Unit 1: VEHICLE STRUCTURE AND ENGINES
Module 3: **IC engines components- functions and materials, variable valve timing (VVT).**

Components of an Engine:

Even though reciprocating internal combustion engines look quite simple, there are hundreds of components that have to perform their functions satisfactorily to produce output power. There are two types of engines, viz., spark ignition (S1) and compression-ignition (CI) engine. Let us now go through the important engine components and the nomenclature associated with an engine.

Terms connected with I.C. engines

Bore: The inside diameter of the cylinder is called bore

Stroke: The linear distance along the cylinder axis between two limiting position s is called stroke.

Top Dead Center (T.D.C.) : the top most position of the piston towards cover end side of the cylinder is called T.D.C.

Bottom dead Center (B.D.C.) : The lowest position of the piston towards the crank end side of the cylinder is called B.D.C.

Clearance Volume: The volume contained in the cylinder above the top of the piston , when the piston is at top dead center , is called the clearance volume.

Swept Volume: The volume swept through by the piston in moving between T.D.C. and B.D.C, is called swept volume or piston displacement.

Compression Ratio: It is the ratio of Total cylinder volume to clearance volume.

Definition of 'Engine'

An engine is a device, which transforms one form of energy into another form. Normally, most of the engines convert thermal energy into mechanical work and therefore they are called _heat engines'.

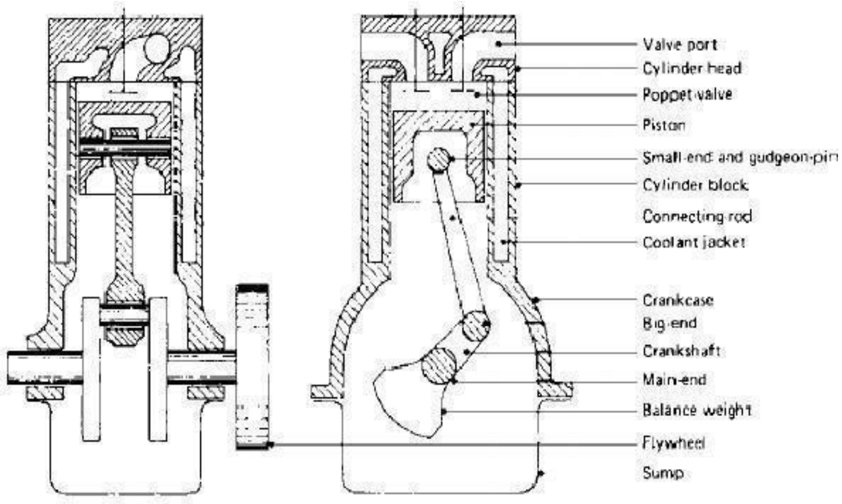


Fig.12 parts of an I.C. Engine

Engine Components

The major components of the engine and their functions are briefly described below.

Cylinder Block:

The cylinder block is the main supporting structure for the various components. The cylinder of a multi cylinder engine is cast as a single unit, called cylinder block. The cylinder head is mounted on the cylinder block.

The cylinder head and cylinder block are provided with water jackets in the case of water- cooling with cooling fins in the case of air-cooling. Cylinder head gasket is incorporated between the cylinder block and cylinder head. The cylinder head is held tight to the cylinder block by number of bolts or studs. The bottom portion of the cylinder block is called crankcase. A cover called crankcase, which becomes a sump for lubricating oil is fastened to the bottom of the crankcase. The inner surface of the cylinder block, which is machined and finished accurately to cylindrical shape, is called bore or face.

Cylinder

As the name implies it is a cylindrical vessel or space in which the piston makes a reciprocating motion. The varying volume created in the cylinder during the operation of the engine is filled with the working fluid and subjected to different thermodynamic processes. The cylinder is supported in the cylinder block.

Piston

It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system. It fits perfectly (snugly) into the cylinder providing a gas-tight space with the piston rings and the lubricant. It forms the first link in transmitting the gas forces to the output shaft.

Combustion Chamber

The space enclosed in the upper part of the cylinder, by the cylinder head and the piston top during the combustion process, is called the combustion chamber. The combustion of fuel and the consequent release of thermal energy results in the building up of pressure in this part of the cylinder.

Inlet Manifold

The pipe which connects the intake system to the inlet valve of the engine and through which air or air-fuel mixture is drawn into the cylinder is called the inlet manifold.

Gudgeon Pin

It forms the link between the small end of the connecting rod and the piston.

Exhaust Manifold

The pipe that connects the exhaust system to the exhaust valve of the engine and through which the products of combustion escape into the atmosphere is called the exhaust manifold.

Inlet and Exhaust Valves

Valves are commonly mushroom shaped poppet type. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) and for discharging the products of combustion (exhaust valve) from the cylinder.

Connecting Rod

It interconnects the piston and the crankshaft and transmits the gas forces from the piston to the crankshaft. The two ends of the connecting rod are called as small end and the big end. Small end is connected to the piston by gudgeon pin and the big end is connected to the crankshaft by crankpin.

Crankshaft

It converts the reciprocating motion of the piston into useful rotary motion of the output shaft. In the crankshaft of a single cylinder engine there is pair of crank arms and balance weights. The balance weights are provided for static and dynamic balancing of the rotating system. The crankshaft is enclosed in a crankcase.

Piston Rings

Piston rings, fitted into the slots around the piston, provide a tight seal between the piston and the cylinder wall thus preventing leakage of combustion gases

Camshaft

The camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. This shaft also provides the drive to the ignition system. The camshaft is driven by the crankshaft through timing gears.

Cams

These are made *as* integral parts of the camshaft and are designed in such a way to open the valves at the correct timing and to keep them open for the necessary duration.

Fly Wheel

The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates causing a change in the angular velocity of the shaft. In order to achieve a uniform torque an inertia *mass* in the form of a wheel is attached to the output shaft and this wheel is calledthe flywheel.

Basic Parts of the Gasoline Engine:

Basic Parts of the Gasoline Engine are listed below;

- Cylinder block
- Piston
- Piston rings
- Piston pin
- Connecting rod
- Crankshaft
- Cylinder head
- Intake valve
- Exhaust valve
- Camshaft
- Timing gears
- Spark plug

Cylinder Block:

Cylinder Block Basic frame of gasoline engine. Contains the cylinder.

Piston:

Piston A sliding plug that harnesses the force of the burning gases in the cylinder.

Piston Rings:

Piston rings seal the compression gases above the piston keep the oil below the piston rings.

Piston Pins:

Piston Pins Also known as the wrist pin, it connects the piston to the small end of the connecting rod. It transfers the force and allows the rod to swing back and forth.

Connecting Rod:

Connecting Rod Connects the piston and piston pin to the crankshaft.

Crankshaft:

Crankshaft Along the the piston pin and connecting rod it converts the up and down motion (reciprocating) of the engine to spinning (rotary) motion.

Flywheel:

Flywheel Carries the inertia when there is no power stroke.

Cylinder Head:

Cylinder Head Forms the top of the combustion chamber. Contains the valves, the passageways for the fuel mixture to move in and out of the engine.

Intake and Exhaust Valves:

Intake and Exhaust Valves Doorway that lets the gases in and out of the engine.

Camshaft:

Camshaft Through the use of an eccentric the cam lobes push the valves open. The valve springs close them.

Timing Gears:

Timing Gears These gears drive the camshaft from the crankshaft.

Variable Valve Timing

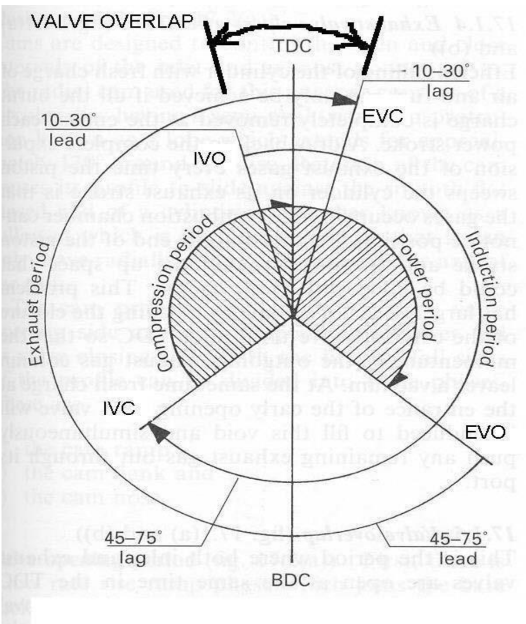
It is inherent to the operation of internal combustion engines to possess inlet and exhaust valves (4-stroke) or ports (2-stroke) for proper functioning. The idea here is to entrap the incoming fresh charge in a well-designed combustion chamber and then initiate ignition in order to release and convert the stored fuel chemical energy into the thermal energy. Subsequent to this release of energy, a mechanical system, such as piston-connecting-rod-crankshaft, is needed forconversion of the thermal energy into the mechanical energy of the crankshaft. The incoming fresh charge usually consists of fuel, air, and possibly exhaust gas recalculated (EGR) chemical species. EGR is used for nitric oxide (NO_X) emission control purposes. In this scenario, theroles that valves, particularly the intake valves, play are critical for the engine's efficient operation, optimum performance, and minimization of pollutants emission. In this tutorial, these aspects are addressed in a concise manner.

Historically speaking, many different types of valves and valve actuation mechanisms have been tried in the past. Most have disappeared to the point that at present time nearly all 4-stroke engines use poppet valves opened by a cam and closed by a spring. A typical valve timing for a 4-stroke engine is shown in Fig. 1. At wide open throttle operation of an SI engine, the exhaust gases rushing out of the exhaust valve can assist pulling fresh charge into the cylinder (moving the intake manifold fresh charge even before the piston has moved appreciably), therefore justifying opening of the intake valve (IVO) even before TDC, see Fig. 1. At part loadoperation, however, situation is a bit more complex and the below-atmospheric pressure createdby the partially open throttle valve can become less than the chamber pressure at the time when intake valve is opened. This causes backflow of burned gases from the cylinder into the intake system during the valve overlap period. The overlap period is the time during which both intakeand exhaust valves are open (intake is being opened and exhaust being closed). Too early IVO will also cause fresh charge to be lost out of the exhaust, for example, NASCAR engines.

At the closing, it is customary to delay the IVC beyond the BDC to take advantage of the inertia of the fresh charge rushing into the engine, see Fig. 1. This will increase what is referred to as the –volumetric efficiency‖ of the engine. The volumetric efficiency indicates the breathing ability of the engine and is defined as the actual mass of the fresh air trapped in the cylinder (after valves are closed) divided by the theoretical mass of air calculated based on the piston displacement volume. The higher the volumetric efficiency, the higher the engine ability to trap fresh air, providing opportunity for combustion of a more mass of fuel on account of a more entrapped oxygen, thereby producing higher power for the same piston displacement. Furthermore, the engine brake power rises and then falls off with speed for a number of reasons: mainly the fall in volumetric efficiency, and the fall in mechanical efficiency. The delayed closure of the intake valve for achieving higher volumetric efficiency usually works best at higher engine speeds due to sufficiently high inertia of the incoming fresh charge. Note that the IVO does also affect the volumetric efficiency through the magnitude of the backflow into the intake system mentioned earlier.

In engines, even though attempts are made to thoroughly scavenge the chamber from burned gases, there is always a certain amount of burned gases left to be mixed with the incoming fresh charge. As far as the combustion (really, flame burning rate) is concerned, the amount of this residual burned gases left from the previous cycle combustion is not desirable. The higher the quantity of residual burned gases, the slower the flame mass burning rate. It is known that increases in the valve overlap period will elevate the fraction of the residual gases in the entrapped charge. Also, past research indicates that the amount of the residual gases correlates inversely with the engine load (i.e. throttle valve position in SI engines), being maximum at idle condition. This is the primary reason for engine stability problems at idle condition. It should therefore be clear that the valve overlap period can affect engine stability and hence efficiency. On the positive side, this residual gases is useful to lower the burned gases temperature after combustion is complete, reducing the NO_X emissions. Figure 2 shows effects of the valve overlap period on emissions of NO_X and hydrocarbon (HC) at two different engine loads.

In summary, adjustments in valve timing (usually achieved by camshaft phasing) affect the raw emissions, engine torque/power, and idle stability. However, researchers have shownbenefits in tailoring valve lift profile, primarily to achieve higher efficiency and power, although emission benefits were also seen. Combination of adjustments in valve timing and changes in valve lift are being used to influence both emission levels and engine efficiency and, hence, fuel economy. Finally, potential of SI engine load control is being considered through variable lift designs. Research has shown that improvements in fuel economy and emission can be achieved through an optimized combination of variable valve timing and lift, see Fig. 3. To conclude, the adjustment of the valve timing in spark-ignited (SI) engines is dictated by a set of conflicting targets and goals. These goals cannot be achieved with fixed valve timing. Systems that provide



variable timing and lift have recently found widespread use in engine design.

Figure . Indicates positions of intake and exhaust valves openings and closures with respect to the top-dead and bottom-dead centers, TDC and BDC respectively. TDC and BDC indicate the uppermost and lowermost positions of the piston top on the diagram. The angles shown are crankshaft angles. EVO and EVC are exhaust valve opening and closures angles.

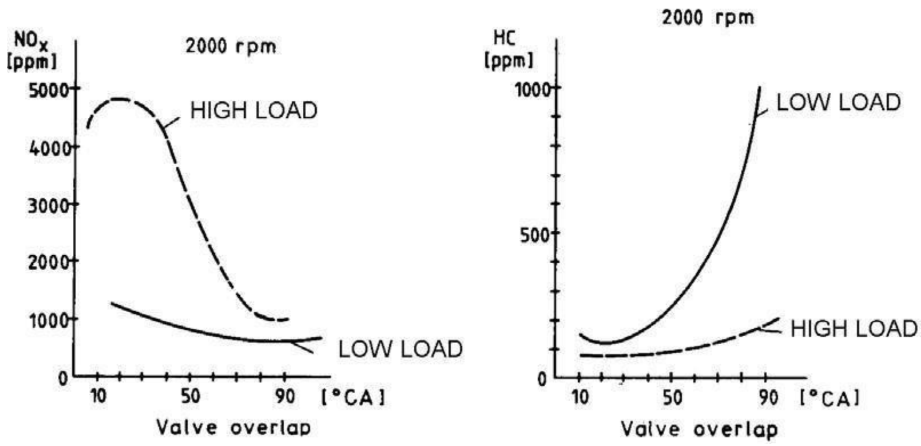


Figure . Effects of valve overlap on emission of pollutants at 2000 rpm and two different engine loads. HC and NO_X are hydrocarbon and nitric oxides emissions.