MCE 523: INTERNAL COMBUSTION ENGINES

1.0 ENGINES

An engine is a system/ machine that convert energy in a matter into useful mechanical motion. The matter in which energy is extracted from is called FUEL.

In most engines, the fuel is combusted to liberate energy which in turn is converted to useful work through the motion of engines parts. Engines that operate through the combustion of fuel are called heat engines. Heat engines are further classified as either internal or external combustion engines. Engines in which its fuel is combusted in the engine cylinder is called an INTERNAL COMBUSTION ENGINE while the engines in which its combustion takes place in an external source is called an EXTERNAL COMBUSTION ENGINE. An example of an internal combustion engine is a spark ignition engine while an example of an external combustion engine is a steam engine.

1.1 HISTORY OF THE EVOLUTION OF INTERNAL COMBUSTION ENGINES

Internal combustion engines have been in operation for over a century. Nikolaus A. Otto built the first successful four-stroke engine which is known as the OTTO CYCLE in 1876 although in 1862, a French Scientist, Alphonse Beau de Rochas, patented a four-stroke engine design (Note: it was not built) . Before the successful invention of the four-stroke cycle by Otto, attempts were previously made by several scientists and engineers to successfully build a working internal combustion engine.

Christian Huygens, a Dutch physicist was the first to experiment with an internal combustion engine in 1680 but he was unable to develop a running engine. A breakthrough came in 1859 when J. J. Etienne Lenoir, a French engineer built a double-acting, spark ignition engine that could be operated continuously. George Brayton, an American engineer developed a kerosene engine running on a two-stroke cycle in 1873 but it was too bulky and too slow for commercial purposes. A less bulky two-stroke cycle engine was built in 1876 by Sir Dougald Clerk and the engine design was simplified by Joseph Day in 1891. An engine taken as a prototype of modern gas engines was built by Gottlieb Daimler in 1885. Its gasoline injection system was through a carburettor. It had a vertical cylinder, was fast and small in size. The V configuration of an engine was first built by Daimler in 1889. It was a four-stoke engine with mushroom-shaped valves, it was a two-cylinder engine and had a much higher power-to-weight ratio compared to other configurations. An engine with an electric starter was developed in 1924 by Daimler.

1.2 BASIC ENGINE OPERATION

Internal Combustion Engines (ICEs) are engine in which the combustion of its fuel takes place inside the engine cylinder. They are broadly classified as spark ignition (S.I.) and Compression Ignition (C.I.) engines. These classifications are based on the principle of ignition of the air-fuel mixture (charge) in the combustion chamber. If the air-fuel mixture inside the engine cylinder is ignited by the introduction of spark from the spark plug, the engine is termed a spark ignition engine while the engine is termed a compression ignition engine, if the air-fuel mixture is ignited by the high temperature generated from the compression of the air-fuel mixture. Basically, internal combustion engine that operate on petrol are spark ignition engines while those that operate with diesel fuel are compression ignition engines.

Internal combustion engines are also classified based on its cycle of operation both the spark ignition (petrol) and compression ignition (diesel) engines could operate on two-stroke or four stroke cycles. Two –stroke cycle operation implying the completion of an engine cycle in one crankshaft revolution while the four-stroke cycle requires two crankshaft revolutions to complete an engine cycle.

1.3 CLASSIFICATIONS OF INTERNAL COMBUSTION ENGINES

Internal combustion engines are classified based on the following:-

- Arrangement of Cylinders
- Type of fuel burned
- Type of aspiration
- Number of valve / cylinder
- Mode of ignition
- Valve location
- Camshaft location
- Number of strokes / cycle
- Cooling system type
- Combustion chamber design

CLASSIFICATIONS OF INTERNAL COMBUSTION ENGINES

Internal Combustion engine classifications can be done based on the following:-

- **Arrangement of Cylinders**

- **In-line:** in this arrangement, the cylinders are positioned in a straight line, one behind the other along the length of the crankshaft. This type of engine could have cylinders ranging from 2 to 11 cylinders or more. For automobile engines, the in-line four-cylinder engines are more common. They are sometimes called STRAIGHT (four, six or eight).

- **V-engine:** this configuration has two-banks of cylinder at angle with each other, all connected to a single crankshaft. The angle between the banks of cylinder ranges from 15˚ to 120˚, with 60˚ to 90˚ being common. V6s and V8s are common automobile engines used while V12s and V16s are found in some luxury and high-performance vehicles.

- **Opposed piston:** In this arrangement, two pistons are found in a single cylinder with the combustion chamber in-between them. A single combustion process caused two power strokes at the same time, with each piston being pushed away from the center and delivering power to a separate crankshaft t each end of the cylinder. Engine output is either on two rotating crankshafts or on one crankshaft incorporating complex mechanical linkages.

- **Opposed cylinder:** In this arrangement, two banks of cylinders opposite each, other are connected to a single crankshaft (it is also a V engine with 180˚V). This type of engine is common in small aircrafts and some automobiles, with an even number of cylinder from two to eight or more. They are mainly called flat engines.

- **Radial type:** in this arrangement, the engine pistons are positioned in a circular plane around a central crankshaft. The connecting rods are connected to a master rod which, in turn, is connected to the crankshaft. A bank of cylinders on a radial engine always has an odd number of cylinders ranging from 3 to 13 or more. Operating on a four-stroke cycle implies that every other cylinder fires as the crankshaft rotates, giving a smooth operation. A lot of medium and large-size propeller-driven aircraft use the radial engine. In large aircrafts, two or more banks of cylinders are mounted together (one behind the other on a single crankshaft, given a more powerful and smooth engine operation. Very large ship engines exist with up to 54 cylinders, six banks of 9 cylinders each.

- **W type:** this arrangement is similar to the V engine except that it has three cylinder banks connected to a single crankshaft. This design is not common but has been developed for some racing automobiles in the past and present. Usually such engines have 12 cylinders with 60˚ in between them.

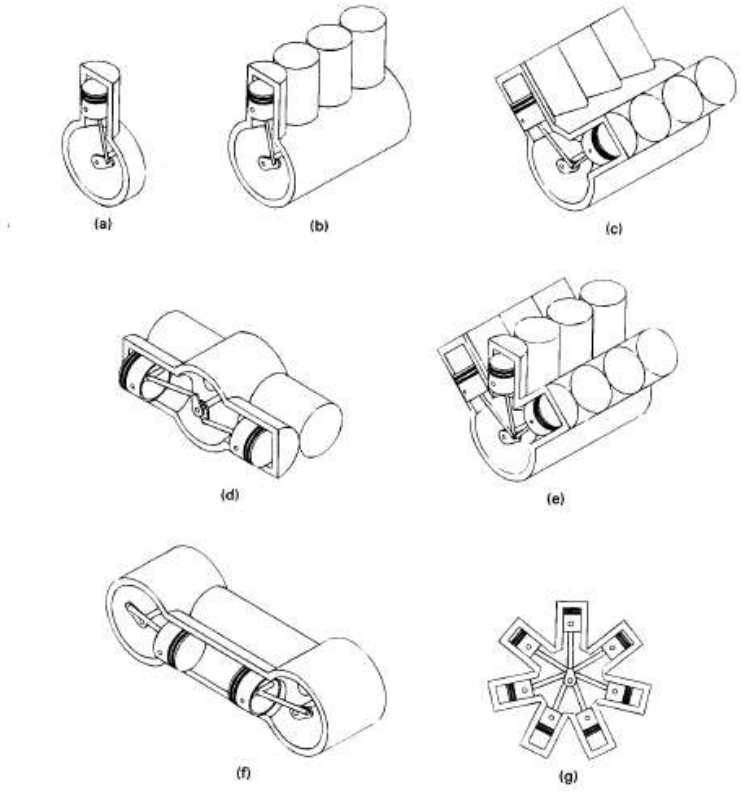

Figure 3.1: Engine configurations (a) Single Cylinder (b) Straight or In-line (c) V Engine (d) Opposed Cylinder (e) W Engine (f) Opposed Piston (g) Radial

• Type of fuel burned

- Diesel
- Petrol
- CNG / LPG
- Dual fuel engine

• Type of aspiration

– Naturally aspirated engine

– Turbo / super charged engine

• Number of valve / cylinder

– 2 valves per cylinder

– 3 valves per cylinder

– 4 valves per cylinder

– 5 valves per cylinder

• Mode of ignition

– Compression ignition

– Spark ignition

- **Gas exchange control**
    - Ports
    - Overhead valve with overhead cam
    - Overhead valve with side cam

• Valve location

Four stroke engines employ the opening and closing of valves for the purpose of gas exchange in its combustion chamber by the various valve arrangements.

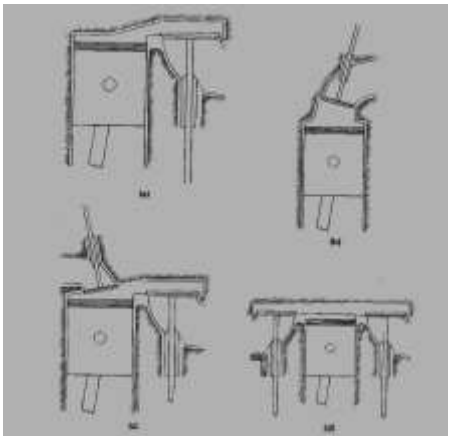

Figure 3.2: Four-stroke engine classification based on valve location (a) Valve in block, L head (b) Valve in head, I head (c) One valve in head and one valve in block, F head. (d) Valve in block on opposite sides of cylinder, T head.

- **Valve in block, L head:** this type of valve arrangement was used in older automobiles and is still being used in some smaller engines.

- **Valve in head, I head:** This valve arrangement is the standard used in modern automobile engines.
- **One valve in head and one valve in block, F head:** this arrangement was used in older automobile engines and their usage was not so common.
- **Valve in block on opposite sides of cylinder, T head:** this arrangement was used in some historic automobile engines.

• **Camshaft location**

- Overhead cam engine
- Cam in the block engine

• **Number of strokes / cycle**

- 4 – stroke cycle
- 2 – stroke cycle
- Double acting engine

• Cooling system type

– Water cooled engine

– Air cooled engine

• Combustion chamber design

- Single open combustion chamber
- Divided combustion chamber
  - Pre-chamber systems
  - Swirl chamber systems

  Shapes:
  - Pancake
  - Wedge
  - Hemispherical
  - pent roof
  - precombustion chamber