Module – 2
IC ENGINES

Lecture 9:

Objective: Introduction to IC engines and its classification.

Internal Combustion Engines

Introduction

Any machine, which converts heat energy into useful mechanical energy, is known as an engine. The machine may be a gas turbine, steam turbine or an engine.

All the engines come under two classifications, they are-

i) Internal combustion engines, and
ii) External combustion engines

(i) Internal combustion engine:

If the combustion of fuel takes place in a cylinder and the heat is converted into mechanical work, it is known as internal combustion engine, e.g. Engines of moped, scooter, bikes, cars, bus, trucks etc;

(ii) External combustion engine:

If the combustion of fuel takes place in a combustion chamber and the heat energy is taken to a machine through pipe line there the heat energy is converted in to mechanical energy is known as external combustion engines. Ex, gas turbine and steam engine.

Classification of internal combustion engines

Internal combustion engines are classified-

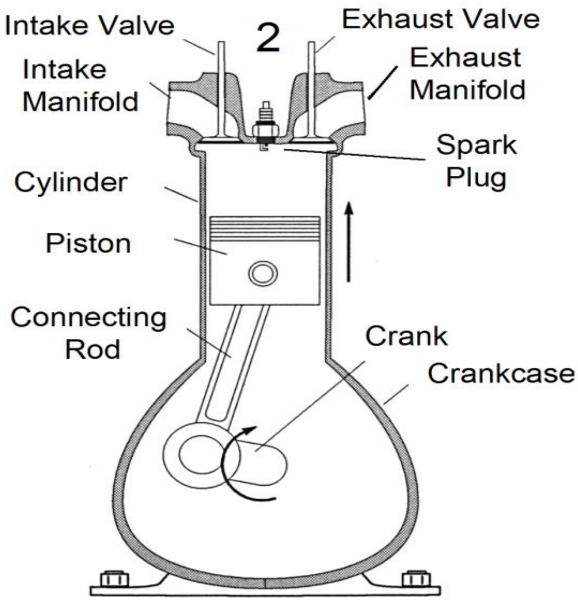
1) According to thermodynamic cycle
   i) Otto cycle ii) Diesel cycle iii) Dual combustion cycle
2) According to number of strokes
   i) Two stroke ii) Four stroke
3) According to number of cylinders
   i) Single cylinder engine ii) Multi cylinder engine
4) According to method of ignition
   i) Spark ignition (petrol, gas engine)
   ii) Compression ignition (diesel, vegetable oil)
5) According to type of fuel used
   i) Petrolii) Diesel iii) Gas
   iv) Bio fuel (peanut oil, sunflower oil, linseed oil)
6) According to position of cylinder
   i) Horizontal engine (hero Honda)
   ii) Vertical engine (car, bus, truck engines)
   iii) Vee engine
   iv) Radial engine (old aeroplane engine)
   v) Opposed cylinder engine
7) According to method of cooling

i) Air cooling ii) Water cooling iii) Liquid cooling

8) According to speed of engine

i) Slow speed engine ii) Medium speed engine iii) High speed engine

Parts of an internal combustion engine



Parts of an IC Engine

Cylinder: (cylinder block) Cylinder is the main part of an engine. The combustion takes place in the combustion chamber and these gases exert pressure on the piston, due to high gas pressures the piston reciprocates in the cylinder block. The cylinder is designed to with stand high gas pressure. The temperature in the combustion chamber (cylinder block) will reach up to 2800^0 C. The cylinder has to be cooled properly either by air-cooling or water-cooling. In case of air cooled engines fins are provided around the cylinder block (Scooter and bikes); in water-cooled engines water jackets are provided for the circulation of water to carry away the heat around the cylinder block. The cylinder block material is aluminium alloy.

Head: (cylinder head) The head is fitted on the top of the cylinder block. In two stroke engines only spark plug is fitted in the cylinder head. In four stroke engine inlet valve, exhaust valve and spark-plug are fitted in the cylinder head. - The head is built with two ports, one port, which allows the charge in to the cylinder block, is known as inlet port and the second port that allows the exhaust gases to leave the cylinder block is known as exhaust port. In case of petrol engine spark plug is fitted in the head, in diesel engines fuel injector is fitted to inject the diesel into the cylinder block. The cylinder head material is aluminum alloy.

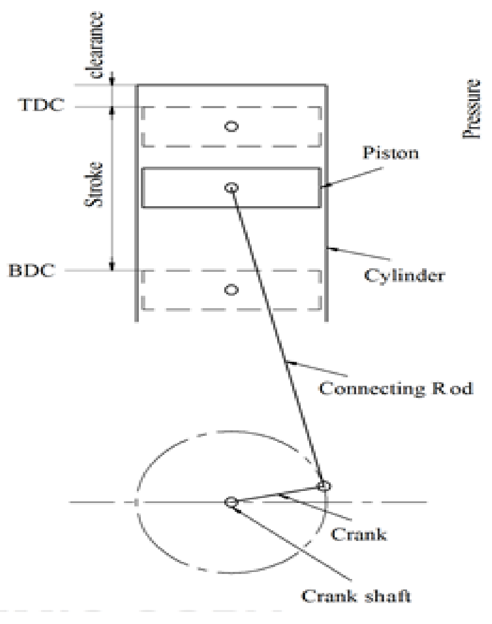
Piston: The piston is a cylindrical plug, which converts heat energy in to mechanical energy. A two-stroke piston is fitted with only compression ring. In four-stroke engine both compression ring and oil control rings are fitted. The piston is connecting to the small end of the connecting rod. The piston is made of aluminum alloy. Functions of piston are:

i) The piston acts as a seal.
ii) To provide the passage for heat flow from piston to cylinder block through rings.
iii) It transmits the force of explosion to the crankshaft through connecting rod.

Connecting rod: The small end of the connecting rod is connected to the piston and the big end of the connecting rod is connecting to the crankshaft. The connecting rod converts the reciprocating motion of piston in to rotary motion of crankshaft. The connecting rod is made of I-beam cross section to provide maximum rigidity with minimum weight.

Crankshaft: The big end of the connecting rod is connected to the crankshaft. The power transmission starts from the crankshaft. The crankshaft is rigidly fixed in the crankcase. The other end of the crankshaft is connected to a clutch. IC-Engine parts

Crankcase: Crankcase is fitted at the bottom of the cylinder block. Two-stroke engine crankcase is properly sealed and made airtight. Four-stroke engine crankcase will serve as a reservoir, filled with sufficient quantity of lubricating oil. This oil lubricates the main bearings of crankshaft, big end bearings of connecting rod, lubricates the cylinder liner, piston and piston rings.



IC Engine Terminology

Top dead center (TDC): The top most position of the piston at the cover end is known as top dead center.

Bottom dead center (BDC): The lower most position of the piston at the crank end is known as bottom dead center.

Stroke length (l): Rotate the crankshaft slowly, the piston starts moving slowly towards the top dead center, Further rotation of crank shaft moves the piston towards the top and suddenly it changes its direction (it starts moving in down ward direction), The momentary stopping of the piston indicates the position of TDC.

Rotate the crankshaft further; the piston starts moving in down ward direction, this movement continues till the piston reaches the bottom dead center. Here also the piston reaches the Bottom and suddenly it changes its direction, the point at which it stops is known as BDC.

Clearance volume

When the piston is at TDC position the cylinder volume above it, it is known as clearance volume and it is denoted by V_c

Swept volume

The volume swept by piston while traveling from TDC to BDC in known as swept volume and is denoted by V_s.

$$V_s = \quad (\pi\, d^2 / 4)\, l \quad cm^3$$

Compression ratio:

It is the ratio of total volume of cylinder ($V_s.+V_c$) to the clearance volume (V_c). it is denoted ' r'.

$$r = (V_s.+V_c) / \; V_c$$

The compression ratio of petrol engine varies from 7 to 10.

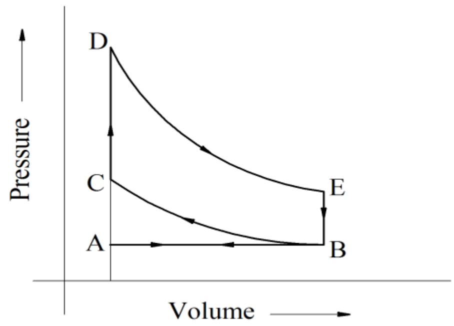
The compression ratio of diesel engine varies from 15 to 24.

Lecture 10:

Objective: discussion about 4 stroke petrol and diesel engine.

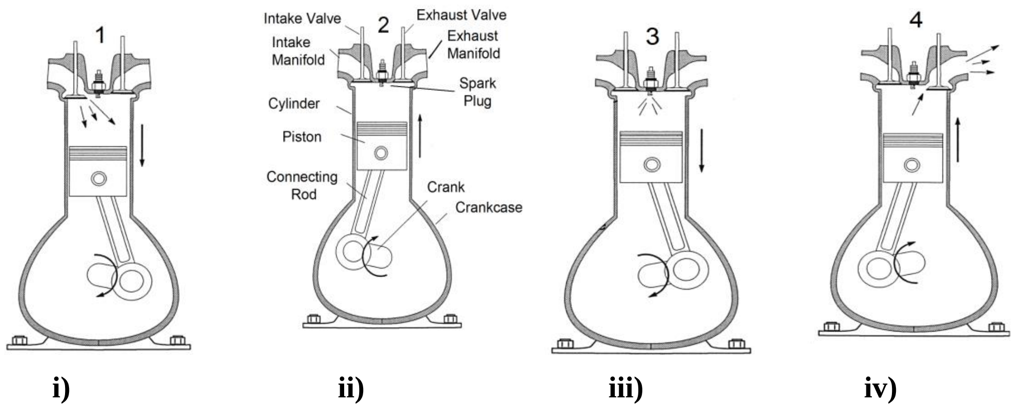
Four stroke petrol engine

The four-stroke petrol engine works on the principle of Otto (constant volume) cycle. The parts of four-stroke petrol engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, spark plug, and inlet and exhaust valve. The four-stroke petrol engine may be air-cooled or water-cooled. The piston performs four strokes to complete one cycle. The four different strokes are i) Suction stroke ii) Compression stroke iii) Power or Expansion stroke iv)Exhaust stroke.



Otto cycle

(i) Suction stroke: Rotation of the crankshaft from 0^o to 180^o completes the suction stroke. During suction stroke the inlet valve opens and exhaust valve are closed. When the piston starts moving from TDC to BDC, the volume above the piston increases, resulting in a decrease in pressure (vacuum). This decrease in pressure draws the petrol and air mixture from the carburetor to the cylinder. This process continues till the pressure inside the cylinder becomes equal to that of the atmosphere. At the end of suction stroke the cylinder is completely filled with petrol and air mixture. At the end of suction stroke the inlet valve is closed. The line AB on the PV diagram represents suction stroke (volume of mixture filled in the cylinder).



Four-stroke petrol engine.

(ii) Compression stroke: Rotation of crankshaft from 180^0 to 360^0 completes the compression stroke. During compression stroke both inlet and exhaust valves are closed. In this stroke the piston travels from BDC to TDC. When the piston starts moving from BDC to

TDC the mixture is compressed, and the pressure increases in the cylinder. The line BC represents the compression stroke.

At or before the end of the compression stroke, a spark occurs. This spark ignites the petrol and air mixture. The combustion of mixture releases hot gases, which increase pressure at constant volume. The line CD represents increase in the pressure at constant volume.

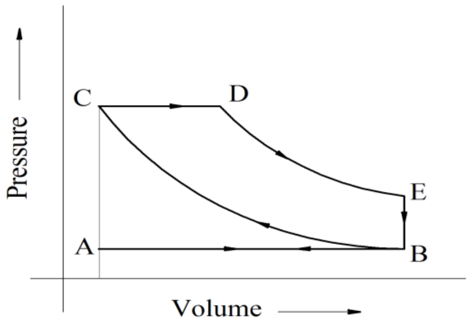
(iii) Power stroke: Rotation of crankshaft from 360^0 to 540^0 completes the power stroke. During power stroke (expansion stroke) both inlet valve and exhaust valve are closed. The high-pressure gases produced due to combustion, exert pressure on the top face of the piston, the piston moves rapidly in the downward direction and performs power stroke.

(iv)Exhaust stroke: Rotation of crankshaft from 540^0 to 720^0 completes the exhaust stroke. At the beginning of exhaust stroke, the exhaust valve is opened, and the upward movement of the piston pushes the exhaust gases out of the cylinder. At the end of the exhaust stroke the exhaust valve is closed.

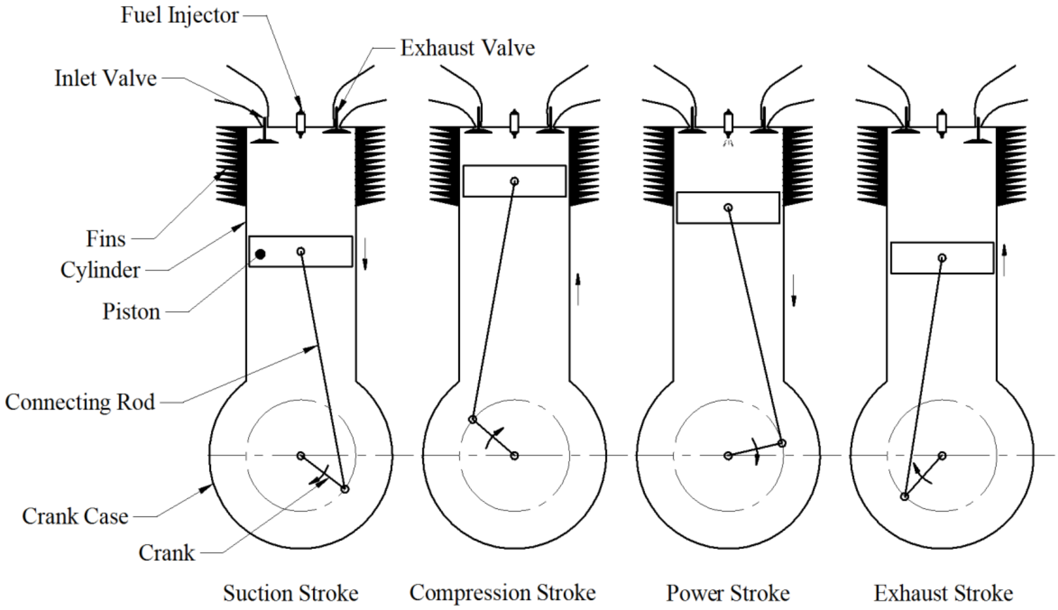
Thus one cycle is completed during rotation of the crankshaft from 0^o to 720^o.

Four stroke diesel engine

The four-stroke diesel engine works on the principle of diesel (constant pressure) cycle. The parts of four-stroke diesel engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, and fuel injector, inlet and exhaust valve. The four-stroke diesel engine may be air-cooled or water-cooled. The piston performs four strokes to complete one cycle. The four different strokes are i) Suction stroke ii) Compression stroke iii) Power or Expansion stroke iv) Exhaust stroke.



Diesel cycle



Four-stroke diesel engine.

i) Suction stroke: Rotation of the crankshaft from 0^o to 180^o completes the suction stroke. During suction stroke the inlet valve is opened and exhaust valve is kept closed. When the piston starts moving from TDC to BDC, the volume above the piston increases, resulting in decrease in pressure (vacuum), this decrease in pressure draws the air from atmosphere and fills the air into the cylinder. This process continues till the pressure inside the cylinder becomes equal to that of the atmosphere. At the end of suction stroke the cylinder is completely filled with air and the inlet valve is closed. The line AB in the PV diagram represents suction stroke (Volume of air filled in the cylinder).

ii) Compression stroke: Rotation of crankshaft from 180^o to 360^o completes the compression stroke. During compression stroke both inlet and exhaust valves are closed. In this stroke the piston travels from BDC to TDC. When the piston starts moving from BDC to TDC the air is compressed; both pressure and temperature of the air increases. At the end of the compression stroke the temperature of the air reaches the ignition temperature of diesel. The line BC represents the compression stroke.

Before the end of the compression stroke, the fuel injector starts injecting the diesel in to the combustion chamber. The heat of the compressed air burns the injected diesel. The combustion takes place at constant pressure. The line CD represents increase in the volume at constant pressure.

iii) Power stroke: Rotation of crankshaft from 360^o to 540^o completes the power stroke. During power stroke (expansion stroke) both inlet valve and exhaust valve are closed. The high-pressure gases produced during combustion, exert pressure on the top face of the piston, and the piston moves rapidly in the downward direction performing power stroke. The energy is supplied to the flywheel during power stroke. This energy propels the vehicle .

iv) Exhaust stroke: Rotation of crankshaft from 540^o to 720^o completes the exhaust stroke. At the beginning of exhaust stroke, the exhaust valve is opened, and the upward movement of the piston pushes the exhaust gases out of the cylinder. At the end of the exhaust stroke the exhaust valve is closed.

Thus one cycle is completed during rotation of the crankshaft from 0^o to 720^o, i.e., two revolutions of the crankshaft.

Lecture 11:

Objective: discussion about 2 stroke petrol and comparision of IC engines.

Two stroke petrol engine.

The parts of two-stroke petrol engine are

Cylinder: The cylinder liner is made in the form of barrel (hollow cylinder). The head is connected at the top of the cylinder. A crankcase is connected at the bottom of the cylinder. The cylinder liner is provided with cooling fins for cooling purpose; an exhaust port is located opposite to the transfer port. One end of the transfer port is connected to the cylinder and the other end is connected to the crankcase through which the charge enters.

Head: A spark plug is fitted at the top of the head. Fins are provided in the head for cooling purpose.

Crankcase: The crankcase is fitted at the bottom of the cylinder. An inlet port is provided in the crankcase to allow the charge from carburetor to the crankcase, another port is known as transfer port, which transfers the charge from transfer port to the cylinder. The crankcase of two-stroke engine should be an airtight chamber, which prevents the leakage of air in or out of the cylinder.

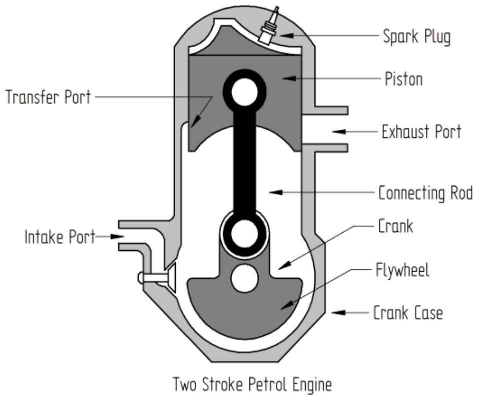
Piston: the movement of the piston in the cylinder does the opening and blocking of the ports. The piston is fitted with only compression rings (2 or 3 rings)

The two-stroke petrol engine works on the principle of Otto cycle. The parts of two-stroke petrol engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, spark plug, inlet port, transfer port and exhaust port. The piston performs two strokes to complete one cycle. The two strokes are i) First stroke or down ward, ii) Second stroke or upward stroke.

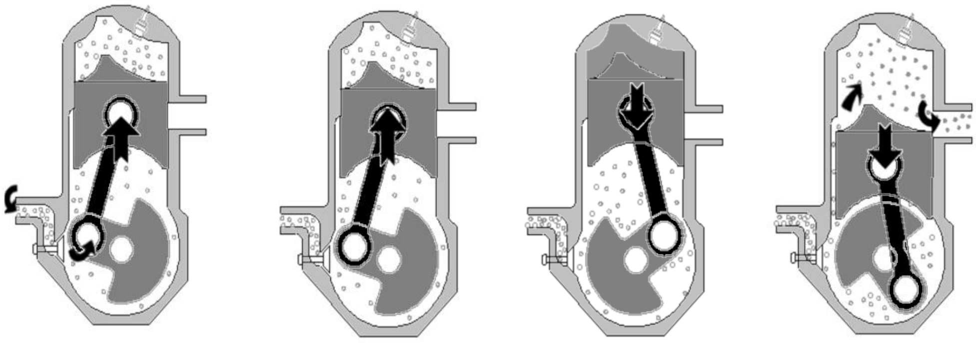
Upward stroke or working stroke: In two-stroke petrol engine some charge is present either in the cylinder block or in the crankcase. To start a two-stroke engine, power is supplied either by using a kicker or by electric start.

During upward stroke, the piston reciprocates from top dead center to bottom dead center. As the piston moves upward; volume below the piston increases and results in decrease in pressure in the crankcase. Due to pressure difference charge (petrol & air) is drawn from the carburetor. As the piston moves further upwards covers both exhaust and transfer port, now the charge is subjected to compression. Before the end of the compression stroke the spark (crank angle 20^{o} before TDC) occurs in the combustion chamber. Due to combustion of charge, the pressure increase, which pushes the piston downwards i.e. the working stroke of the piston? As the piston moves rapidly in the down ward direction compresses the charge present in the crankcase.

Down ward stroke or exhaust stroke: As the piston moves further down wards, first it uncovers the exhaust port. Due to pressure difference the high-pressure gases leaves the combustion chamber. As the piston moves further down wards, it uncovers transfer port, which allows the compressed charge in the crankcase to the cylinder. The fresh charge is deflected upwards by the deflector provided on the top of the piston and pushes the remaining exhaust gases present in the cylinder. The process of removal of exhaust gases from the cylinder is known as scavenging.



Two-stroke petrol engine



Working of two-stroke petrol engine

Difference between petrol and diesel engine.

SI. No	Petrol Engine (SI Engine)	Diesel Engine (CI Engine)
1	Draws a mixture of petrol and air during suction stroke.	Draws only air during suction stroke.
2	The carburetor is employed to mix air and petrol in the required proportion and to supply it to the engine during suction stroke.	The injector is employed to inject thefuel at the end of compression stroke.
3	Compression ratio ranges from 7: 1 to 12: I	Compression ratio ranges from 18:1 to 22:01
4	The charge (Le petrol and air mixture) is ignited with the help of spark plug. This type of ignition is called spark ignition.	The ignition of the diesel is accomplished by the compressed air which will have been heated due to high compression ratio, to the temperature higher than the ignition Temperature of the diesel. This type of Ignition is called compression ignition.
5	The combustion of fuel takes place Approximately at constant volume.	The combustion of fuel takes place Approximately at constant pressure.
6	Works on theoretical Otto Cycle.	Works on theoretical Diesel Cycle.
7	Power developed is less.	Power developed is more.
8	Thermal efficiency is low. It is up to about 26%	Thermal efficiency is high. It is up to about 40%.
9	These are high speed engines	These are low speed engines.
10	The maintenance cost is less.	The maintenance cost is more.
11	The running cost is high because of the higher cost of petrol.	The running cost is low because of lower cost of diesel

12	Lighter and cheaper because of low compression ratio	Heavier and costlier because of high Compression ratio.

Difference between two stroke and four stroke engines.

SI.No	2-Stroke Engine	4-Stroke Engine
1	Requires two separate strokes to complete one cycle of operation.	Requires four separate strokes to complete one cycle of operation.
2	Power is developed in every revolution of the crankshaft	Power is developed for every revolutions of the crankshaft.
3	The inlet, transfer and exhaust ports are opened and closed by the movement of piston itself.	The inlet and exhaust are opened and closed by the valves.
4	Turing moment is not uniform and hence requires a heavier flywheel.	Turing moment is uniform and hence Requires lighter flywheel.
5	The charge is first admitted into the crankcase and then transferred to the engine cylinder.	The charge is directly admitted in to the engine cylinder during the suction stroke.
6	For the same power developed the engine is heavy and bulky.	F or the same power developed the Engine is light and compact.
7	Thermal efficiency is low.	Thermal efficiency is high.
8	Requires greater lubricant and coolant.	Requires lesser lubricant and coolant.
9	Fuel consumption is more.	Fuel consumption is less.
10	Initial cost is less.	Initial cost is more.

Lecture 12:

Objective: discussion about efficiency of working of IC engines.

Calculations in internal combustion engines

i) **Mean effective pressure (p_m)**: It is defined as the average pressure acting on the piston during the expansion stroke which does the same amount of work as the varying pressure in one cycle.

p_m = Mean effective pressure **N / m²**

ii**) Indicated power (IP)**: The power developed within the piston –cylinder arrangement by the combustion of fuel is known as the indicated power. The pressure acting on the piston varies throughout the working cycle. To record the variation of pressure for one cycle of operation, a device called *piston indicator* is mounted by drilling a small hole on the cylinder cover. It mainly consists of a small plunger and a cylinder. The plunger displacement is proportional to the pressure acting on it from one side against the spring force on the other side. The movement of the plunger is transmitted to a stylus through linkages. The stylus traces out a graph on a recording drum, which rotates at a constant speed. The graph thus obtained is called the indicator diagram. The area of the indicator diagram is proportional to the work done in a cycle.

Mean effective pressure (p_m):

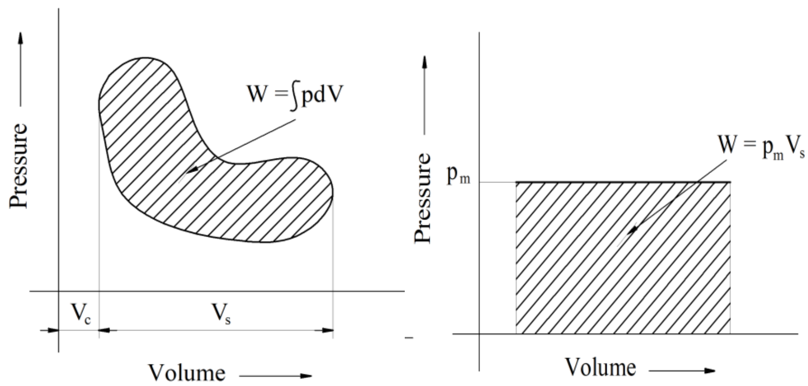
The work done on the piston for one cycle of operation is given by

$W = \int pdV$,

Where the integration is carried out for one cycle,

p is the pressure,

V is the volume.



(a) Indicator diagram. (b)Mean effective pressure.

The right hand side of the equation is nothing but the area within the loop on the pressure-volume diagram.

The mean effective pressure is defined as the equivalent constant pressure which has to be acting on the piston during the expansion stroke, to give the same work output as the varying pressure, in one cycle.

From the indicator diagram, the mean effective pressure can be calculated as,

$p_m = s.a/l.$

where,

s = spring constant of the spring used in the piston indicator,
l = length of the indicator diagram,
a = area of the indicator diagram.

Note that, spring constant is the pressure required to cause unit deflection of the spring.

When p_m is expressed in **N/ m²**

$$IP = \frac{p_m L A n}{60 \times 1000} \ \mathbf{kW}$$

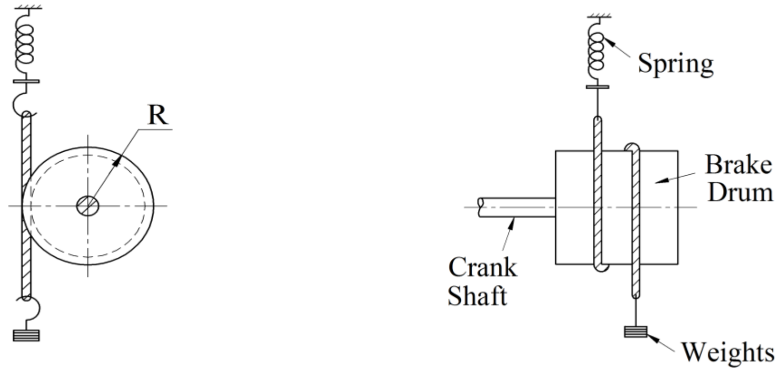
When p_m is expressed in **bar**

$$IP = \frac{100\, p_m L A n}{60} \ \mathbf{kW}$$

Where,

p_m = mean effective pressure,
L = stroke length,
A = area of cross-section of the piston,
n = number of cycles per minute,
= $N/2$ for a four stroke engine,
= N for a two stroke engine.
N = crank shaft speed, rpm

iii) **Brake power (BP)**: The power available at the crank shaft is always less than the power developed within the piston-cylinder arrangement because of frictional losses in the moving parts. The power actually available at the crankshaft is called the brake power. It can be measured using *dynamometers.* One such dynamometer is the *brake-drum* dynamometer.



Brake-drum dynamometer

It consists of a drum, which is mounted on the crankshaft. A rope is wound on the drum. One end of the rope is connected to a spring balance, and the other end, to a weight-loading device.

The torque on the brake drum is given by,

$$T = (W - S) \times R$$

Where,

W = weight on the rope, N.
S = spring balance reading, N.
R = mean radius of brake drum, m.

Brake power is given by,

$$BP = \frac{2\pi N T}{60 \times 1000} \quad \textbf{kW}$$

iv) Frictional power: The difference between indicated power and brake power is known as frictional power

$$FP = IP - BP \quad \textbf{kW}$$

v) Mechanical efficiency: It is defined as the ratio of brake power to indicated power

$$\eta_{mech} = \frac{\text{Brake power}}{\text{Indicated power}}$$

vi) Thermal efficiency: In IC engines, energy is supplied to the engine by burning fuel. But all of the energy that is supplied is not converted into useful mechanical work. Some of the energy supplied is lost through hot exhaust gases, some due to the cooling of the engine and some through radiation and convection heat losses. The fraction of the energy supplied that is available as useful work determines the thermal efficiency of the engine. The thermal efficiency can be calculated either for the indicated power, or for the brake power. Accordingly they are referred to as indicated thermal efficiency, and brake thermal efficiency.

Heat supplied to the engine per sec = mass of fuel burnt x calorific value.

$$\eta_{\text{indicated thermal}} = \frac{\text{Indicated power}}{m_f \times CV}$$

$$\eta_{\text{brake thermal}} = \frac{\text{Brake power}}{m_f \times CV}$$

Where,

m_f = Mass of fuel used in **kg / sec**.
CV = Calorific value of fuel **kJ / kg**

vii) Specific fuel consumption (SFC):

It is the mass of fuel supplied per hour in order to get unit power output.

$$SFC = \frac{m_f}{\text{Power}} \text{ kg/kW-hr}$$

SFC can be calculated on indicated power basis or on brake power basis.

Lecture 13:

Objective: Solving numerical on IC engines**.**

Problem 1: The following observations were recorded during a test on a 4-stroke engine. Bore = 25cm, stroke=40cm, crank speed=250 rpm, net load on the brake drum=700N, diameter of brake drum=2m, indicated mean effective pressure=6bar, fuel consumption = 0.0013kg/s, specific gravity of fuel=0.78, calorific value of fuel=43900kJ/kg. Determine (i) BP, (ii) IP, (iii) FP, and (iv) mechanical efficiency (v) indicated and brake thermal efficiency. (VTU Jan 2003)

Given : d = 250 mm = 0.25 m
L = 400 mm = 0.4 m
N = 250 rpm, $n = N/2$ for a 4 stroke engine = 250/2 = 125 cycles/min
$(W - s)$ = 700 N
D = 2 m
p_m = 6 bar = 600 kPa
m_f = 0.0013 kg/sec
Specific gravity = 0.78
CV= 43900 kJ/kg.

Solution:

i) Brake power (BP)

$$BP = \frac{2\pi N T}{60} \text{ kW}$$

$T = (W - S)\,R$ = 700 x 2/2 = 700 N-m.

$$BP = \frac{2\pi N T}{60}$$

$$BP = \frac{2\pi \times 250 \times 700}{} = 18.32 \text{ kW}$$

60 x 1000

ii) Indicated power (IP)

$$IP = \frac{ip_m\, LAn}{60} \text{ kW}$$

i = Number of cylinders

$$A = \frac{\pi\, d^2}{4} = \frac{\pi \text{ x } (0.25)^2}{4} = 0.049\text{m}^2$$

$$IP = \frac{1 \text{ x } 600 \text{ x } 0.4 \text{ x } 0.049\text{x } 125}{60} = 24.54 \text{ kW}$$

iii) Frictional power (FP)

FP = IP – BP

FP = 24.54-18.32 = 6.22 kW

iv) Mechanical efficiency

$$\eta_{mech} = \frac{BP}{IP} = \frac{18.32}{24.54} = 0.7465 \text{ or } 74.65\%$$

v) Indicated thermal efficiency

$$\eta_{ind\ thermal} = \frac{IP}{m_f \text{ x } CV} = \frac{24.54}{0.0013\text{x}43900} = 0.4299 \text{ or } 42.99\%$$

vi) Brake thermal efficiency

$$\eta_{brake\ thermal} = \frac{BP}{m_f \text{ x } CV} = \frac{18.32}{0.0013\text{x}43900} = 0.321 \text{ or } 32.1\%$$

Problem 2: The following are the details of a 4-stroke petrol engine. (i) diameter of brake drum=60.03cm, (ii) full brake load on drum=250N, (iii) brake drum speed = 450 rpm, (iv) calorific value of petrol = 40MJ/kg, (v) brake thermal efficiency=32%, (vi) mechanical efficiency=80%, specific gravity of petrol=0.82. Determine – (i) brake power, (ii) indicated power, (iii) fuel consumption in liter per second, and (iv) indicated thermal efficiency.

(VTU -JAN 2004)

Given data: N = 450 rpm $n = N/2$ for a 4 stroke engine = 450/2 = 225 cycles/min

$(W – s)$ = 2500 N

D = 600.3 mm = 0.6003 m.

Specific gravity of petrol = 0. 82 Density, ρ = 0.82 x 1000 kg/ m^3

CV= 40 MJ/ kg = 40 x 10^3 KJ/Kg.

$\eta_{brake\ thermal} = 0.32$

$\eta_{mech} = 0.8$

Solution: i) Brake power (BP)

$$T = (W\text{-}S) / R = 250 \times (0.6006 / 2) = 75.03 \text{ N-m.}$$

$$BP = \frac{2\pi N T}{60}$$

$$BP = \frac{2\pi \times 450 \times 75.03}{60 \times 1000} = 3.536 \text{ kW}$$

ii) Indicated power (IP)

$$\eta_{mech} = \frac{BP}{IP} \qquad IP = \frac{BP}{\eta_{mech}} = \frac{3.536}{0.8} = 4.42 \text{ kW}$$

iii) Indicated thermal efficiency

$$\eta_{mech} = \frac{\eta_{brake\ thermal}}{\eta_{ind\ thermal}}$$

$\eta_{ind\ thermal} = 0.32 / 0.8 = 0.4$ 0r 40 %

iv) Fuel consumption

$$\eta_{brake\ thermal} = \frac{BP}{m_f \times CV}$$

$$m_f = \frac{BP}{\eta_{brake\ thermal} \times CV} = \frac{3.536}{0.32 \times 40 \times 10^3} = 0.2762 \times 10^{-3} \text{ kg / sec}$$

Mass = Volume x density

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{0.2762 \times 10^{-3}}{0.82} = 0.3368 \times 10^{-3} \text{ m}^3/\text{s} = 0.3368 \text{ lt / sec.}$$

Problem 3: A four-cylinder two-stroke petrol engine develops 30kW at 2500 rpm. The mean effective pressure on each piston is 8bar, and mechanical efficiency is 80%. Calculate the diameter and stroke of each cylinder, stroke to bore ratio is 1.5. Also calculate the fuel consumption if brake thermal efficiency is 28%. The calorific value of fuel is 43900 kJ/kg. (VTU – Feb 2005)

Given data: i = 4 cylinders
BP = 30 kW
N = 2500 rpm, for a 2 stroke engine $n = N$ = 2500 cycles /min
p_m = 6 bar = 600 kPa
CV = 43900 kJ/kg.
η_{mech} = 80 % = 0.8
d / D = 1.5
$\eta_{brake\ thermal}$ = 28 % = 0.28

Solution:

i) $\eta_{mech} = \dfrac{BP}{IP}$ $\qquad IP = \dfrac{BP}{\eta_{mech}} = \dfrac{30}{0.8} = 37.5$ kW

ii) $IP = \dfrac{i\, p_m\, LAn}{60}$ kW $\qquad l = 1.5\, d$; i = Number of cylinders; $A = (\pi d^2)/4$

$$= \frac{4 \times 600 \times 1.5\, d \times (\pi d^2 / 4) \times 2500}{60}$$

d = 0.062 m = 62 mm.
$l = 1.5 \times d = 1.5 \times 62 = 93$ mm

iii)) Brake thermal efficiency

$$\eta_{brake\ thermal} = \frac{BP}{m_f \times CV}$$

$$m_f = \frac{BP}{\eta_{brake\ thermal} \times CV} = \frac{30}{0.28 \times 43900} = 2.44 \times 10^{-3} \text{ kg / sec}$$

$m_f = 2.44 \times 10^{-3} \times 3600$ kg / hr

Problem 4: A person conducted a test on a single cylinder two-stroke petrol engine and found that the mechanical efficiency and brake thermal efficiency of the engine are 0.7 and 0.2 respectively. The engine with a mean effective pressure of 6bar ran at 300 rev/min consuming fuel at a rate of 2.2kg/hr. Given that the calorific value of fuel is 42500 kJ/kg and that the stroke to bore ratio of the engine is 1.2, find the bore and stroke of the engine. (VTU – Jan 2006)

Given: i = 1 cylinders
N = 300 rpm for a 2 stroke engine n = 300 cycles /min
p_m = 6 bar = 600 kPa
CV= 42500 kJ/kg.
η_{mech} = 70 % = 0.7
l / D = 1.2
$\eta_{brake\ thermal}$ = 20 % = 0.2
m_f = 2.2 kg / hr = 2.2/3600 kg/sec

Solution:

$$\eta_{brake\ thermal} = \frac{BP}{m_f \times CV}$$

BP = $\eta_{brake\ thermal}$ x m_f x CV = (0.2 x 2.2 x 42500) / 3600 = 5.19 kW

$$\eta_{mech} = \frac{BP}{IP} \qquad IP = \frac{BP}{\eta_{mech}} = \frac{5.19}{0.7} = 7.42 \text{ kW}$$

$$IP = \frac{i\, p_m\, LAn}{60} \text{ kW}$$

$$7.42 = \frac{1 \times 600 \times 1.2\, d \times (\pi d^2 / 4) \times 300}{60}$$

d = 0.138 m = 138 mm
l = 1.2 d = 1.2 x 138 = 166 mm

Problem 5: The following data are obtained on a 4-stroke petrol engine - Bore = 250mm, stroke length = 450mm, speed of the engine = 180 rpm, mechanical efficiency 80%, mean effective pressure = 0.65 MPa. Find the frictional power loss for the engine.

Given data: d = 250 mm = 0.25 m
L = 450 mm = 0.45 m
N = 180 rpm n = N/2 for a 4 stroke engine = 180/2 = 90 cycles/min
η_{mech} = 80 % = 0.8
p_m = 0.65 MPa = 650 kPa

Solution :

$$IP = \frac{i\, p_m\, LAn}{60} \text{ kW} \qquad i = \text{Number of cylinders}$$

$$1 \times 650 \times 0.45\, (\pi\, 0.25^2 / 4) \times 90$$

$$= \frac{\quad}{60} = 21.53 \text{ kW}$$

$$\eta_{mech} = \frac{BP}{IP}$$

$$BP = \eta_{mech} \times IP = 0.8 \times 21.53 = 17.53 \text{ kW}$$

Frictional power (FP)

$$FP = IP - BP$$

$$FP = 21.53 - 17.24 = 4.29 \text{ kW.}$$

MODULE-3
Machines & Machine Tools

Lecture 14:

Objective: Understanding about the meaning of “machine tools” and discussion about working of lathe and its parts.

Introduction

Machining is a material removal process in which a sharp cutting tool is used to mechanically cut away material to obtain desired geometry. The machine used for this purpose is known as a Machine Tool. So, **Machine tools** are defined as power driven cutting tools or machines which enable the removal of excess stock of material from the work piece. It holds both Work-piece (i.e. the one which has to be machined) and the Cutting tool, the one which is used to separate/remove material stock from the work piece. For Eg: hack saw, chisel etc

Machining operation is done by Relative motions between the tool and the work-piece.

There are two different types of Cutting tools and they are Single and Multipoint cutting tools. There are two Metal Cutting Process namely i) Orthogonal Cutting in which the cutting edge of tool is perpendicular to the workpiece axis. ii) Oblique Cutting: The cutting edge is inclined at an acute angle with normal to the cutting velocity vector.

Classification of machine tools based on the tools used: