Ex. 1: A four stroke diesel engine has the following specifications :
Brake power = 5 kW ; Speed = 1200 r.p.m. ; Indicated mean effective pressure = 0.35 N / mm^2 Mechanical efficiency = 80 %.

Determine :

1. bore and length of the cylinder ;
2. thickness of the cylinder head ; and
3. size of studs for the cylinder head.

Ex. 2: Design a cast iron piston for a single acting four stroke engine for the following data:

Cylinder bore = 100 mm ; Stroke = 125 mm ;

Maximum gas pressure = 5 N/mm^2 ;

Indicated mean effective pressure = 0.75 N/mm^2

Mechanical efficiency = 80% ;

Fuel consumption = 0.15 kg per brake power per hour ;

Higher calorific value of fuel = 42×10^3 kJ/kg ;

Speed = 2000 r.p.m.

Any other data required for the design may be assumed.

EX. 3: Design a connecting rod for an I.C. engine running at 1800 r.p.m. and developing a maximum pressure of 3.15 N/mm^2. The diameter of the piston is 100 mm ; mass of the reciprocating parts per cylinder 2.25 kg; length of connecting rod 380 mm; stroke of piston 190 mm and compression ratio 6 : 1. Take a factor of safety of 6 for the design. Take length to diameter ratio for big end bearing as 1.3 and small end bearing as 2 and the corresponding bearing pressures as 10 N/mm^2 and 15 N/mm^2.

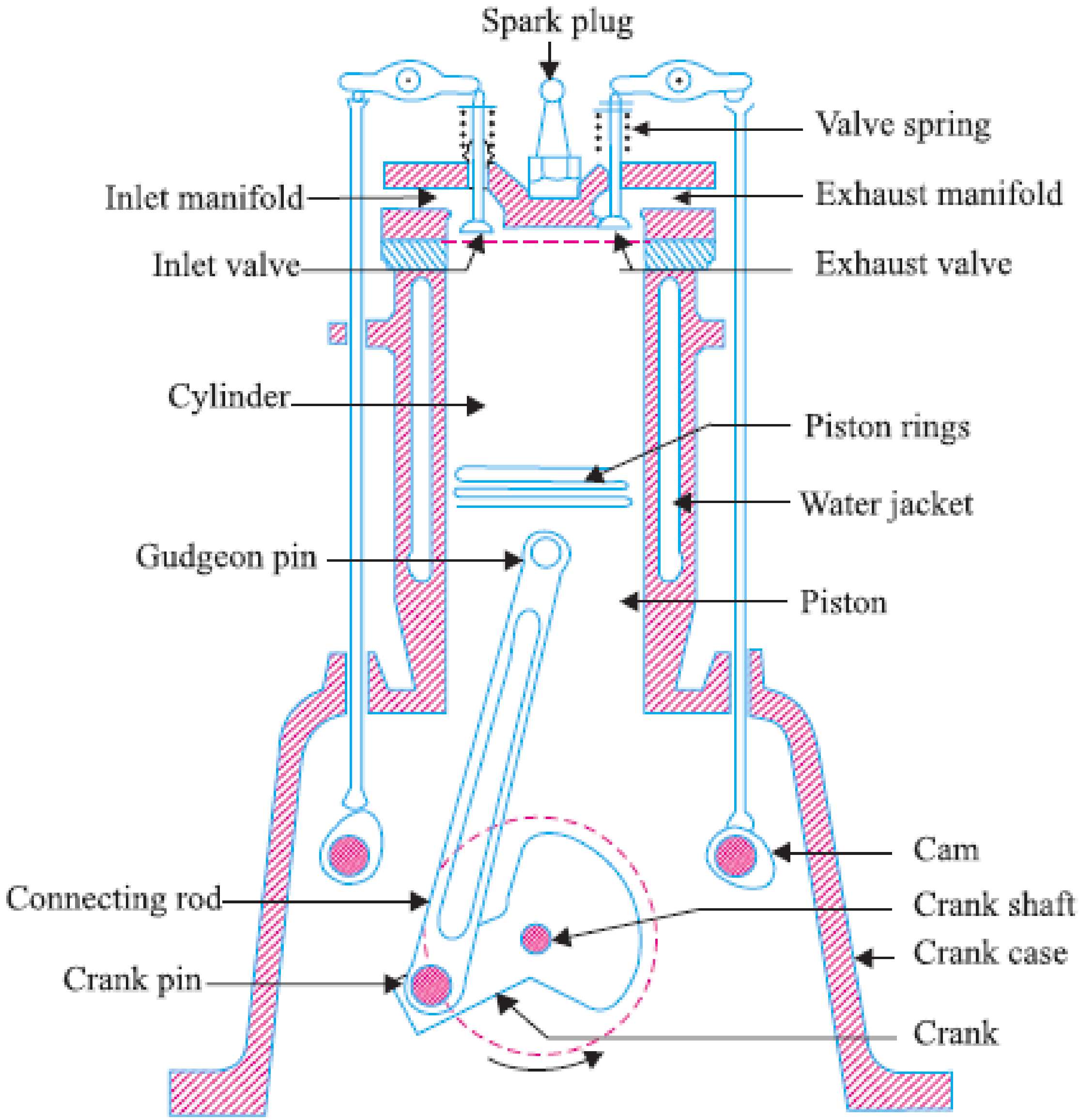
The density of material of the rod may be taken as 8000 kg/m^3 and the allowable stress in the bolts as 60 N/mm^2 and in cap as 80 N/mm^2.

The rod is to be of I-section for which you can choose your own proportions.

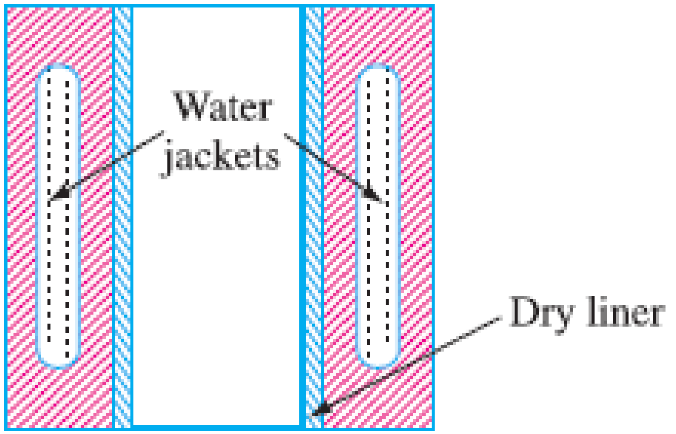
Draw a neat dimensioned sketch showing provision for lubrication. Use Rankine formula for which the numerator constant may be taken as 320 N/mm^2 and the denominator constant 1 / 7500.

I.C. Engine Part - 1

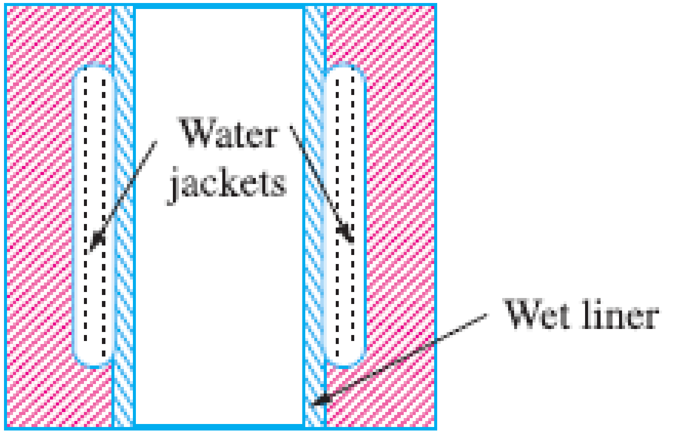
PRINCIPAL PARTS OF AN ENGINE



CYLINDER LINER



(*a*) Dry liner.

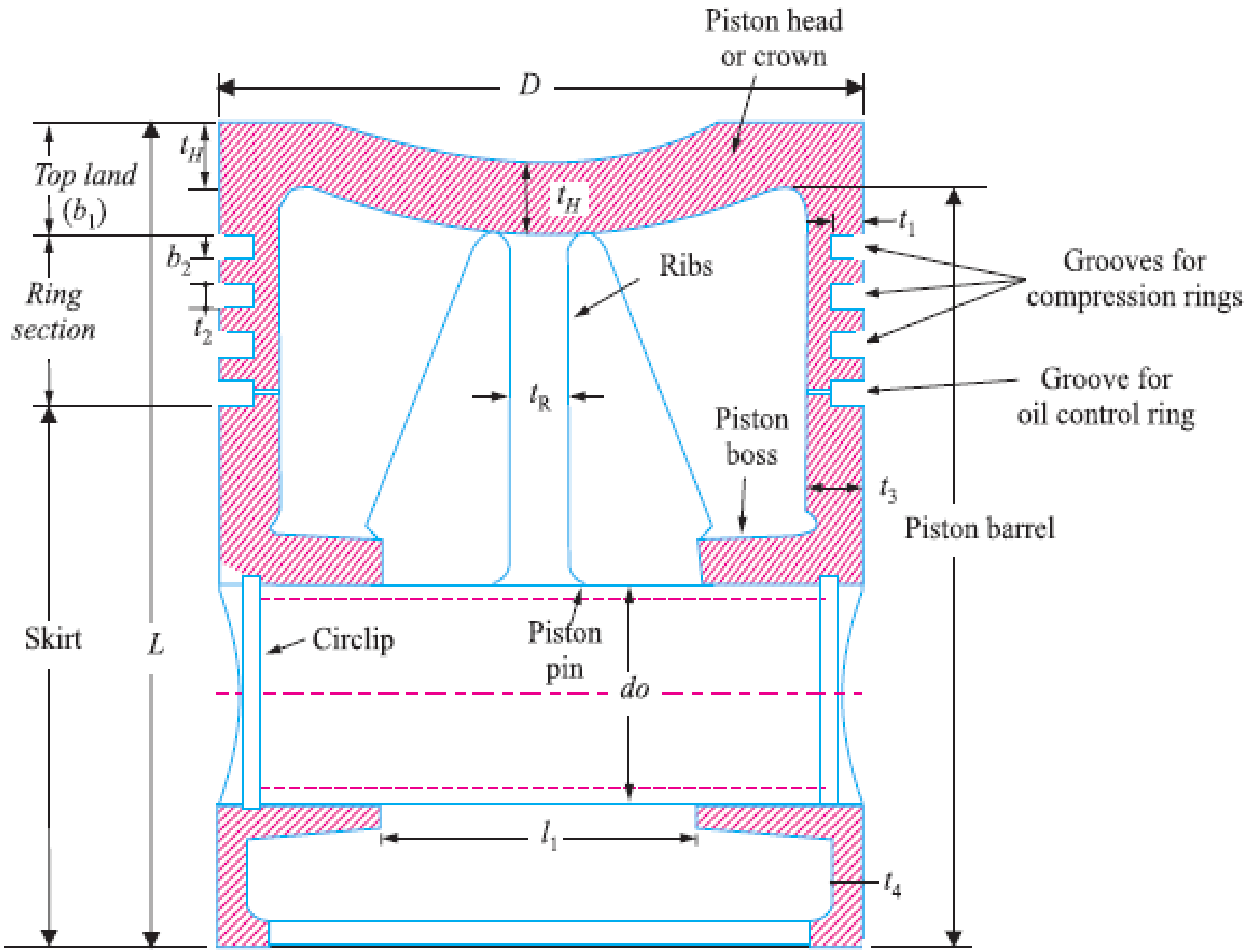


(*b*) Wet liner.

A cylinder liner which does not have any direct contact with the engine cooling water, is known as **dry liner, as shown in Fig.(a)**.

A cylinder liner which have its outer surface in direct contact with the engine cooling water, is known as **wet liner, as shown in Fig.(b).**

PISTON NOMENCLATURE

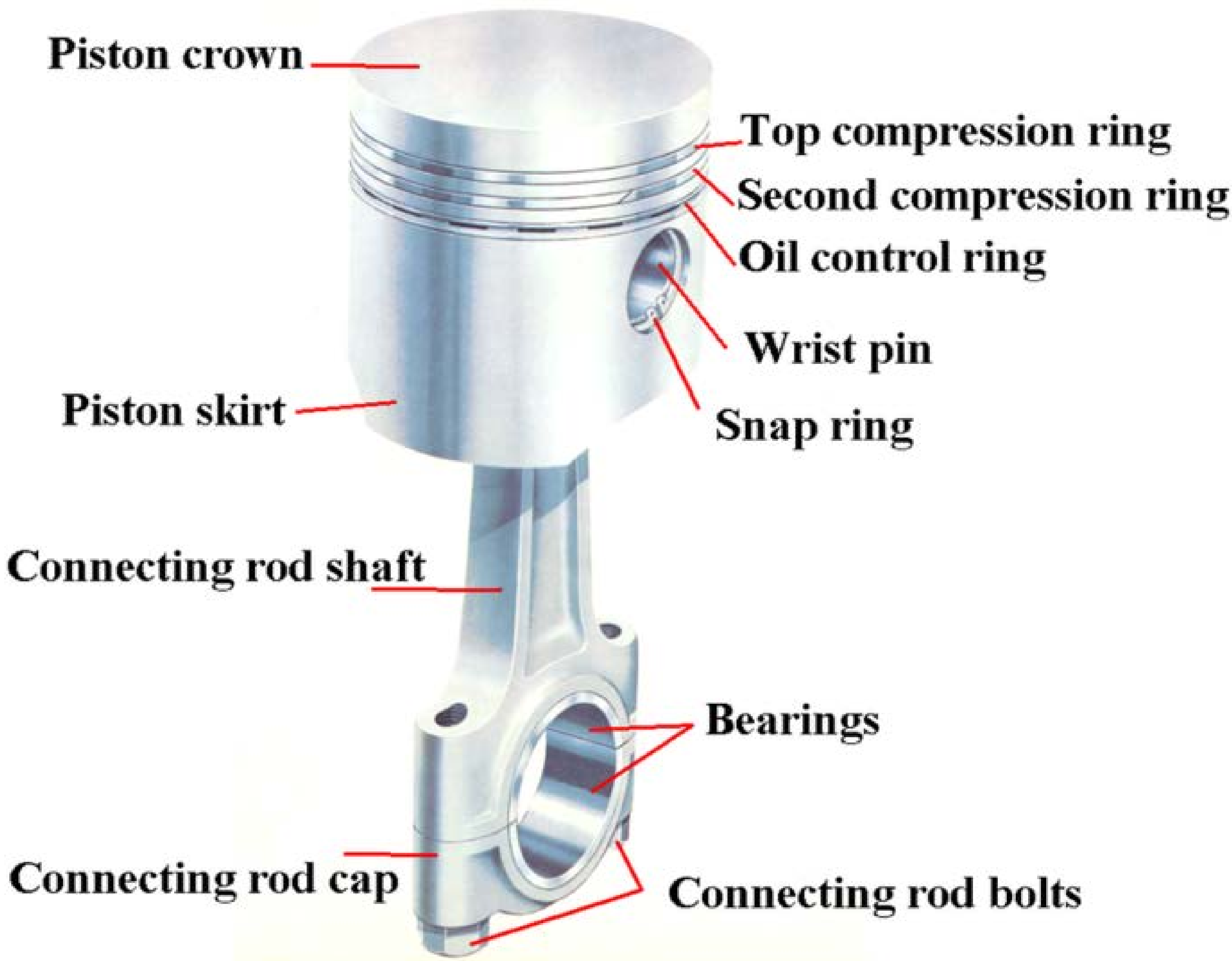


1. Head or crown. The piston head or crown may be flat, convex or concave depending upon the design of combustion chamber. It withstands the pressure of gas in the cylinder.

2. Piston rings. The piston rings are used to seal the cylinder in order to prevent leakage of the gas past the piston.

3. Skirt. The skirt acts as a bearing for the side thrust of the connecting rod on the walls of cylinder.

4. Piston pin. It is also called gudgeon pin or wrist pin. It is used to connect the piston to the connecting rod.


Piston crown
Top compression ring
Second compression ring
Oil control ring
Wrist pin
Piston skirt
Snap ring
Connecting rod shaft
Bearings
Connecting rod cap
Connecting rod bolts

DESIGN CONSIDERATIONS FOR A PISTON

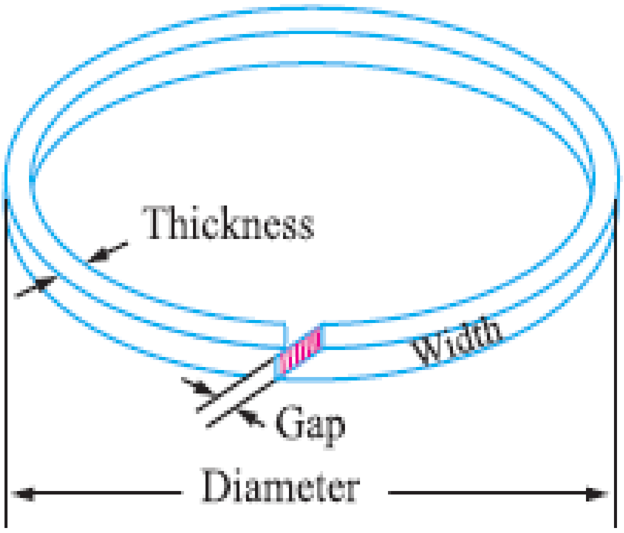
In designing a piston for I.C. engine, the following points should be taken into consideration :

1. It should have enormous strength to withstand the high gas pressure and inertia forces.
2. It should have minimum mass to minimise the inertia forces.
3. It should form an effective gas and oil sealing of the cylinder.
4. It should provide sufficient bearing area to prevent undue wear.
5. It should disprese the heat of combustion quickly to the cylinder walls.

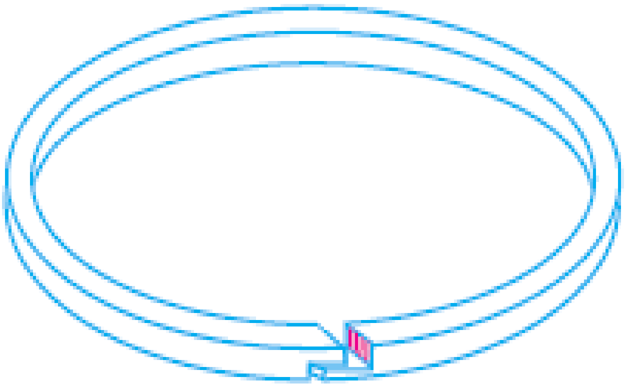
6. It should have high speed reciprocation without noise.
7. It should be of sufficient rigid construction to withstand thermal and mechanical distortion.
8. It should have sufficient support for the piston pin.

The most commonly used materials for pistons of I.C. engines are **cast iron, cast aluminium, forged aluminium, cast steel and forged steel**.

PISTON RINGS

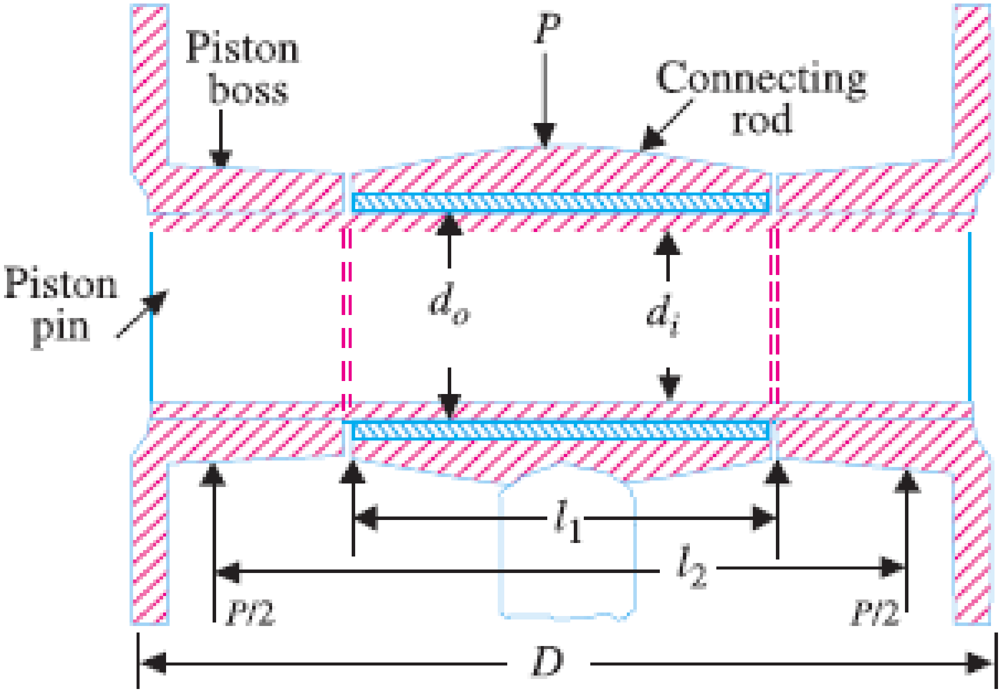


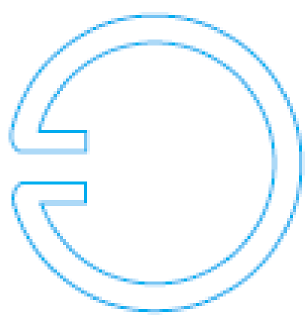
(a) Diagonal cut.



(b) Step cut.

PISTON PIN





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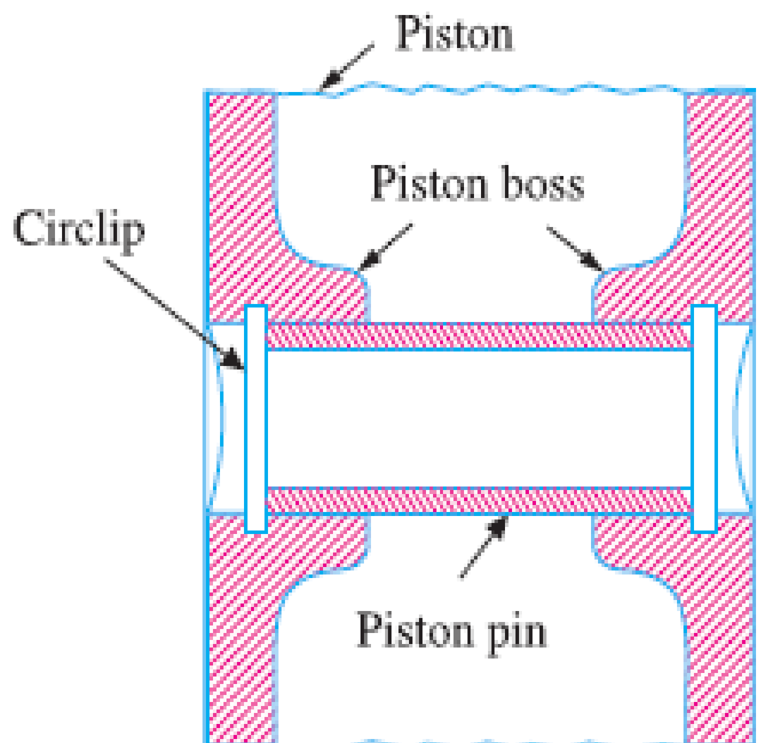

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Basic Terminology used for a Engine

BORE AND STROKE

The diameter of the cylinder is known as bore and the displacement of the piston, i.e. its travel from top dead centre (TDC) to bottom dead centre (BDC) is called stroke (Fig. 1). In old engines, the stroke was always greater than the bore but the recent trend is towards a shorter piston stroke. This is because in the short piston stroke, the less of power due to friction is minimized. Also, the inertia and centrifugal load on the bearings are reduced. In the square engine, which is the latest in technology, the bore and strokes are equal.

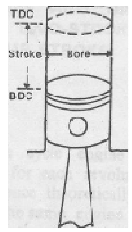

Fig. 1. Bore and stroke of a heat engine

PISTON DISPLACEMENT (SWEPT VOLUME)

This is the volume that the piston displaces during its movement from BDC to TDC (Fig. 2). Suppose *D* is the bore dia. and L is the stroke length. The piston displacement is given as $(\pi/4)\ D^2L$.

Example: For a four-cylinder engine with a 10 cm bore dia. and 8 cm stroke length, the piston displacement (v) will be = $(\pi/4)\ x\ 10^2\ x\ 8\ x\ 4= 2512cm^3$

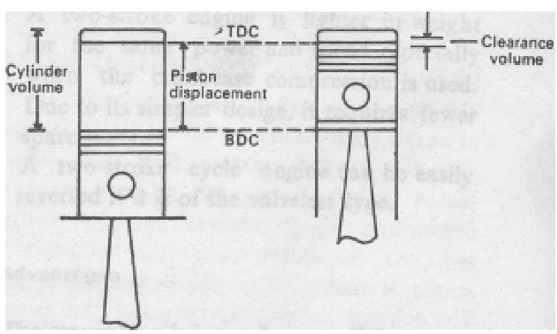

Fig. 2 Piston displacement and clearance volume

COMPRESSION RATIO

The compression ratio (CR) of an engine is a measure of how much the air/air-fuel mixture is compressed in the cylinder. It is the volume of air when the piston is at BDC divided by its volume of air when the piston is at TDC. The volume above the piston is called ***clearance volume.***

The CR of an engine is an important factor in its performance. By increasing only the compression ratio, the engine power increases, the other factors remaining unchanged.

HORSE POWER

Power is the rate at which work is done. The rate at which the engine can do work is measured in *horse power (HP).* One HP is equivalent to 4500 kg m per min. The various methods of defining horsepower are described below.

Indicated Horse Power

The amount of power that can be measured on the flywheel is always less than the power generated in the engine on account of expansion of the combusted fuel. The power that is actually developed in the cylinder is called *indicated horse power* and is given by:

$$IHP = \frac{PL\ A\ N}{4500}$$

where

P - means effective pressure in kg/cm^2

L - stroke length in m

A - area of cylinder in cm^2

N - power stroke per min (for a four stroke engine N = rpm/2 and for a two-stroke engine *N* = rpm)

Brake Horse Power

It is the horsepower available on the crankshaft and is measured by a suitable dynamometer**.**

SAE Horse Power (Taxable Horse Power)

The SAE (Society of Automotive Engineers) horse power rating is used to compare engines on a uniform basis, usually for tax purposes. The formula is

$$HP = \frac{D^2\ N}{2.5}$$

where

D - diameter of cylinder in inches

N- number of cylinders

Belt Horse Power

It is the power of the engine. measured at the end of a suitable belt, receiving drive from the PTO shaft of the tractor.

Power Take Off Horse Power

It is the power delivered by a tractor through its PTO shaft. In general the belt and PTO horse power of a tractor will approximately be the same and is measured by either a hydraulic or an electrical dynamometer.

Drawbar Horse Power

It is the power of a tractor measured at the end of the drawbar. It is that power which is available to pull loads.

Maximum Horse power and Net Horse power

The maximum HP is measured at the engine flywheel without any of the power consuming accessories being attached. This is not a practical rating as it does not represent "usable" HP.

Net HP is measured at the engine flywheel in the same manner as the maximum HP. The difference in the two is because the engine is equipped with accessories. Net HP is the basis for rating the HP of industrial and farm tractors.

Effect of Environment on Horse power.

HP is affected by barometric pressure and atmospheric temperature. Therefore, whatever actual horsepower is observed on the dynamometer is called the observed HP, whereas the corrected HP is the observed HP corrected to standard atmospheric conditions.

The standard operating conditions are:

1. Mean barometric pressure of 736 mm of mercury corresponding to an altitude of 300 m above mean sea level.
2. Water vapour pressure of 27.4 mm of mercury corresponding to a relative humidity of 65 per cent at 35°C.
3. Intake air temperature of 35°C.

For decreases in the atmospheric pressure, a deduction from the rated output of the engine shall be made at the rate of 1.4 per cent per 100 m of altitude above 300 m. This de-rating is valid up to an altitude of 2500 m.

Also, for any increase of the intake air temperature above 35°C, a further deduction shall be made at the rate of 0.25 per cent per ^{0}C.

MEAN EFFECTIVE PRESSURE

The mean effective pressure (MEP) is the average pressure during the power stroke, minus the average pressure during the other three strokes (Fig. 3). In fact, the MEP is the pressure that actually forces the piston down during the power stroke.

A- starting of suction stroke; B -start of compression; C-start of injection; D-start of combustion; E-peak firing pressure; F-start of exhaust; G-ignition delay

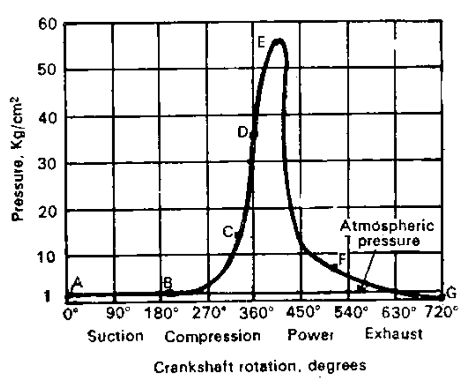

Fig. 3 Typical diesel engine pressure indicator diagram:

VOLUMETRIC EFFICIENCY

The amount of air entering the cylinder due to the vacuum created by the downward motion of the piston is always less than the actual displacement of the piston because of the constriction of the air intake system. Therefore, the actual air taken into the cylinder divided by the swept volume is known as volumetric efficiency.

TORQUE

Like power, torque is another important measure of engine performance. Any force applied on some point to cause a turning effect is called torque (T), mathematically represented by force (F) multiplied by the distance of force from the centre of shaft (r), i.e.

$$T = F \times r$$

In an engine, the piston applies a torque to the crankshaft through the connecting rod and crank when it is moving down on the power stroke. The amount of torque depends on the pressure exerted by the piston and the length of the crank arm. The greater the push on the piston, the greater the torque.

Torque should not be confused with power. Torque is the twisting effort that the engine applies through the crankshaft, whereas power is the rate at which the engine does work. The unit of torque is kg m.

RELATION OF HORSE POWER, SPEED AND TORQUE FOR ENGINES

An engine is capable of running faster than the speed at which it reaches maximum HP and HP decreases after reaching its maximum point. The reason for this is that an engine is designed to operate most efficiently up to a certain speed, depending upon its design.

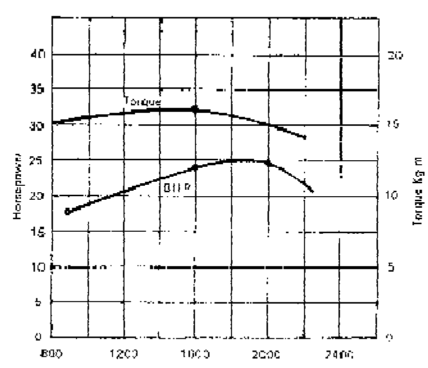

Fig. 4 Torque compared with BHP

The HP curve continues to rise as the engine speed increases until maximum power is attained. This is also true with the torque curve, but the torque curve will reach its maximum point much earlier. An engine develops more torque at intermediate speeds than at the maximum speed. This is because the volumetric efficiency is higher at intermediate speeds. Thus, there is a greater amount of air to burn during the power stroke. This results in higher combustion pressure and therefore, a greater torque is applied to the crankshaft. At higher speeds the volumetric efficiency and combustion pressure are both lower and thus, the torque is also lower.

In farm tractor engines, the rated operating speed may be as much as 800-1000 rpm higher than the peak torque rpm. As the rated operating speed is higher than the peak torque speed, it becomes possible for the engine to take advantage of the "torque reserve" when the engine is loaded with an unexpected increase in the torque due to overloads. The operating speed in such a state has a tendency to drop immediately. As the speed decreases towards the peak torque, the speed torque increases and enables the engine to overcome the overload, thus maintaining its power. If the overload is so great as to reduce the engine speed too below the peak torque speed, the engine will lose its capacity to carry the overload. The engine speed will in such a case continue to drop unless the load is reduced.

MEASUREMENT OF HORSE POWER

Dynamometers are used to measure the horse power. Dynamometers are classified as *brake, drawbar* or *torsion* according to the manner in which the work is applied. Also, they may be classed as *absorption* or *transmission,* depending on the nature of energy.