as engine load is increased.

However, for diesel engines the frictional losses are more or less independent of engine load.

DETERMINATION OF ENGINE FRICTION

There are five methods of determining the engine friction. These are:

From the ip and bp measurements.

Morse test.

Willan's line method.

Motoring method.

Deceleration method.

From ip and bp measurements

If the ihp is obtained from the indicator diagram and bhp from dynamometer, the fhp can be obtained by simply subtracting the latter from the former. The main disadvantage of this method is that it is very difficult to obtain accurate indicator diagram for calculation of ip. A slight error in location of the tdc position on the indicator diagram may lead to significant changes in ip obtained.

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Morse test

In the Morse test, which is applicable for both petrol and diesel engines, the individual cylinders are successively cut-off and the brake horse-power is determined. This gives the ip developed by each cylinder, and hence by the full engine from which if bp is subtracted, fp can be obtained. Morse test is applicable to multicylinder engines only.

Willan's line method

In the Willan's line method which is applicable for diesel engines only, the gross fuel consumption is plotted against bp and the line so obtained is extended backwards to zero fuel consumption. The negative intercept on the bp axis gives the value of fp. The main disadvantage of this method is that the fuel consumption-bp line is not straight but it turns up slightly at weak end and considerably at rich end so that unless sufficient data are taken to accurately plot the straight line portion of the curve the result would be significantly different. However, method is quite accurate if sufficient care is taken to plot the graph.

Motoring method

In the motoring method, engine is driven with the help of an external motor. The powerconsumed by this motor, ifcorrected for mechanical and other losses of the motor, gives the fp of the engine. The main criticism of this method is that since no actual firing takes place the peak pressure, exhaust back pressure, engine temperature etc., are quite different from the firing condition and consequently, the fp value obtained is different. The main advantage of this method lies in the fact that by successive 'stripping off of the engine the contribution of each part ot the engine to the overall engine friction can be accurately obtained.

Deceleration method

In the deceleration method use is made of the fact that if a running engine is left free after cutting-off the fuel supply it will decelerate due to the effect of the engine friction. If this deceleration is measured and the polar moment of inertia of the engine is known, fp can be calculated because engine friction is the product of polar moment of inertia and initial deceleration.

LUBRICATION PRINCIPLES

Consider a block resting on a flat surface covered with a layer of lubricating oil. If the weight of the block is very high or the oil *is* thin, the oil will squeeze out. In other words, a thick oil can support a higher load than that supported by a thin oil.

Hydrodynamic lubrication

When this block is moved oversurface, a wedge-shaped oil film is built up between moving block and the surface. This wedge-shaped film is thicker at leading edge than at the rear. In other words the moving block acts as pump to force oil into clearance that narrows down progressively as the block moves. This generates appreciable oil film pressure which carries the load. This type of lubrication where a wedge-shaped oil film is formed between two moving surfaces is called hydrodynamic lubrication. The important feature of this type of lubrication is that the load carrying capacity of the bearing increases with increase in relative speed of the moving surfaces. This occurs because at higher speed the time available to
the oil to squeeze out is less.

The force required to move the block over the surface depends upon the weight of the block, the speed of movement, and the thickness or viscosity of the oil. This force divided by the pressure caused by the weight of the block is called the coefficient of friction. *A higher coefficient o friction signifies a greater force to move the block.*

The flat surface lubrication of the kind referred above exists at places such as thrust bearings, valve tips and cam lifters. Many other surfaces which use hydrodynamic lubrication are cylinder wall, valve guide, man bearings, connecting rod bearings, and camshaft bearings.

Elasto hydrodynamic lubrication

When the load acting on the bearings is very high, the material itself deforms elastically against the pressure built up of the oil film. This type of lubrication, calledelastohydrodynamic lubrication, occurs between earns and followers, gear teeth, and rolling bearings where the contact pressures are extremely high.

Boundary lubrication

If the film thickness between the two surfaces in relative motion becomes so thin that formation of hydrodynamic oil film is not possible and the surface high spots or asperities penetrate this thin film to make metal-to-metal contact then such a lubrication is called boundary lubrication. Such a situation may arise due to too high a load, too thin an oil or insufficient supply of oil due to low speed of movement. Most of the wear associated with friction occurs during boundary lubrication due to metal-to-metal contact. A condition of boundary lubrication always exists when the engine is first started. The shaft is in contact with the bottom of the bearing with only a thin surface film ofoil formed on them. The bearing surfaces are not perfectly smooth-they have 'hills' and Valleys' which tear this thin film which is constantly formed while the crankshaft is turning slowly. As the speed increases it switches on to hydrodynamic lubrication. Boundary lubrication may also occur when the engine is under very high loads or when the oil supply to the bearing is insufficient.

Hydrostatic lubrication

In hydrostatic lubrication a thin oil film resists its instantaneous squeezing-out under reversal of loads with relatively slow motions. The oil film acts as a cushion. If oil supply is sufficient the oil film thickness is restored before next reversal of load.

FUNCTIONS OF THE LUBRICATING SYSTEM

The following are the important functions of a lubricating system:

Lubrication

The main function of the lubricating system is tokeep the moving parts sliding freely past each other and, thus, reduce theengine friction and wear.

Cooling

To keep the surfaces cool by taking away a part of theirheat through the oil passing over them. This cooling action usually takesplace simultaneous to the lubricating function. However, under certainconditions lubrication system is used to keep certain engine parts coolwhich due to their typical location do not come in direct contact with thecooling water. One typical example is the oil cooling of pistons of highspecific output engines.

While performing its cooling function the lubricant is exposed to heating and agitation which promote oxidation. This requires oil to possess good oxidation stability. The heat input to the oil increases if the cooling function is extended to piston cooling. For a naturally aspirated diesel engine the heat input to the oil can be equal to some 6-8% of engine power output. This value is further increased by 50% for an indirect injection engine and doubled for turbocharged engines

Cleaning.

To keep the bearings and piston rings clean of the *pro*ducts of wear and the products of combustion, especially the carbon, by washing them away and then, not allowing them to agglomerate to form sludge.

Sealing.

The lubricating oil must form a good seal between piston rings and cylinder walls. The oil should be physically capable offilling the minute leakage paths and surface irregularities of the mechanical sealing elements, i.e., cylinders, pistons and piston rings. The oil as a sealantis subjected to high temperatures and hence must possess adequateviscosity stability.

Reduction of noise.

Lubrication reduces the noise of the engine

These functions are conflicting functions. The oil cools best when it is thin but seals best when it is thick. The oil must collect dirt to scavenge an clean but to lubricate it must be clean. The engine produces not onlypower but a number of oil contaminants also. The oil should be able to absorb these-contaminants without affecting its main functions.

Increased speed, compression ratio and, hence, increased power output all result in higher pressures and temperatures. The shock loading of bearing is also severe. Larger valves require stiffer valve springs which, m turn, result in increased stresses and elevated temperatures for many related parts.

All these conflicting and difficult to meet requirements require skilful juggling at the hands of the engine designer.

PROPERTIES OF THE LUBRICATING OIL

Viscosity

Viscosity of an oil is measure of its resistance to flow and is usually measured in terms of Saybolt Universal Seconds (SUS) which is the time required, in seconds, for a given quantity of the oil to flow through a capillary tube under specified test conditions. Viscosity is usually expressed at two temperatures - 18°C (0°F) and 99°C (210°F). Viscosity is also expressed in centistokes, centipoise and Redwood seconds. The basic difference between all these systems of expressing viscosity lies in the type of apparatus, called viscometer, used for its determination.

Viscosity Index.

The viscosity of an oil is substantially affected by its temperature, higher the temperature lower is the viscosity. This variation of viscosity of an oil with changes in temperature is measured by its Viscosity Index (V.I.) The oil is compared with two reference oils having same viscosity at 99°C (210°F). One, a paraffinic base oil (considerable change in viscosity with temperature), is arbitrarily assigned an index of zero and the other, a naphthenic base oil (little change in viscosity with temperature), is assigned an index of 100.

A high viscosity index number indicates relatively smaller changes in viscosity of the oil with temperature. Viscosity index of an oil is very important where extreme temperatures are encountered. The lubricating oil must maintain a sufficient viscosity at high temperatures and still should not be too viscous for starting the engine at low temperatures. Typical examples of extreme temperature conditions are the hydraulic system in an aircraft and automobile engine in cold weather.

To improve the viscosity index of an oil certain compounds, called V.I. improvers, are added to it. These are viscous, long chain paraffinic, compounds which enable to obtain an oil having easy starting characteristic of thin oils combined with good protection against high temperature.

For automobile applications oils having a viscosity index above 90 are considered to be of high VX, oils between 55 and 90 medium V.I., and below 55, low V.L

Cloud Point and Pour Point

If an oil is cooled, it will start solidifying at some temperature. This temperature is called cloud point. This clouding or haziness of the oil interferes with its flow. The pour point is that temperature just above which the oil sample will not flow under certain prescribed conditions. This temperature is largely determined by the wax content of the oil since as the temperature is reduced was crystallizes out in long needle-shaped crystals, forming honeycomb with oil held in the voids between the crystals. Generally oil derived from paraffinic crudes tend to have higher pour points than those derived from naphthenic crudes. The pour point can, however, be lowered by the addition of a pour point depressant usually a polymerised phenol or ester. These substances function by depositing insulating films on the wax crystals as they begin to separate out from the oil and by reducing the size of crystals.

This characteristic of the oil is very important at low temperature operation since it will affect the flow in the pressure line of the lubricating system. Pour point must be at least 15°F lower than the operating temperature to ensure maximum circulation. Even at this temperature the oil may be viscous so that high power may be necessary for starting.

Flash Point.

The temperature at which the vapours of an oil flash when subject to a naked flame is known as the flash point of the oil. If the container is closed at the time of the test it is called closed flash point, and if open it is called Open flash point. Fire point is the temperature at which the oil, if once lit with flame, will burn steadily at least for 5 seconds. This is usually 11°C higher than open flash point and varies from 190°C to 290°C for the lubricants used for the internal combustion engines.

Fire and flash points are good indication of relative flammability of the oil and except for the safety from fire hazards, they do not have any significance for engine operation. However, fire and flash points of used lube oil are very good indication of the crankcase dilution. The light ends of the fuel, which leak into the crankcase, readily evaporate and burn at considerably lower temperature than the temperature at which the oil would have burned, clearly indicating the degree of dilution.

Specific Gravity

The specific gravity of the engine lube oils varies from 0.85 to 0.96. Naphthenic base oils have higher specificgravity than the paraffin base oils. This property is of little importance except as an indicator of weight and volume.

Carbon Residue

Carbon residue is that quantity of the known mass sample of the oil, which on evaporation under specific conditions remains as carboneous residue. This is a very rough pointer to the deposit characteristics of the oil. However, it cannot be relied upon to predict deposits because the formation of deposits is strongly affected by the design of the engine, the fuel used, and the operating conditions.Paraffinic-base oils have higher carbon residue than the asphaltic base oils.

Oiliness

The property of an oil to cling to the metal surfaces by molecular action and then to provide a very thin layer of lubricant under boundary lubrication conditions is called the oiliness or lubricity or film strength. This is measured by the coefficient of friction under extreme conditions of operations. This is very significant at high pressures and small clearance as it controls the Squeezing out' of the oil, takes care of temporary loss of oil pressure and also affects starting.

Oxidation Stability

Oxidation stability of an oil is its resistance to oxidation. Due to oxidation the oil will form deposits on the piston rings and will lose its lubricating property. Low-temperature operation avoiding the hot-area contact and crankcase ventilation can help in preservingthe stability of an oil over longer periods. The products of oxidation vary widely according to the type of oil and the temperature reached and include carbon, lacquer, sludge and organic acids which can be corrosive to certain metals. Oxidation inhibitors to improve oxidation stability are used in crankcase oils to counter these tendencies. These are complex compounds of sulphur and phosphorous or amine and phenol derivatives

Cleanliness

The absence of water and sediments are essential requirements for an oil. Water is not a lubricating fluid and it pro- Fig. *14.18.* Engine sludge motes corrosion while dirt and small foreign formation location, particles of insoluble matter cause great wear of engine parts.

Colour

This has no practical significance except that it is an indication of the degree of refining of the oil.

Acidity and Neutralisation Number

The oil must have low acidity. The neutralisation number is a measure of acidic or alkaline contents of oil. NEW oil has low neutralisation number, which is the quantity of alkaline solution or acid solution required to make the oil neutral. Used oil has high neutralization number.

ADDITIVES

Simple mineral oil has most of the characteristics needed for a good lubricant. However, varying operating conditions require some specific properties it cannot meet. The examples are the ability of an oil togive good viscosity over a range of temperatures, i.e. high viscosity index, resistance to oxidation, the property to dissolve and cleanse the deposits, the detergency properties, corrosive resistiveness, etc. Water, resins, and soot from burnt or unburnt fuel which depend upon the mechanical conditions of operation and load, greatly affect the lube oil.

So, in order to confer upon the oil all or some of the above required attributes different types of compounds, called additives, are added. The compounds may give one or more of characteristics, or different compounds can be used to give distinct properties and accordingly they are called VJ. improvers, anti-oxidants, detergent-dispersants etc. Table 142 illustrates the major classes of engine oil additives and their primary functions.

Oxidation inhibitors retard oil oxidation within the engine but they cannot prevent the formation of carboneous deposits within the combustion zones, some of which are carried into the crankcase by blowby gases. Neither can they prevent the sludge so formed from settling out within the engine. Detergents dispersants do not permit such sludge formation by keeping them suspended in the oil. They prevent agglomeration of the small carbon or dust particles which if allowed to do so would block filters and oil passages.

Pour depressants do not allow wax crystals to grow and thick together and give the oil good flow characteristics as lower temperatures. Extreme pressure and anti-wear additives avoid boundary lubrication by forming *a* chemical film.

Other additives used for motor oils are corrosion preventive to reduce acid formation, rust preventives, metal deactivators, water repellents, colour stabilizer, foam inhibitors, emulsifiers, dyes and odour control agents.

Oil contamination and sludge formation

After *a* period of operation the lubricating oil is so much contaminated that it becomes unsuitable for further use. Contamination occurs because of oxidation, dilution, water, formation of carbon, lead compounds, metals, dust and dirt. These contaminants, when mixed with the oil, contribute to the formation of sludge in an engine.

Sludge may be described as a black, brown or gray deposit having the consistency of soft mud. It is formed in engines as a result of operation at low engine temperatures during starting warming up, and idling periods.

LUBRICATION SYSTEMS

Various lubricating systems used for internal combustion engines may be classified as: |

Mist lubrication system

Wet sump lubrication system

Dry sump lubrication system.

MIST LUBRICATION SYSTEM

This system is used for 2-stroke cycle engines. Most of these engines are crankcharged, i.e. *they employ crankcase compression and, thus, are not suitable for crankcase lubrication.*

Such engines are lubricated by adding 2 to 3 per cent lubricating oil in the fuel tank. The oil and the fuel mixture is inducted through the carburettor. The gasoline is vaporised; and the oil, in its form of mist, goes via crankcase into the cylinder. The oil which impinges on the crankcase walls lubricates the main and connecting rod bearings, and the rest of the oil which passes on to the cylinder during charging and scavenging period lubricates the piston, piston rings and the cylinder.

The 2-stroke engine is very sensitive to particular oil and fuel combination. The composition of fuels and lubricants used influence the exhaust smoke, internal corrosion, bearing life, ring and cylinder bore wear, ring sticking, exhaust and combustion chamber deposits, and one of the most irritating and difficult problem of spark plug fouling and whiskering. Therefore, specially formulated ashless oils are used for 2-stroke engines.

The fuel/oil ratio used is also important for good performance. Afuel/oil ratio of 40 to 50 :1 is optimum. Higher ratios increase the rate ofwear and lower ratios result in spark plug fouling.

The main advantage of this system is simplicity and low cost because no oil pump, filter, etc., are required. However, this simplicity is at the cost of many troubles some of which are enumerated below:

Some of the lubricating oil invariably burns in combustion chamber. This heavy oil when burned, and still worse, when partially burned in combustion chamber leads to heavy exhaust emissions and formation of heavy deposits on piston crown, ring grooves and exhaust port which interferes with the efficient engine operation.

One of the main functions of the lubricating oil is protection of anti-friction bearings, etc., against corrosion. Since the oil comes in close contact with acidic vapours produced during the combustion process, it rapidly loses its anti-corrosion properties resulting in corrosion damage of bearings.

For effective lubrication, oil and the fuel must be thoroughly mixed. This requires either separate mixing prior to use or use of some additive to give the oil good mixing characteristics.

One important limitation of this system is oil starvation of the working parts especially when the throttle is closed on a descent on a long hill. A closed throttle means no fuel, and, hence, no oil. The prolonged absence of oil so produced may result in overheating and piston seizure. This oil starvation can be controlled if the driver while descending on a hill periodically releases the throttle to replenish for the complete absence of oil.

Due to high exhaust temperature and less efficient scavenging the crankcase oil is diluted In addition, some lubricating oil also burns in combustion chamber. This results in about 5 to 15 per cent high lubrication consumption for two-stroke engines as compared to four-stroke engines of similar size.

Since there is no control over the lubricating oil, once introduced with fuel, most of the two-stroke engines are over-oiled most of the time.

WET SUMP LUBRICATION SYSTEM

In wet sump lubrication system^ the bottom part of the crankcase, called sump, contains the lubricating oil from which the oil is supplied to various parts. Fig. 14.19 shows three versions of wet sump lubrication system. These are:

Splash system

Modified splash system

Full pressure system

The splash system is used for small engines. In this system the oil level in the sump is so maintained that when the connecting rod big end is at its lowest position the drippers on the connecting rod end strike the oil in the troughs which are supplied with oil from the sump by an oil pump. Due to this striking of the drippers, oil splashes over various engine parts like crankpin bearings, piston skirt and rings, piston pins, etc. Excess oil supplied drips back to the sump.

The splash system is not sufficient if the bearing loads are high. For such cases, the modified splash system is used. The main and camshaft bearings are lubricated by oil under pressure pumped by an oil pump. The other engine parts are lubricated by

In the full pressure system, an oil pump is used to lubricate all parts of the engine. Drilled passages are used to lubricate connecting rod bearings. The cylinder walls, piston and piston rings arc [lubricated by the sprays thrown from the crankshaft and connecting rod. Full pressure system is used for engines which are exposed in high engine loads.

Since the bearings are machined to *a* very close tolerance *and* are likely to be damaged if any foreign materials are allowed to enter the lubricationline, a strainer is always used in oil circuit. *A* gear type pump or rotor type pump submerged in the oil and driven *by* the camshaft draws oil from the sump through a strainer to prevent foreign material from entering the *I* system. *A* pressure relief valve is also used to avoid very high pressure built up in case of filter clogging or if the oil is very cold or sluggish

OIL FILTERS

From the pump all the oil used for lubrication usually passes through an oil filter before it reaches the engine bearings. The bearings are machined to a very close tolerance and are likely to be damaged if any foreign materials are allowed to enter the lubrication line. The filter does not keep the engine clean. This function is performed by the lubricating oil. The extremely small particles from cleaning of carbon and gum remain suspended in the oil and are able to pass freely through the minimum oil film thickness of about 6-7 micron at the bearings and are removed from the engine only when the oil is drained. The job of the filter is to remove from oil the abrasive particles that cause wear of the working surfaces. The size of abrasive particles to be removed is about 10 to 15 microns. Filters also prevent sludge deposit to pass to the bearings.

The filter arrangement may be of

By-pass type, or

Open system, and

Closed crankcase ventilation

In the open system a fresh air supply is induced into the crankcase with the help of breather. The air picks up the water vapour before it condenses md also the blowby gases and flows back to the atmosphere. The main disadvantage of the open system is that the ventilation is quite inadequate when it is most desired such as during idle running or running at low speed* The second disadvantage is increased air pollution.

ENGINE PERFORMANCE AND LUBRICATION

If the viscosity of the lubricating oil is too high, more work will be dissipated in shearing and pumping the oil which will result in:

Reduction in the torque and power of the engine.

Increase in fuel consumption up to 15 per cent.

On the other hand if the viscosity of the lubricating oil is too low, sealing of the piston rings and cylinder will be poor which will result in:

Increase in blowby with consequent increase in oxidation of the crankcase oil.

Increase in oil consumption

In automobiles the lowest viscosity oil (in the SAE 10-40) range whichgives satisfactory oil consumption should be used. Multi-grade oils are preferable.

The consumption of lubricating oil increases with increase in either speed or load since engine temperatures and pressures increase. The viscosity of the hotter oil is reduced and hence a greater quantity of oil passes the piston rings. This characteristic of the lube oil can be improved by increasing the viscosity index {i.e., *using a multigrade oil). However, at high speed, high temperature operation the volatility of the lubricating oil, as shown by its flash point, may control oil consumption.*

The other reasons of increased oil consumption are increased clearance of the connecting rod bearing with forced-feed oil system, oval cylinders, uneven wear from top to bottom of the cylinder, out-of-square grooves for the piston rings or plugged oil control rings. The oil should invariably be changed according to the recommendation of the manufacturer. The filter should also be changed with each oil *change.*