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General concept and history of Internal Combustion Engine

Prof. A. D. Anjikar **Ashutosh Zode** **Harshal Ramteke**
Department of Mechanical Engineering,
Priyadarshini Bhagwati College of Engineering, RTMNU University, Nagpur

Abstract- *The aim of this report is to introduce the fundamentals of Internal Combustion Engines (ICE). The report traces the mechanism of operation of ICE and its different kinds based on the operation mechanism, specially the two stroke and four stroke engines. It also involves the thermodynamics relations that govern the processes of these engines, highlighting two main important cycles, which are: Otto Cycle and Diesel cycles. Thus, it uses both cycles to introduce the second categorization of ICE based on the thermodynamic relations; introducing Gasoline engines and Diesel engines. Whenever possible, the report refers to current research and future developments in this field.*

1.INTRODUCTION

Perhaps the invention of the engine, or even introducing its concept, was the most important scientific event in the human history. Replacing the horse carriage by the automobile or the horse-less carriage, as it was initially called, was an event that increased the distance human beings can endeavor into space. Engines are basic mechanical engineering devices, and they have variety of applications in moving and non-moving machines.

An engine is defined as the machine that converts the chemical energy liberated through combustion of a certain fuel, into a mechanical energy that is used to derive a certain vehicle.

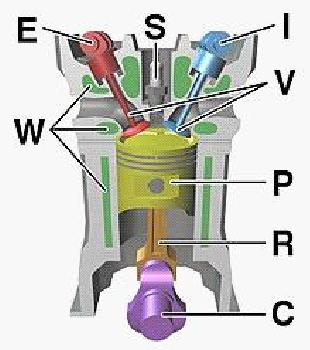

Diagram of a cylinder as found in 4-stroke gasoline engines.:
C – Crankshaft.
E – Exhaust Camshaft.
I – Inlet Camshaft.
P – Piston.
R – Connecting Rod.
S – Spark Plug
V – Valves. red: exhaust, blue: intake.
W – Cooling Water Jacket
Gray Structure – Engine Block.

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2. STROKE CATEGORIZATION

The stroke is defined as the length of the path that the piston goes through inside the cylinder. The upper end of the cylinder is referred to as the Top Dead Center (TDC), and the lower end is referred to as the Bottom Dead Center (BDC). Using the crankshaft mechanism, the linear motion that comes out from the piston due to the combustion is converted into rotational motion. Rotational motion is the required one to derive the wheels. Following is the explanation of the two-stroke and four-stroke engines.

A. 2-Stroke Engines

The defining characteristic of this kind of engine is that each piston completes a cycle every crankshaft revolution. The 4 processes of intake, compression, power and exhaust take place in only 2 strokes so that it is not possible to dedicate a stroke exclusively for each of them. Starting at TDC the cycle consist of:

Power*:* While the piston is descending the combustion gases perform work on it—as in a 4-stroke engine—. The same thermodynamic considerations about the expansion apply.

Scavenging*:* Around 75° of crankshaft rotation before BDC the exhaust valve or port opens, and blowdown occurs. Shortly thereafter the intake valve or transfer port opens. The incoming charge displaces the remaining combustion gases to the exhaust system and a part of the charge may enter the exhaust system as well.

Compression*:* With both intake and exhaust closed the piston continues moving upwards compressing the charge and performing a work on it. As in the case of a 4-stroke engine, ignition starts just before the piston reaches TDC and the same consideration on the thermodynamics of the compression on the charge.

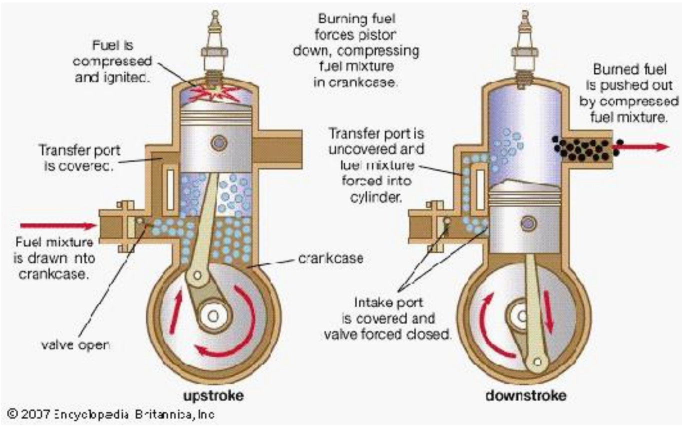

Fig:- 2-Stroke Engine

B. 4- Stroke Engines

The *top dead center* (TDC) of a piston is the position where it is nearest to the valves; *bottom dead center* (BDC) is the opposite position where it is furthest from them.

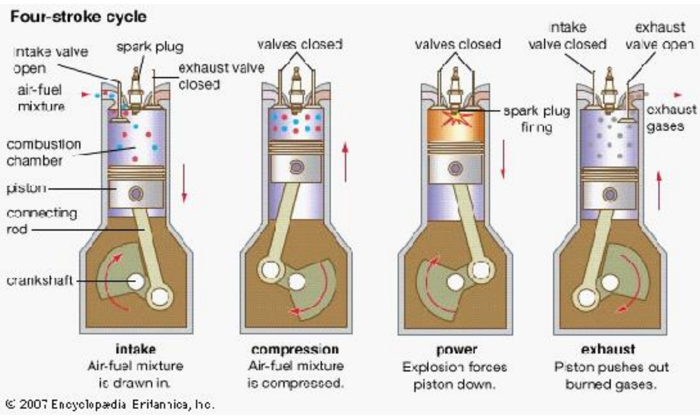

Fig:- 4-Stroke Engines

A *stroke* is the movement of a piston from TDC to BDC or vice versa together with the associated process. While an engine is in operation the crankshaft rotates continuously at a nearly constant speed. In a 4-stroke ICE each piston experiences 2 strokes per crankshaft revolution in the following order. Starting the description at TDC, these are:

***Intake**, **induction** or **suction**:* The intake valves are open as a result of the cam lobe pressing down on the valve stem. The piston moves downward increasing the volume of the combustion chamber and allowing air to enter in the case of a CI engine or an air fuel mix in the case of SI engines that do not use direct injection.

Compression: In this stroke, both valves are closed and the piston moves upward reducing the combustion chamber volume which reaches its minimum when the piston is at TDC. The piston performs work on the charge as it is being compressed; as a result its pressure, temperature and density increase; an approximation to this behavior is provided by the ideal gas law. Just before the piston reaches TDC, ignition begins.

***Power** or **working stroke**:* The pressure of the combustion gases pushes the piston downward, generating more work than it required to compress the charge. Complementary to the compression stroke, the combustion gases expand and as a result their temperature, pressure and density decreases. When the piston is near to BDC the exhaust valve opens.

***Exhaust**:* The exhaust valve remains open while the piston moves upward expelling the combustion gases. For naturally aspirated engines a small part of the combustion gases may remain in the cylinder during normal operation because the piston does not close the combustion chamber completely; these gases dissolve in the next charge.

3. CYCLE CATEGORIZATION

This is one of the important points to discuss, which is the thermodynamics of the combustion process. There are two main cycles based on which we can categorize internal combustion engines, which are: *Otto cycle and Diesel cycle.*

A. Otto Cycle

Otto cycle is the typical cycle for most of the cars internal combustion engines, that work using gasoline as a fuel. Otto cycle is exactly the same one that was described for the four-stroke engine. It consists of the same major steps: Intake, compression, ignition, expansion and exhaust.

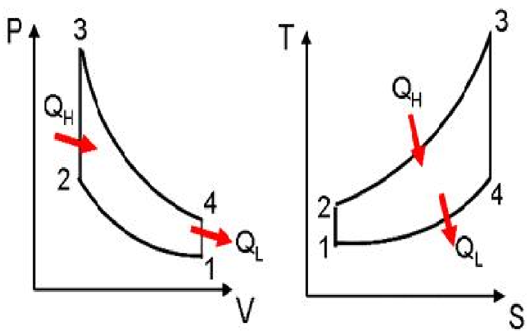

Fig:-P-V And T-S Diagram of Otto Cycle

B. Diesel Cycle

Most truck and automotive diesel engines use a cycle reminiscent of a four-stroke cycle, but with a compression heating ignition system, rather than needing a separate ignition system. This variation is called the diesel cycle. In the diesel cycle, diesel fuel is injected directly into the cylinder so that combustion occurs at constant pressure, as the piston moves.

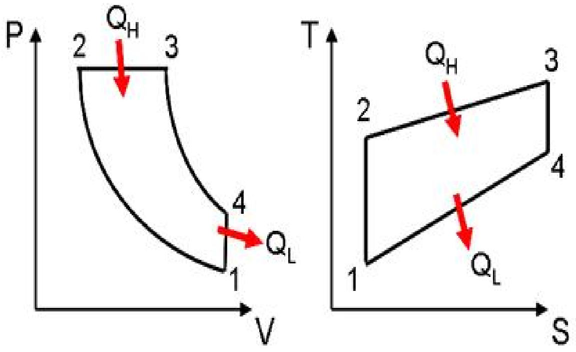

Fig:- P-V And T-S Diagram of Diesel cycle.

4. MEASURES OF ENGINE PERFORMANCE

Engine types vary greatly in a number of different ways:

a. Energy efficiency.

b.Fuel/Propellant consumption (brake specific fuel consumption for shaft engines, thrust specific fuel consumption for jet engines)

c. Power to weight ratio.

d. Thrust to weight ratio

e.Torque curves (for shaft engines) thrust lapse (jet engines).

A. Energy efficiency

Once ignited and burnt, the combustion products—hot gases—have more available thermal energy than the original compressed fuel-air mixture (which had higher chemical energy). The available energy is manifested as high temperature and pressure that can be translated into work by the engine. In a reciprocating engine, the high-pressure gases inside the cylinders drive the engine's pistons.

B. Measures of fuel efficiency and propellant efficiency

For stationary and shaft engines including propeller engines, fuel consumption is measured by calculating the brake specific fuel consumption, which measures the mass flow rate of fuel consumption divided by the power produced.

For internal combustion engines in the form of jet engines, the power output varies drastically with airspeed and a less variable measure is used: thrust specific fuel consumption (TSFC), which is the mass of propellant needed to generate impulses that is measured in either pound force-hour or the grams of propellant needed to generate an impulse that measures one kilonewton-second. For rockets, TSFC can be used, but typically other equivalent measures are traditionally used, such as specific impulse and effective exhaust velocity.

5. APPLICATIONS

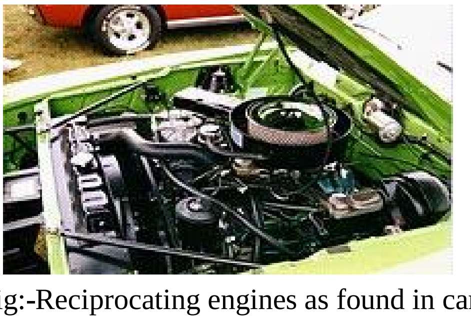

Fig:-Reciprocating engines as found in car

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Reciprocating piston engines are by far the most common power source for land and water vehicles, including automobiles, motorcycles, ships and to a lesser extent, locomotives (some are electrical but most use Diesel engines[5][6]). Rotary engines of the Wankel design are used in some automobiles, aircraft and motorcycles.

Where very high power-to-weight ratios are required, internal combustion engines appear in the form of combustion turbines or Wankel engines. Powered aircraft typically uses an ICE which may be a reciprocating engine. Airplanes can instead use jet engines and helicopters can instead employ turboshafts; both of which are types of turbines.

Fig:-Big Diesel Generator Used For Backup Power

Fig:-Combined cycle power plant

ICEs drive some of the large electric generators that power electrical grids. They are found in the form of combustion turbines in combined cycle power plants with a typical electrical output in the range of 100 MW to 1 GW.

Small engines (usually 2-stroke gasoline engines) are a common power source for lawnmowers, string trimmers, chain saws, leafblowers, pressure washers, snowmobiles, jet skis, outboard motors, mopeds, and motorcycles.

6. ADVANTAGES

a. An internal combustion engine (or petrol engine) is smaller and lighter. On the other hand, an external combustion engine (or steam engine) is big and heavy.

b. An internal combustion engine (or petrol engine) can be started at once at a moment's notice. On the other hand, an external combustion engine (or steam engine) takes a long time to start.

c. An internal combustion engine (or petrol engine) is quite safe to use. On the other hand, an external combustion engine (or steam engine) is not very safe to use.

d. An internal combustion engine (or petrol engine) has higher efficiency. On the other hand an external combustion engine (or steam engine) has a lower efficiency.

7. CONCLUSION

Internal combustion engines are among the most important engineering applications. The theory of application either depends on Diesel or Otto cycles. They are categorized either according to the operating cycle, or due to the mechanism of working. Each type of engines has some advantages over the other one. Thus, the selection of the appropriate engine requires determining the conditions of application.

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