

Chapter Two

Literature Review

2.1 Introduction

The internal combustion (IC) engine is considered as one of the most successful inventions in the last century, because of its significant impact on the society, especially human mobility [1]. It drives all kinds of utility devices (e.g., pumps, mowers, chain-saws, portable generators, etc.), as well as earth-moving equipment, tractors, propeller aircraft, ocean liners and ships, personal watercraft and motorcycles [2], not to forget the one billion cars running throughout the world, and it's expected to be about two billion by 2020. The success achieved by the IC engines was made because of many reasons. The initial cost is relatively low, they have a high power density, a reasonable driving range, reasonable efficiency, and the ability to meet regulation emission limits [3].

An IC engine is defined as an engine that converts the chemical energy stored in the fuel through combustion to thermal energy which in turn is converted to mechanical energy [1].

2.2 Early History and Development

The very first engine came to general use was built in 1860 by J.J.E. Lenoir, it can be classified as atmospheric engine [4]. The engine consisted from single-cylinder, double acting horizontal steam engine, with two power strokes per revolution. Induction of the air/gas charge anti exhaust of the burnt

mixture were controlled by slide valves; and the ignition was obtained by an electric spark [5]. power up to about 4.5 kW (6 hp) and mechanical efficiency up to 5% [4].

In 1872, George Bryton, an American mechanical engineer, patented a constant pressure internal combustion engine. The engine used a compression cylinder, and an expansion cylinder. This cycle was also called the “flame cycle”, as ignition of the gas-air mixture was by a pilot flame, and the mixture was ignited and burned at constant pressure as it was pumped from the compression cylinder to the expansion cylinder [1].

The first practical two-stroke engine was invented and built in 1878 by Sir Dugald Clerk, a Scottish mechanical engineer. Clerk’s engine was made of two cylinders. One a working cylinder to produce power, and the other a pumping cylinder to compress and transfer the intake air and fuel mixture to the working cylinder. Poppet valves were used for intake flow, and a cylinder port uncovered by the piston on the expansion stroke was used to exhaust the combustion gases [1].

The first practical four stroke engine was developed by Nikolaus Otto, a German engineer [4]. The engine compression ratio of 2.5, producing 2 hp at 160 rpm, and the brake efficiency was 14% [1].

The development of the modern compression ignition (CI) engine referred to two people, Akroyd Stuart and Rudolf Diesel. Stuart engine was patented in 1890, it was a four stroke engine with a compression ratio of about 3. He used a vaporizer connected to the main cylinder in the purpose of preheating the fuel before ignition in the combustion chamber [5]. In 1897 Rudolph Diesel developed the first four stroke engine uses the direct injection

technology, which injects the liquid fuel directly into the combustion chamber [1].

Engine developments, perhaps less fundamental but nonetheless important to the steadily widening internal combustion engine markets, have continued ever [6]. In 1859, the discovery of crude oil in Pennsylvania finally made available the development of reliable fuels which could be used in these newly developed engines [4]. Gasoline, and lighter fractions of crude oil, became available in the late 1800s and various types of carburetors were developed to vaporize the fuel and mix it with air. Before 1905 there were few problems with gasoline; though compression ratios were low (4 or less) to avoid knock, the highly volatile fuel made starting easy and gave good cold weather performance [6].

2.3 Engine Classifications

Internal combustion (IC) engines can be classified into different groups using deferent features as characteristics, the following are some major characteristics that may be used in designating engines:

2.3.1 Operating Cycles

This classification considers the number of strokes done by the piston in order to complete one thermodynamic cycle. And they can be divided to:

(a) Four stroke engine: In this type each cylinder requires four strokes of its piston, two revolutions of the crank shaft, to complete the sequence of events which produces one power stroke [6]. (See figure 2.1)

(b) Two Stroke engine: In this type the engine needs only two strokes of the piston in order to complete the cycle [1]. (See figure 2.2)

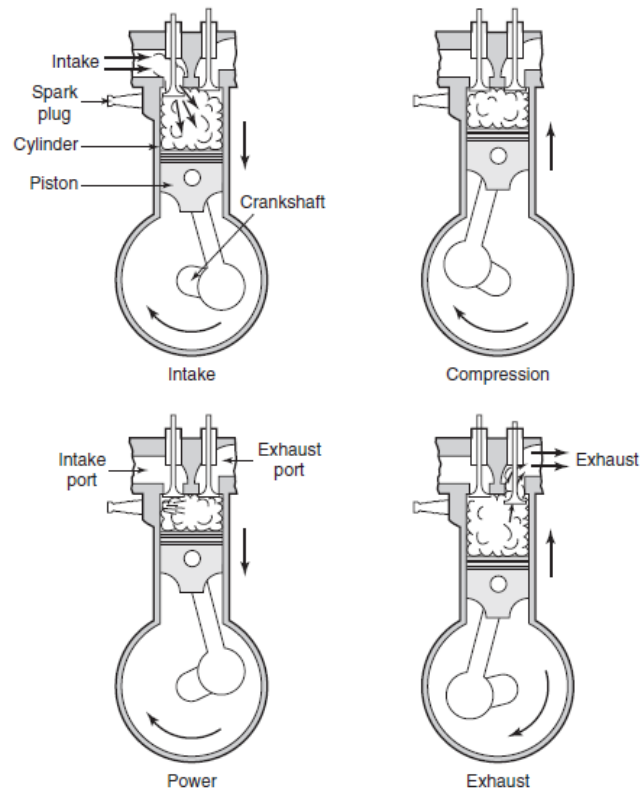


Figure (2.1): Four-stroke spark ignition engine

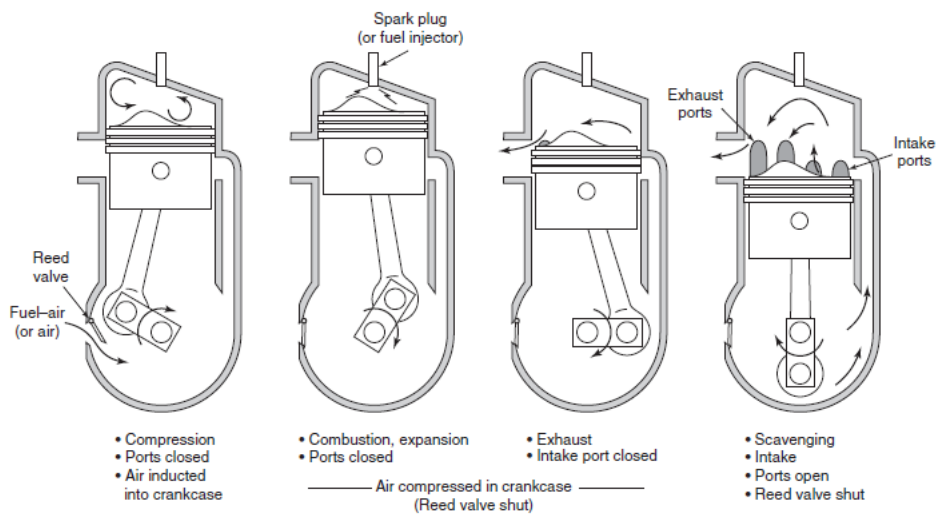


Figure (2.2): Across-scavenged two-stroke cycle

2.3.2 Type of Ignition

IC engines are classified as **spark-ignition (SI) engines** or **compression-ignition (CI) engines**, depending on how the combustion process in the cylinder is initiated. In SI engines, the combustion of the air–fuel mixture is initiated by a spark plug. In CI engines, the air–fuel mixture is self-ignited as a result of compressing the mixture above its self-ignition temperature [7].

2.3.3 Basic Design

(a) Reciprocating: Engine has one or more cylinders in which pistons reciprocate back and forth. The combustion chamber is located in the closed end of each cylinder. Power is delivered to a rotating output crankshaft by mechanical linkage with the pistons [4].

(b) Rotary: Engine is made of a block (stator) built around a large non-concentric rotor and crankshaft. The combustion chambers are built into the nonrotating block.

2.3.4 Position and Number of Cylinders of Reciprocating Engines

(a) Single Cylinder: Engine has one cylinder and piston connected to the Crank shaft.

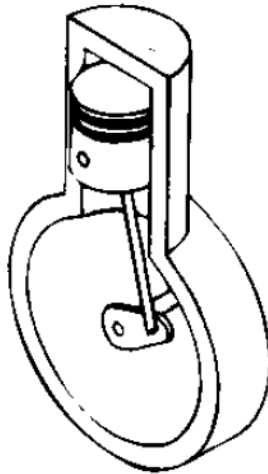


Figure (2.3): Single Cylinder engine

(b) In-Line: Cylinders are positioned in a straight line, one behind the other along the length of the crankshaft. They can consist of 2 to 11 cylinders or possibly more. In-line engines are sometimes called straight (e.g., straight six or straight eight).

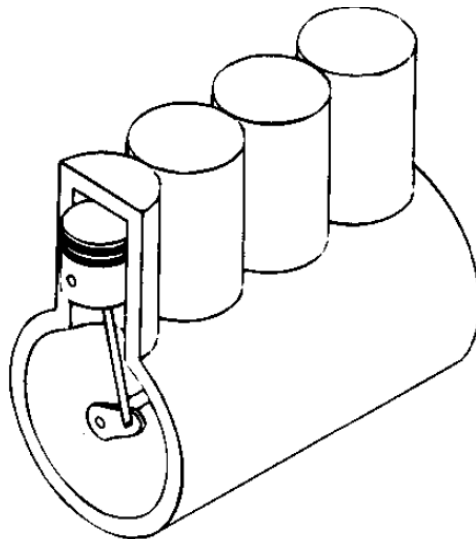


Figure (2.4): in-line engine

(c) V Engine: Two banks of cylinders at an angle with each other along a single crankshaft. The angle between the banks of cylinders can be anywhere from 15° to 120° , with 60° - 90° being common.

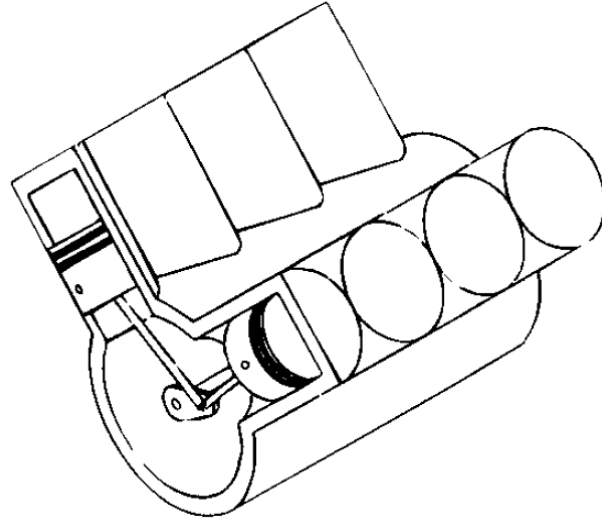


Figure (2.5): V engine

(d) Opposed Cylinder Engine: Two banks of cylinders opposite each other on a single crankshaft (a V engine with a 180° V). These engines are often called flat engines (e.g., flat four).

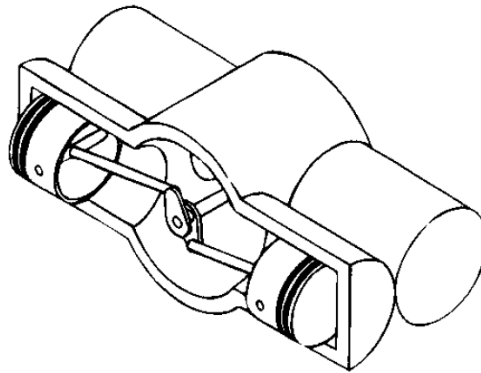


Figure (2.6): Opposed Cylinder Engine

(e) Opposed Piston Engine: Two pistons in each cylinder with the combustion chamber in the center between the pistons. A single-combustion process causes two power strokes at the same time, with each piston being pushed away from the center and delivering power to a separate crankshaft at each end of the cylinder. Engine output is either on two rotating crankshafts or on one crankshaft incorporating complex mechanical linkage.

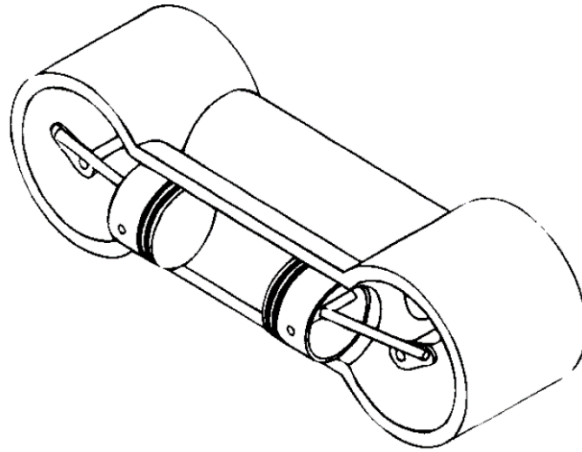


Figure (2.7): Opposed piston engine

(f) Radial Engine: Engine with pistons positioned in a circular plane around the central crankshaft. The connecting rods of the pistons 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, every other cylinder fires and has a power stroke as the crankshaft rotates, giving a smooth operation[4] .

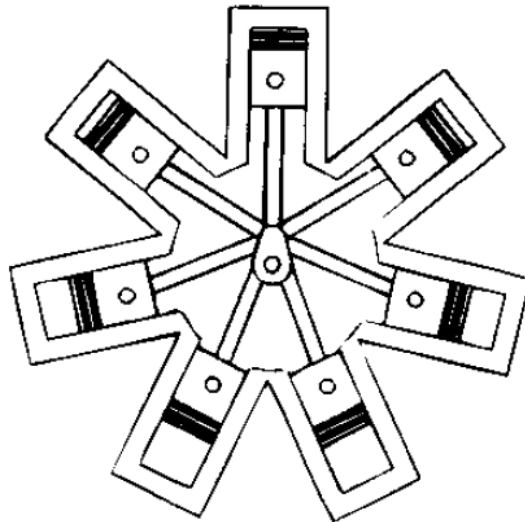


Figure (2.8): Radial engine

2.4 Engine Components

The following is a list of major components found in most reciprocating internal combustion engines.

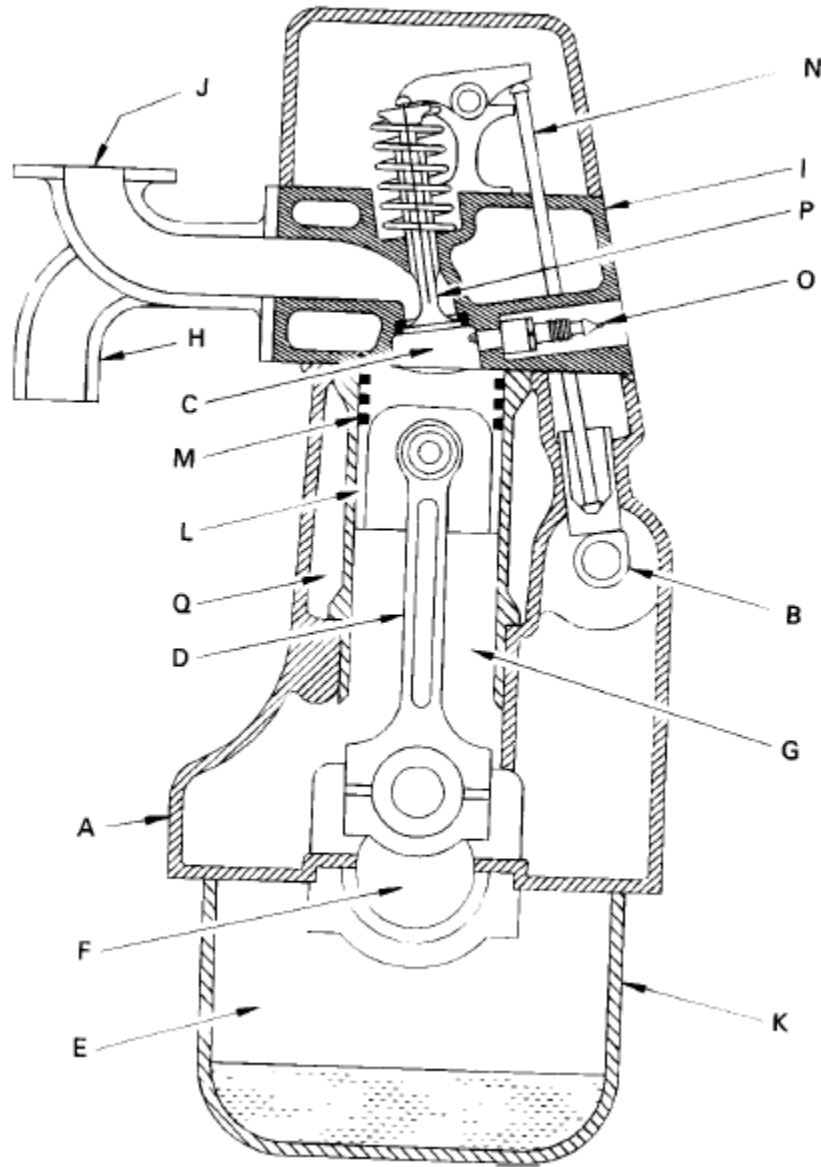


Figure 2.9 Cross-section of four-stroke cycle SI engine showing engine components; (A) block, (B) camshaft, (C) combustion chamber, (D) connecting rod, (E) crankcase, (F) crankshaft, (G) cylinder, (H) exhaust manifold, (I) head, (J) intake manifold, (K) oil pan, (L) piston, (M) piston rings, (N) push rod, (O) spark plug, (P) valve, (Q) water jacket.

2.4.1 Engine Block

The engine block is usually made of gray cast iron because of its good wear resistance and low cost. Passages for the cooling water are cast into the block. Heavy-duty and truck engines often use removable cylinder sleeves pressed into the block that can be replaced when worn. These are called wet liners or dry liners depending on whether the sleeve is in direct contact with the cooling water. Aluminum is being used increasingly in smaller SI engine blocks to reduce engine weight. Iron cylinder liners may be inserted at the casting stage, or later on in the machining and assembly process [6].

2.4.2 Crank shaft

Rotating shaft through which engine work output is supplied to external systems. The crankshaft is connected to the engine block with the main bearings. It is rotated by the reciprocating pistons through connecting rods connected to the crankshaft, offset from the axis of rotation. This offset is sometimes called crank throw or crank radius. Most crankshafts are made of forged steel, while some are made of cast iron.

2.4.3 Cam shaft

Rotating shaft used to push open valves at the proper time in the engine cycle, either directly or through mechanical or hydraulic linkage. Camshafts are generally made of forged steel or cast iron and are driven off the crankshaft by means of a belt or chain (timing chain). To reduce weight, some cams are made from a hollow shaft with the cam lobes press-fit on. In four-stroke cycle engines, the camshaft rotates a half engine speed [4].

2.4.4 Cylinder

The circular cylinders in the engine block in which the pistons reciprocate back and forth. The walls of the cylinder have highly polished hard surfaces. Cylinders may be machined directly in the engine block, or a hard metal (drawn steel) sleeve may be pressed into the softer metal block. Sleeves may be dry sleeves, which do not contact the liquid in the water jacket, or wet sleeves, which form part of the water jacket. In a few engines, the cylinder walls are given a knurled surface to help hold a lubricant film on the walls. In some very rare cases, the cross section of the cylinder is not round [5].

2.4.5 Piston

It's the cylindrical-shaped mass that reciprocates back and forth in the cylinder, transmitting the pressure forces in the combustion chamber to the rotating crankshaft. Pistons are made of aluminum in small engines or cast iron in larger slower-speed engines. Pistons are made of cast iron, steel, or aluminum. Iron and steel pistons can have sharper corners because of their higher strength. They also have lower thermal expansion, which allows for tighter tolerances and less crevice volume. Aluminum pistons are lighter and have less mass inertia. Sometimes synthetic or composite materials are used for the body of the piston [4].

2.5 Turbochargers

A turbocharger is an exhaust gas-driven, centrifugal pump that “recycles” some of the rejected heat from the engine’s cylinders [8]. Turbochargers are being used for its main object, increasing the air charged to the cylinder and burn larger amount of fuel, thus increasing the power output of the engine [9].

A turbocharger consists of a turbine and a compressor connected by a shaft. The turbine section is mounted to the exhaust line from the engine. The compressor is connected to the turbine by a shaft and its outlet is routed to the engine air intake. Exhaust gas from the engine enters the turbine and expands, performing work on the turbine. The turbine spins the shaft connected to the compressor. The compressor draws in ambient air and compresses it [4].

2.6 Cooling Systems

Part of the heat developed during combustion stroke flows from the gases to the cylinder walls, raising this temperature. As temperature increases the oil used to lubricate the piston begins to evaporate rapidly, and both piston and cylinder maybe injured. Also high local temperature in certain parts of the engine, e.g. cylinder head and piston may cause excessive stresses and cracking of these parts [9]. For all these reasons the heat developed should be carried away from the engine block.

Cooling systems transfers a percentage of engine rejected heat. Engine rejected heat has to be transferred to atmosphere, either in the exhaust gas or indirectly using the engine cooling system [10].

There are two types of engine cooling systems used for heat transfer from the engine block and head liquid cooling and air cooling. With a liquid coolant, thermal energy is removed through the use of internal cooling channels within the engine block. With air as a coolant, thermal energy is removed through the use of fins attached to the cylinder wall. Both types of cooling systems have various advantages and disadvantages. Liquid systems are much quieter than air systems, since the cooling channels absorb the noise

from the combustion processes. However, liquid systems are subject to freezing, corrosion, and leakage problems that do not exist in air systems [1].

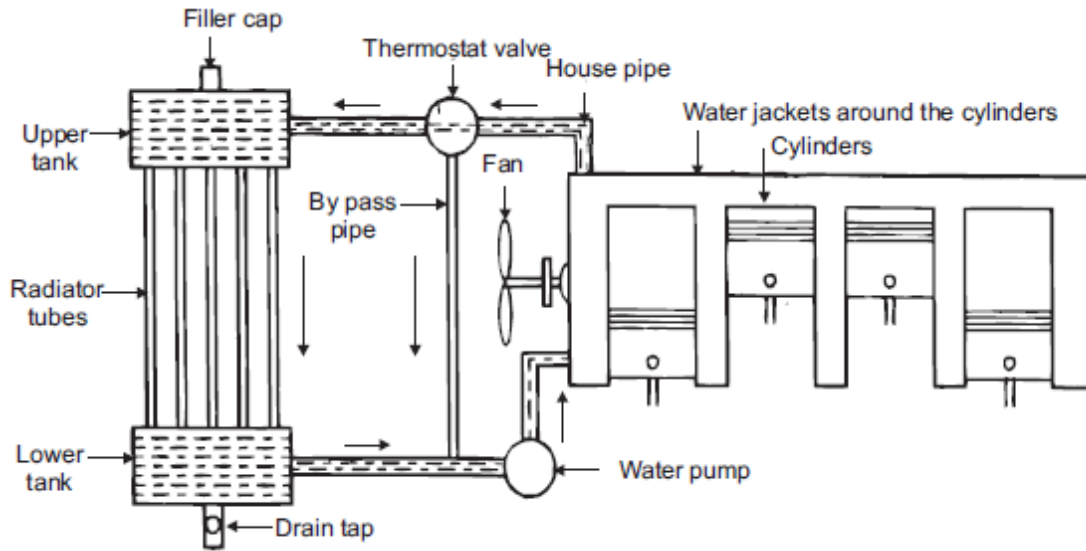


Figure (2.10): Water cooling system of a 4-cylinder engine

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