Department	**Mechanical**			**Program**		**M.Tech (MSD)**	
Subject Name	**Advanced Engine Design**			**Subject Code**		**MSD302**	
Semester	**3rd**	**Credits**	**4**	**Teacher Incharge/ Mentor**			**Prof.(Dr.) M.M.Wani**
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Lecture-01

Topic: Introduction to IC Engines and Engine classification.

Link: https://www.youtube.com/watch?v=1X3vl6Qt9YU

Book: Internal Combustion Engine Fundamentals by J.B. Heywood (page 7-9)

Lecture Notes:

Introduction

Heat engine:
A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. It is classified into two types-
(a) External combustion engine

(b) Internal combustion engine

External combustion engine:
In this engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle.
Examples:
*In the steam engine or a steam turbine plant, the heat of combustion is employed to generate steam which is used in a piston engine (reciprocating type engine) or a turbine (rotary type engine) for useful work.
*In a closed cycle gas turbine, the heat of combustion in an external furnace is transferred to gas, usually air which the working fluid of the cycle.
Internal combustion engine:
In this engine, the combustion of air and fuels take place inside the cylinder and are used as the direct motive force.

Main Components of Reciprocating Engines:
Cylinder: It is the main part of the engine inside which piston reciprocates to and fro. It should have high strength to withstand high pressure above 50 bar and temperature above 2000^{o}C. The ordinary engine is made of cast iron and heavy duty engines are made of steel alloys or aluminum alloys. In the multi-cylinder engine, the cylinders are cast in one block known as cylinder block.

Cylinder head: The top end of the cylinder is covered by cylinder head over which inlet and exhaust valve, spark plug or injectors are mounted. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an air tight joint.

Piston: Transmit the force exerted by the burning of charge to the connecting rod. It is usually made of aluminum alloy which has good heat conducting property and greater strength at higher temperature.

Figure 1 shows the different components of IC engine.

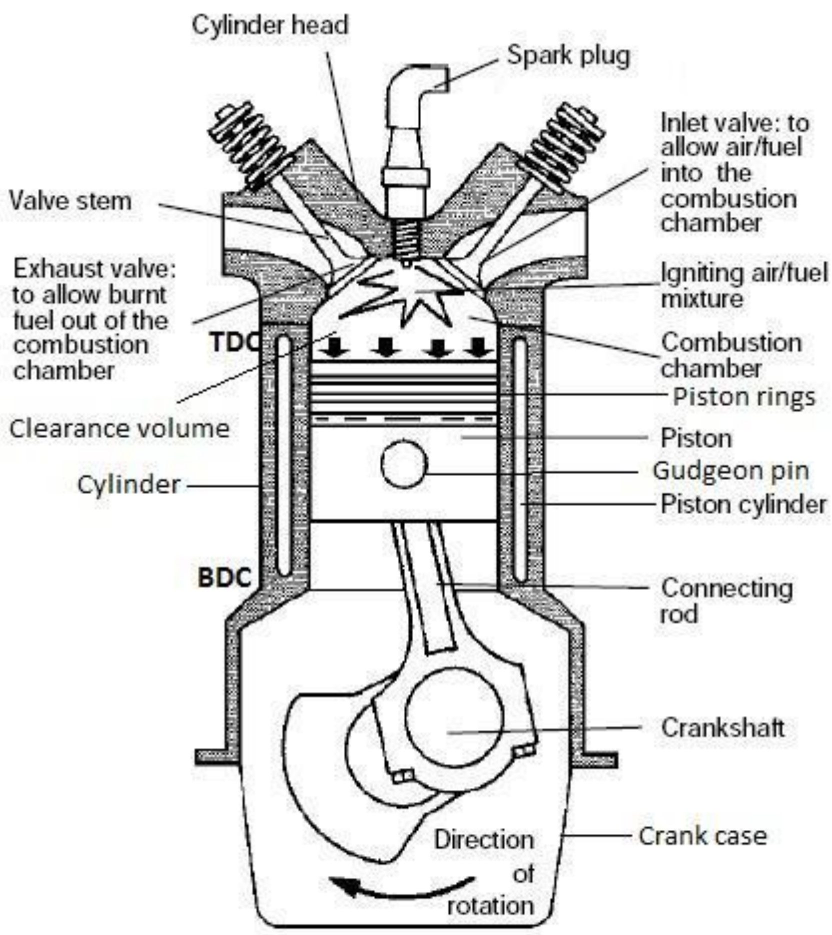


Fig.1 Main components of reciprocating IC Engine

Piston rings: These are housed in the circumferential grooves provided on the outer surface of the piston and made of steel alloys which retain elastic properties even at high temperature. 2 types of rings- compression and oil rings. Compression ring is upper ring of the piston which provides air tight seal to prevent leakage of the burnt gases into the lower portion. Oil ring is lower ring which provides effective seal to prevent leakage of the oil into the engine cylinder.

Connecting rod: It converts reciprocating motion of the piston into circular motion of the crank shaft, in the working stroke. The smaller end of the connecting rod is connected with the piston by gudgeon pin and bigger end of the connecting rod is connected with the crank with crank pin. The special steel alloys or aluminum alloys are used for the manufacture of connecting rod.

Crankshaft: It converts the reciprocating motion of the piston into the rotary motion with the help of connecting rod. The special steel alloys are used for the manufacturing of the crankshaft. It consists of eccentric portion called crank.

Crank case: It houses cylinder and crankshaft of the IC engine and also serves as sump for the lubricating oil.

Flywheel: It is big wheel mounted on the crankshaft, whose function is to maintain its speed constant. It is done by storing excess energy during the power stroke, which is returned during other stroke.

<u>Terminology used in IC engine</u>:

1. **Cylinder bore (D):** The nominal inner diameter of the working cylinder.
2. **Piston area (A):** The area of circle of diameter equal to the cylinder bore.
3. **Stroke (L):** The nominal distance through which a working piston moves between two successive reversals of its direction of motion.
4. **Dead centre**: The position of the working piston and the moving parts which are mechanically connected to it at the moment when the direction of the piston motion is reversed (at either end point of the stroke).

(a) Bottom dead centre (BDC): Dead centre when the piston is nearest to the crankshaft.

(b) Top dead centre (TDC): Dead centre when the position is farthest from the crankshaft.

5. **Displacement volume or swept volume (V_s):** The nominal volume generated by the working piston when travelling from the one dead centre to next one and given as,

$$V_s = A \times L$$

6. **Clearance volume (V_c):** the nominal volume of the space on the combustion side of the piston at the top dead centre.
7. **Cylinder volume (V):** Total volume of the cylinder.

$$V = V_s + V_c$$

8. **Compression ratio (r):** It is the ratio of total volume to the swept volume

$$R = V/V_c$$

<u>Engine Classification</u>

Internal Combustion Engines are classified as:

1. **According to the basic engine design-** (a) Reciprocating engine (Use of cylinder piston arrangement), (b) Rotary engine (Use of turbine)
2. **According to the type of fuel used-** (a) Petrol engine, (b) diesel engine, (c) gas engine (CNG, LPG), (d) Alcohol engine (ethanol, methanol etc)
3. **According to the number of strokes per cycle-** (a) Four stroke and (b) Two stroke engine
4. **According to the method of igniting the fuel-** (a) Spark ignition engine, (b) compression ignition engine and (c) hot spot ignition engine
5. **According to the working cycle-** (a) Otto cycle (constant volume cycle) engine, (b) diesel cycle (constant pressure cycle) engine, (c) dual combustion cycle (semi diesel cycle) engine.
6. **According to the fuel supply and mixture preparation-** (a) Carburetted type (fuel supplied through the carburettor), (b) Injection type (fuel injected into inlet ports or inlet manifold, fuel injected into the cylinder just before ignition).

7. **According to the number of cylinder**- (a) Single cylinder and (b) multi-cylinder engine
8. **According to the method of cooling-** water cooled or air cooled
9. **According to the speed of the engine-** Slow speed, medium speed and high speed engine
10. **According to the cylinder arrangement-**Vertical, horizontal, inline, V-type, radial, opposed cylinder or piston engines.
11. **According to the valve or port design and location-** Overhead (I head), side valve (L head); in two stroke engines: cross scavenging, loop scavenging, uniflow scavenging.
12. **According to the method governing**- Hit and miss governed engines, quantitatively governed engines and qualitatively governed engine

14. **According to the Application-** Automotive engines for land transport, marine engines for propulsion of ships, aircraft engines for aircraft propulsion, industrial engines, prime movers for electrical generators.

Lecture-02

Topic: Geometric properties of I C Engines.

Link: https://www.youtube.com/watch?v=1X3vl6Qt9YU

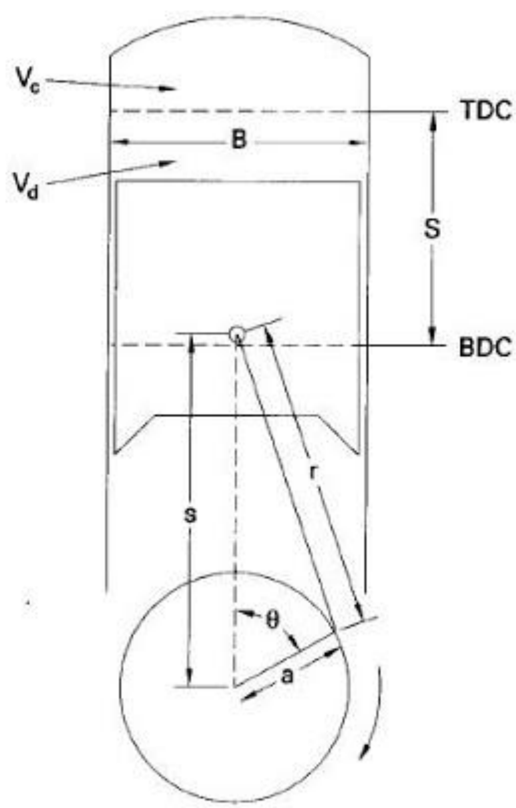
Book: Internal Combustion Engine Fundamentals by J.B. Heywood (page 42-53)

Lecture Notes:

Geometric properties of I C Engines.

The performance of the internal combustion engine is characterized with several geometric and thermodynamic parameters.

The following geometric parameters are of particular interest: Bore (B), connecting rod length (l), crank radius (a), stroke (S) and crank angle (ɵ). For any single cylinder, the cranks shaft, connecting rod, piston, and head assembly can be represented by the mechanism shown in the figure. The top dead center TDC of an engine refers to the crankshaft being in a position such that $\theta=0^0$. The volume at TDC is minimum and is often called the clearance volume V_c . The bottom dead center (BDC) refers to the crankshaft being at $\theta=180^0$, the volume at BDC is maximum and often denoted by V_T. The difference between the V_T and V_c is the displacement volume or swept volume V_s



<u>**Lecture-03**</u>

Topic: Basic Engine Definitions.

Link: https://www.youtube.com/watch?v=1X3vl6Qt9YU

Book: Internal Combustion Engine Fundamentals by J.B. Heywood (page 53-57)

Lecture Notes:

Power and Thermal Efficiency:

(i) **Indicated Power.** The total power developed by the combustion of fuel in the combustion chamber of a cylinder is called indicated power.

$$\mathbf{IP = P_{mi} LAN / n}$$

Where, A= Area of th piston
L= the length of stroke
N= the engine speed
n= the number of crank revolutions to complete one cycle of operation (2 for 4-stroke and 1 for 2-stroke engine)
P_{mi}= mean effective pressure

(ii) **Brake Power.** The power delivered by an engine to the output shaft is called the brake power.

$$\mathbf{BP = 2\pi NT/60}$$

Where T is the torque developed at the output shaft.

(iii) **Frictional Power.**the difference between IP and BP is called Frictional power.

(iv) The ratio of BP to IP is called **mechanical efficiency.**

Mean Effective Pressure (m.e.p):

It is a hypothetical pressure which is thought to be acting on the piston throughout the power stroke.

The m.e.p is based on BP is called the Brake mean effective pressure and for IP it is called indicated mean effective pressure

$$\mathbf{P_{mi} = Pn/V_s N}$$

Where P is the corresponding power.

m.e.p gives a measure of the work output per swept volume and is the true indicator of the relative performance of different engines. Higher the m.e.p higher will be the power developed by the engine for a given displacement.

Specific fuel consumption:

The sfc is the mass flow rate of fuel consumed per unit power output and is a criterion for economic power production.

$$Sfc = m_f/P$$

Where m_f is the mass of fuel consumed per unit time.

This parameter is widely used to compare the performance of different engines. Low values of sfc are desirable.

Mean Piston Speed:

The piston speed is zero at the beginning of the stroke, reaches maximum near the middle of the stroke and decreases to zero at the end of the stroke.

$$S_p = 2LN$$

The instantaneous velocity is obtained

$$S_{pi} = dS/dt$$

Compression Ratio: discussed earlier.

Air-Fuel ratio and Fuel-Air ratio:

In engine testing, both the air mass flow rate m_a and the fuel mass flow rate m_f are normally measured. The ratio of these flow rates is useful in defining engine operating conditions.

Air-Fuel ratio = m_a/m_f

Fuel-Air ratio = m_f/m_a

Volumetric Efficiency:

The intake system restricts the amount of air which an engine of a given displacement can induct. The parameter used to measure the effectiveness of an engine induction process is the volumetric efficiency and is only used with 4-stroke cycle engines which have a distinct induction system.

It is defined as the volume flow rate of air into the intake system divided by the rate at which the volume is displaced by the piston.

Maximum rated power

It is defined as the maximum power is allowed to develop for short period of operation

Normal rated power

It is defined as the maximum amount of power an engine is allowed for continuous operation.

Rated speed

The crankshaft rotational speed at which the maximum power is developed is called the rated speed of the engine.

example :

800 CC Car Engine

Rated Power – 39.5 BHP

Rated Speed – 5500 RPM

Rated torque of engine

It is defined as the maximum torque an engine can develop.

The maximum torque is developed at a lower crankshaft rotational speed than the speed required for developing maximum power.

For more numerical value based examples see any indian automotive magazine or refer to the world wide web [www]

Example: the maximum torque for the engine mentioned above is developed at 3000rpm while as the maximum power is developed at 5500 rpm.

Design oriented Numericals:

Q: see solved example on J B Heywood. Page 51.

Q: You are designing a 4-stroke cycle diesel engine to provide a BP of 500kW, naturally aspirated at its maximum rated speed. Based on typical values of brake mean effective pressure and maximum mean piston speed, estimate the required engine displacement and the bore and stroke for sensible cylinder geometry and number of engine cylinders. What is the maximum rated engine speed for your design. What would be the brake torque and the fuel flow rate at the maximum speed. Assume a maximum mean piston speed of 15m/s.

Q: Solve problem 2.11 on J B Heywood. Page 60.

Lecture-04

Topic: Method of verifying the rated power specification of engine manufacturers.

Link: https://www.youtube.com/watch?v=1X3vl6Qt9YU

Book: Advanced Engine Technology by Hoag.

Lecture Notes:

Testing and performance

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

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

Basic measurements:

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

(a) Speed
(b) Fuel consumption
(c) Air consumption
(d) Smoke density
(e) Brake horse-power
(f) Indicated horse power and friction horse power
(g) Heat balance sheet or performance of SI and CI engine
(h) Exhaust gas analysis

1. Measurement of speed:

-One of the basic measurements is that of speed. A wide variety of speed measuring devices are available in the market. They range from a mechanical tachometer to digital and triggered electrical tachometers.

-The best method of measuring speed is to count the number of revolutions in a given time. This gives an accurate measurement of speed. Many engines are fitted with such revolution counters.

-A mechanical tachometer or an electrical tachometer can also be used for measuring the speed.

-The electrical tachometer has a three-phase permanent-magnet alternator to which a voltmeter is attached. -The output of the alternator is a linear function of the speed and is directly indicated on the voltmeter dial.

-Both electrical and mechanical types of tachometers are affected by the temperature variations and are not very accurate. For accurate and continuous measurement of speed a magnetic pick-up placed near a toothed wheel coupled to the engine shaft can be used.

-The magnetic pick-up will produce a pulse for every revolution and a pulse counter will accurately measure the speed.

2. Fuel consumption measurement:

Fuel consumption is measured in two ways:

(a) The fuel consumption of an engine is measured by determining the volume flow in a given time interval and multiplying it by the specific gravity of the fuel which should be measured occasionally to get an accurate value.

(b) Another method is to measure the time required for consumption of a given mass of fuel.

As already mentioned two basic types of fuel measurement methods are:

-Volumetric type

-Gravimetric type

Volumetric type flow meter includes Burette method, Automatic Burette flow meter and Turbine flow meter.

Gravimetric Fuel Flow Measurement

The efficiency of an engine is related to the kilograms of fuel which are consumed and not the number of litres. The method of measuring volume flow and then correcting it for specific gravity variations is quite inconvenient and inherently limited in accuracy. Instead if the weight of the fuel consumed is directly measured a great improvement in accuracy and cost can be obtained. There are three types of gravimetric type systems which are commercially available include Actual weighing of fuel consumed, Four Orifice Flow meter, etc.

3. Measurement of air consumption:

In IC engines, the satisfactory measurement of air consumption is quite difficult because the flow is pulsating, due to the cyclic nature of the engine and because the air a compressible fluid. Therefore, the simple method of using an orifice in the induction pipe is not satisfactory since the reading will be pulsating and unreliable.

All kinetic flow-inferring systems such as nozzles, orifices and venturies have a square law relationship between flow rate and differential pressure which gives rise to severe errors on unsteady flow. Pulsation produced errors are roughly inversely proportional to the pressure across the orifice for a given set of flow conditions. The various methods and meters used for air flow measurement include,

(a) Air box method, and

(b) Viscous-flow air meter

4. Measurement of brake power:

The brake power measurement involves the determination of the torque and the angular speed of the engine output shaft. The torque measuring device is called a dynamometer.

Dynamometers can be broadly classified into two main types, power absorption dynamometers and transmission dynamometer.

Absorption Dynamometers

These dynamometers measure and absorb the power output of the engine to which they are coupled. The power absorbed is usually dissipated as heat by some means. Example of such dynamometers is prony brake, rope brake, hydraulic dynamometer, etc.

Transmission Dynamometers

In transmission dynamometers, the power is transmitted to the load coupled to the engine after it is indicated on some type of scale. These are also called torque-meters.

5. Measurement of friction power*:*

-The difference between indicated power and the brake power output of an engine is the friction power.

-Almost invariably, the difference between a good engine and a bad engine is due to difference between their frictional losses.

-The frictional losses are ultimately dissipated to the cooling system (and exhaust) as they appear in the form of frictional heat and this influences the cooling capacity required. Moreover, lower friction means availability of more brake power; hence brake specific fuel consumption is lower.

-The *bsfc* rises with an increase in speed. Thus, the level of friction decides the maximum output of the engine which can be obtained economically.
The friction force power of an engine is determined by the following methods :
(a) Willan‟s line method.
(b) Morse test.
(c) Motoring test.
(d) Difference between IP and BP.

(a) Willan's line method

-In this method, gross fuel consumption vs. *bp* at a constant speed is plotted and the graph is extrapolated back to zero fuel consumption.
-The point where this graph cuts the *bp* axis is an indication of the friction power of the engine at that speed. This negative work represents the combined loss due to mechanical friction, pumping and blow by.
-The main drawback of this method is the long distance to be extrapolated from data measured between 5 and 40% load towards the zero line of fuel input.
-The directional margin of error is rather wide because of the graph which may not be a straight line many times.
-The changing slope along the curve indicates part efficiencies of increments of fuel. The pronounced change in the slope of this line near full load reflects the limiting influence of the air-fuel ratio and of the quality of combustion.
-Similarly, there is a slight curvature at light loads. This is perhaps due to difficulty in injecting accurately and consistently very small quantities of fuel per cycle.
-Therefore, it is essential that great care should be taken at light loads to establish the true nature of the curve.
-The William's line for a swirl-chamber CI engine is straighter than that for a direct injection type engine.
The accuracy obtained in this method is good and compares favorably with other methods if extrapolation is carefully done.

(b) Morse Test

-The Morse test is applicable only to multi-cylinder engines.
-In this test, the engine is first run at the required speed and the output is measured.
-Then, one cylinder is cut out by short circuiting the spark plug or by disconnecting the injector as the case may be.
-Under this condition all other cylinders „motor‟ this cut-out cylinder.
-The output is measured by keeping the speed constant at its original value.
-The difference in the outputs is a measure of the indicated horse power of the cut-out cylinder.
-Thus, for each cylinder the *ip* is obtained and is added together to find the total *ip* of the engine.
-This method though gives reasonably accurate results and is liable to errors due to changes in mixture distribution and other conditions by cutting-out one cylinder. In gasoline engines, where there is a common manifold for two or more cylinders the mixture distribution as well as the volumetric efficiency both change. Again, almost all engines have a common exhaust manifold for all cylinders and cutting out of one cylinder may greatly affect the pulsations in exhaust system which may significantly change the engine performance by imposing different back pressures.

(c) Motoring Test

-In the motoring test, the engine is first run up to the desired speed by its own power and allowed to remain at the given speed and load conditions for some time so that oil, water, and engine component temperatures reach stable conditions.

-The power of the engine during this period is absorbed by a swinging field type electric dynamometer, which is most suitable for this test.
-The fuel supply is then cut-off and by suitable electric-switching devices the dynamometer is converted to run as a motor to drive for „motor" the engine at the same speed at which it was previously running.
-The power supply to the motor is measured which is a measure of the *fhp* of the engine. During the motoring test the water supply is also cut-off so that the actual operating temperatures are maintained.
-This method, though determines the *fp* at temperature conditions very near to the actual operating temperatures at the test speed and load, does, not give the true losses occurring under firing conditions due to the following reasons.
(i) The temperatures in the motored engine are different from those in a firing engine because even if water circulation is stopped the incoming air cools the cylinder. This reduces the lubricating oil temperature and increases friction increasing the oil viscosity. This problem is much more severing in air-cooled engines.
(ii) The pressure on the bearings and piston rings is lower than the firing pressure. Load on main and connecting road bearings are lower.
(iii) The clearance between piston and cylinder wall is more (due to cooling). This reduces the piston friction.
(iv) The air is drawn at a temperature less than when the engine is firing because it does not get heat from the cylinder (rather loses heat to the cylinder). This makes the expansion line to be lower than the compression line on the p-v diagram. This loss is however counted in the indicator diagram.
(v) During exhaust the back pressure is more because under motoring conditions sufficient pressure difference is not available to impart gases the kinetic energy is necessary to expel them from exhaust.
Motoring method, however, gives reasonably good results and is very suitable for finding the losses due to various engine components. This insight into the losses caused by various components and other parameters is obtained by progressive stripping-off of the under progressive dismantling conditions keeping water and oil circulation intact. Then the cylinder head can be removed to evaluate, by difference, the compression loss. In this manner piston ring, piston etc. can be removed and evaluated for their effect on overall friction.

(d) Difference between *ip* and *bp*

(i) The method of finding the *fp* by computing the difference between *ip*, as obtained from an indicator diagram, and *bp*, as obtained by a dynamometer, is the ideal method.
(ii) In obtaining accurate indicator diagrams, especially at high engine speeds, this method is usually only used in research laboratories. Its use at commercial level is very limited.

6. Heat balance sheet:

The performance of an engine is usually studied by heat balance-sheet. The main components of the heat balance are:
-Heat equivalent to the effective (brake) work of the engine,
-Heat rejected to the cooling medium,
-Heat carried away from the engine with the exhaust gases, and
-Unaccounted losses.
The unaccounted losses include the radiation losses from the various parts of the engine and heat lost due to incomplete combustion. The friction loss is not shown as a separate item to the heat balance-sheet as the friction loss ultimately reappears as heat in cooling water, exhaust and radiation.

Lecture-05

Topic: Design of SI engine.

Link: https://www.youtube.com/watch?v=1X3vl6Qt9YU

Book: Advanced Engine Technology by Hoag.

Lecture Notes:

BASIC REQUIREMENTS FOR POWER DEVELOPMENT IN SPARK IGNITION ENGINES

1. Air
2. Fuel – Example - Petrol
3. Current – Through spark discharge In a spark plug.

BASIC REQUIREMENTS FOR POWER DEVELOPMENT IN COMPRESSION IGNITION ENGINES

1. Air
2. Fuel – Example - Diesel

CONCEPT OF ENGINE TUNING

For any particular S.I. engine design when we supply air, fuel and current in a manner that can develop rated torque or rated power at the corresponding rated speeds, the engine is said to be in tuned condition

For any particular C.I. engine design when we supply air and fuel in a manner that can develop rated torque or rated power at the corresponding rated speeds, the engine is said to be in tuned condition

When we just start our car in the neutral gear and without any acceleration, the engine is said to be running at idle speed or idle rpm.

The engines are designed in such a manner that the tuning is done at idle rpm of the engine crankshaft only. The idle rpm is normally 900 rpm or 1000 rpm for automotive vehicles like cars.

BRAKE SPECIFIC FUEL CONSUMPTION

The brake specific fuel consumption is defined as the ratio of mass flow rate of fuel into an engine to the power developed by the engine.

Alternatively

It is mass of fuel consumed by the engine per unit of energy developed by the engine.

Example:

For spark ignition engine the value of brake specific fuel consumption is
270 g /kw.h.

For compression ignition engine the value of brake specific fuel consumption is 220 g / kw.h

S.I. engine combustion is classified as homogeneous combustion because the air and fuel are present in mixed form throughout the cylinder before giving a spark for combustion.

C.I. engine combustion is classified as heterogeneous combustion because the engine cylinder aspirates only air into the cylinder and the combustion is initiated by the fuel injection towards the end of the compression stroke.

So for same energy to be developed the C.I. engines consume less quantity of fuel. Also C.I. engine fuels are sold at cheaper rates in indian market. So C.I. engines are economical from running cost point of view.

AIR TO FUEL RATIO.

It is defined as the ratio of the mass flow rate of air into the engine to the mass flow rate of fuel into the engine.

It can also be defined as the mass of air inducted into the engine per cycle to the mass of fuel supplied or injected into the engine per cycle

There is a rage of air to fuel ratio for both petrol and diesel types of engine categories at which such engines can operate without fail.

Range of air to fuel ratio for petrol engine ; [12-16]

Range of air to fuel ratio for diesel engine: [17 – 70]

The practical operating value of air to fuel ratio for diesel engines is on the leaner side of the stoichiometric value , say 22 or 23

The reason for lean operation of diesel engines is to minimize soot emissions. Without loosing the required power to be developed..

EFFECT OF AIR TO FUEL RATIO ON POLLUTANT FORMATION FROM I C ENGINES.

Diesel engines follow principles of heterogeneous combustion and as such require to be operated on leaner side for minimizing soot emissions which is not the case for petrol engines which follow principles of homogeneous combustion.

If fuel supplied to the engine is more than that required by the principles of chemically correct air to fuel ratio, the mixture is said to be rich.

If the fuel supplied to the engine is less than that required by the principles of chemically correct air to fuel ratio, the mixture is said to be lean.

Rich mixture produces more CO and HC emissions.

Also rich mixture produces soot emissions in C.I. engines.

Also the NOx emissions are produced from engines from the oxygen and nitrogen of the air only when these two gases get confined to some cylinder volume at high temperatures for a substantial amount of time.

Since C.I. engines are operated lean. High NOx emissions are formed in C.I. engines.

S.I. engines normally produce high NOx emissions when operated at or near the stoichiometric value of air to fuel ratio. The NOx emissions of such engines come down on either side of this value.

Lecture-06

Topic: Design of a Racing car engine.

Link:

Book:

Lecture Notes:

Lecture-07

Topic: Design of CI engine.

Link:

Book: Advanced Engine Technology by Hoag.

Lecture Notes:

Diesel engine design system is an important and leading function in the design and development of modern low emission diesel engines it leads and integrates the designs from the system level to the component level by producing high quality system design specifications with advanced analytical simulation tools.

An attribute driven system design process is developed for advanced for advanced analytical engine design from the system level to the component level in order to coordinate different design attributes and sub-systems.

A diesel engine is a type of CI engine using Diesel fuel. Diesel engines can be classified into various categories. Understanding the differences and the unique characteristics of each category of diesel engines is important for diesel engine system design.

There are four main areas in future diesel engine development to achieve emissions compliance and high thermal efficiency while reducing the overall engine cost:

i) In-Cylinder combustion development;
ii) Exhaust aftertreatment;
iii) Hybrid powertrain engineering; and
iv) Fuel quality and alternate fuels.

In CI engine design it is important to conduct accurate and sophisticated calculations at a system optimization level by using advanced simulation tools. (BOOST, AVL FIRE)

Lecture-08

Topic: Design of Turbocharged diesel engine

Link:

Book:

Lecture Notes:

Lecture-09

Topic: Design of Heavy duty truck engine.

Link:

Book:

Lecture Notes:

Due to the increasing price of fuel, demands for fuel economy of heavy-duty trucks become severer year by year, and many efforts, such as reduction of air drag of vehicle, optimization of transmission and engine performance, improvement of engine combustion, etc., have been taken to meet these demands. However, requirements for the reduction of fuel consumption are expected to become even more critical, so the authors have studied a new design concept for heavy duty truck diesel engines to satisfy these requirements. The basic idea for getting a fuel-economic engine is to make the engine as small as possible and also to apply higher boost turbocharging for obtaining a sufficiently high output. However, measures to improve the undesirable problems which conventional turbocharged engines possess, such as lack of acceleration response and low-speed torque, increase of thermal and mechanical loads, shortage of engine brake torque, poor cold start ability, etc., should also be pursued. A chassis-mounted air-to-air intercooler, inertia-charged air induction system, highly backward-curved impeller of turbocharger, electronically controlled fuel injection timing device, etc., have been applied. And a new design technique as well as new material and construction have also been applied. This engine was installed to a long-haul truck with a gross weight of around 20,000 kg (44,000 lbs) and got better fuel mileage, as expected.

Lecture-10

Topic: Criteria for division of total displacement volume into multi-cylinder engine concept.

Link:

Book:.

Lecture Notes:

Engine displacement is the swept volume of all the pistons inside the cylinders of a reciprocating engine in a single movement from top dead centre (TDC) to bottom dead centre (BDC). It is commonly specified in cubic centimetres (cc or cm3), litres (l), or (mainly in North America) cubic inches (CID). Engine displacement does not include the total volume of the combustion chamber.

Lecture-11

Topic: Concept of firing order.

Link:

Book: Advanced Engine Technology by Hoag.

Lecture Notes:

The sequence in which the power is produced in an engine is called "firing order". Decision of firing order is a part of design so as to get best performance. ... This is achieved by sparking of the spark plugs in a gasoline engine in the correct order, or by the sequence of fuel injection in a Diesel engine.

Firing order refers to the order in which each of the cylinders in a multicylinder engine fires (power stroke). For example, a four cylinder engine's firing order could be 1-4-3-2. This means that the number 1 cylinder fires, then the number 4 cylinder fires, then the number 3 cylinder fires, and so on. Engines are designed so that the power strokes are as uniform as possible, that is, as the crankshaft rotates a certain number of degrees, one of the cylinders will go through a power stroke. This reduces vibration and allows the power generated by the engine to be applied to the load in a smoother fashion than if they were all to fire at once or in odd multiples.

Even and uneven firing order

Firing order affects the balance, noise, vibration, smoothness, cooling, and sound of the engine.

Evenly spaced firing order (also called even firing order or even firing interval) means that the angle between each firing is equal. In four-stroke engines this requires a firing interval of 720° divided by the number of cylinders. On the other hand, engines with unevenly spaced firing order (sometimes called odd firing order) not all angles between firings are equal, for example a six-cylinder engine with unevenly spaced firing order can have a combination of 90° and 150° firing intervals compared to a six-cylinder engine with even firing order which must have 720° / 6 = 120° firing interval.

Engines that are even-firing will sound more smooth and steady, while engines that are odd, or uneven firing will have a burble or a throaty, growling sound in the engine note, and, depending on the crankshaft design, will often have more vibrations due to the unevenness of power delivery. Most racing engines such as those in Formula One often have even firing intervals in all or the most part (e.g. within each bank of a V-engine) of their firing order, mostly for easier packaging of performance exhaust systems. Engines that employ some variation on the Big-bang firing order theme will often have an uneven firing order, because the original point was to roughen up the power delivery to affect traction behaviour.

Examples of odd-firing engines are Harley-Davidson Evolution engines and most 4-stroke V-Twins, 2009–2014 Yamaha YZF-R1, Audi V10 FSI as used in the Audi R8 V10 and 2nd / 3rd generation Lamborghini Gallardo, Viper V10, Yamaha V-Max and VMAX, Buick 231 Odd-Fire V6 .

Examples of even-firing engines are Honda NSR500V and most 2-stroke V-Twins, most current production inline 4s (with the exception of the Yamaha R1), most current production V6s, Lotus Esprit V8, Porsche 918 Spyder, McLaren M838T engine, Audi V10, 1st generation Lamborghini Gallardo and Toyota LR engine