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Spark Ignition and Compression Ignition engines

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Abstract -An engine or motor is a machine designed to convert one form of energy into mechanical energy. Heat engines, like the internal combustion engine, burn a fuel to create heat which is then used to do work. The classification of the engines depends upon the types of fuel used, cycle of operation, number of strokes, type of ignition, number of cylinders, arrangement of cylinders, valve arrangement etc. these engines are used in different areas such as in automotive industries, aircraft industries, marine industries, etc. according to their suitability they are used in different areas. Basically, there are two types of heat engines they are external combustion engine and internal combustion engine. In external combustion engine the fuel is burn outside the engine cylinder and then the generated heat is transferred working fluid but where as in internal combustion engine the ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work.There are two kinds of internal combustion engines currently in production they are spark ignition (SI) and the compression ignition (CI). Further research is needed to identify the internal components, working and differences between these engines.

Key Words:Spark ignition engine, Compression ignition engine, internal components, working principle, Differences, Applications.

1.INTRODUCTION *(Size 11, Times New roman)*

Internal combustion engines provide outstanding drivability and durability, with more than 250 million highway transportation vehicles in the United States relying on them. Along with gasoline or diesel, they can also utilize renewable or alternative fuels like natural gas, propane, biodiesel, or ethanol etc. They can also be combined with hybrid electric powertrains to increase fuel economy or plug-in hybrid electric systems to extend the range of hybrid electric vehicles.

Internal combustion engines are used in applications ranging from marine propulsion and power generating sets with capacity exceeding 100 MW to hand-held tools where the power delivered is less than 100 W. This implies that the size and characteristics of today's engines vary widely between large diesels having cylinder bores exceeding 1,000 mm and reciprocating at speeds as low as 100 rpm to small gasoline two-stroke engines with cylinder bores around20 mm. Within these two extremes lie medium-speed diesel engines, heavy-duty automotive diesels, truck and passenger car engines, aircraft engines, motorcycle engines and small industrial engines. From all these types, the passenger car gasoline and diesel engines have a prominent position since they are, by far, the largest produced engines in the world; as such, their influence on social and economic life is of paramount importance. Internal combustion engines dominate power plants in transportation today due to the high energy density of liquid petroleum fuels and continuous improvement in efficiency and reduction of emissions. Furthermore, their existence and improvements since the 20th century has helped to define their longevity, durability, and promote their acceptance in society. That being said internal combustion engines have developed to the current point with numerous limitations and trade-offs because of fuel and emissions.

There are two types of IC engines: rotary and reciprocating engines. In rotary engines, a rotor rotates inside the engine to produce power. In the case of the reciprocating engines, a piston reciprocates within a cylinder. The reciprocating motion of the piston is converted into the rotary motion of the vehicle's wheels. In automobiles, reciprocating engines are used. They are the most widely used type of engine.

Reciprocating engines are classified into two types: spark ignition (SI) engines and compression ignition (CI) engines. Since reciprocating engines are the most widely used engines, they have become synonymous with the name IC engines. It is this reason that even the IC engines are broadly classified into two types: SI engines and CI engines.

In SI engines the burning of fuel occurs by a spark generated by the spark plug located in the cylinder head of engine. Due to this fact they are called spark ignition engines. In these engines the fuel used is petrol or gasoline, hence SI engines are also known as Petrol or Gasoline Engines.

In the case of CI engines, burning of the fuel occurs because of the high pressure exerted on the fuel. The fuel is compressed to high pressures and it starts burning, hence these engines are called compression ignition engines. In CI engines the fuel used is diesel, hence they are also called Diesel engines.

The SI and CI engines are either two stroke or four stroke engines. In the case of the two-stroke engine, for every two strokes of the piston inside the cylinder the fuel is burnt. This means for every single rotation of the wheel the fuel is burnt. In the case of four-stroke engines, the fuel is burnt for every four strokes of the piston inside the cylinder. That means each time the fuel is burnt there are two rotations of the wheels of the vehicle. The stroke is the distance travelled by the piston inside the cylinder; it is usually equal to the length of the cylinder.

Since the 4-stroke engines produce two rotations while 2-stroke engine produces single rotation each time the fuel is burnt, the efficiency of 4-stroke engines is greater than in 2-stroke engines. Ideally the efficiency of 4-stroke engine should be double of 2-stroke engine, but in actuality it is never so. The following shows the internal components of spark ignition (SI) engine and compression ignition (CI) engine and their working.

2. Spark Ignition (SI) engine

Spark Ignition (SI) Engine is a type of engine in which the combustion takes place by the spark generated by the spark plug. It uses petrol as fuel and works on Otto cycle. In the spark ignition engine, the air fuel mixture is inserted into the cylinder with help of carburetor. The compression of the fuel takes place but it has low compression ratio. The fuel is ignited by the spark generated by the spark plug. SI engine produces less noise and vibration and their starting is very easy. They are light in weight and have less maintenance cost. They are mostly used in light commercial vehicles such as scooters, motorcycles cars etc.

3 Compression Ignition (CI) engine

Spark Ignition (SI) Engine is a type of engine in which the combustion takes place by the spark generated by the spark plug. It uses petrol as fuel and works on Otto cycle. In the spark ignition engine, the air fuel mixture is inserted into the cylinder with help of carburetor. The compression of the fuel takes place but it has low compression ratio. The fuel is ignited by the spark generated by the spark plug. SI engine produces less noise and vibration and their starting is very easy. They are light in weight and have less maintenance cost. They are mostly used in light commercial vehicles such as scooters, motorcycles cars etc.

4 Internal components

4.1 Spark Ignition (SI) engine

The main components of spark ignition engine are as follows

1. **Inlet Valve:** Air-fuel mixture enters into cylinder through inlet valve.
2. **Exhaust Valve:** The burnt or exhaust gases produced in the power stroke escapes out through exhaust valve.
3. **Spark Plug:** It produces spark at the end of the compression stroke, which ignites the compressed air-fuel mixture.
4. **Cylinder:** It is a hollow cylinder in which the piston reciprocates.
5. **Piston:** It is moving part of the engine that performs reciprocating motion and transmits the power generated during power stroke to the crankshaft through connecting rod.
6. **Connecting Rod:** It is that part of the engine which connects the piston to the crankshaft.
7. **Crankshaft:** It is used to convert the reciprocating motion of the engine into rotary motion.

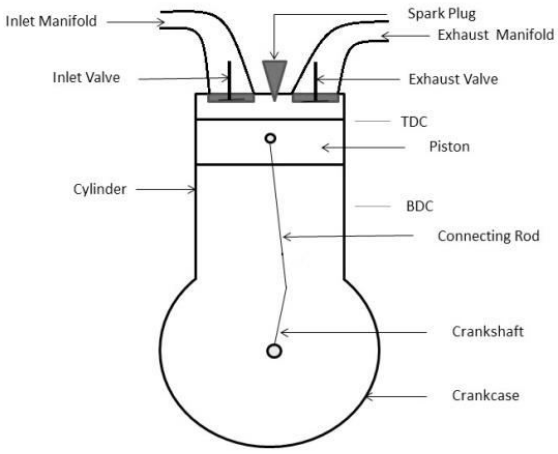

Fig -1: Spark ignition engine

4.2 Ignition combustion (IC) engine

The main components of compression ignition (CI) engine are

1. **Injector:** It is used to inject the fuel into the cylinder during compression of air.
2. **Inlet valve:** The air inside the cylinder is sucked through inlet valve during suction stroke.
3. **Exhaust Valve:** The whole burnt or exhaust from the cylinder thrown out through exhaust valve.
4. **Combustion chamber:** It is a chamber where the combustion of fuel takes place.
5. **Piston:** It is reciprocating part of CI engine which does reciprocating motion inside the cylinder. Its main function is to transmit the thrust force generated during power stroke to the crankshaft through connecting rod.
6. **Connecting rod:** It connects piston to the crankshaft.
7. **Crankshaft:** It is used to convert the reciprocating motion of the piston into rotary motion.

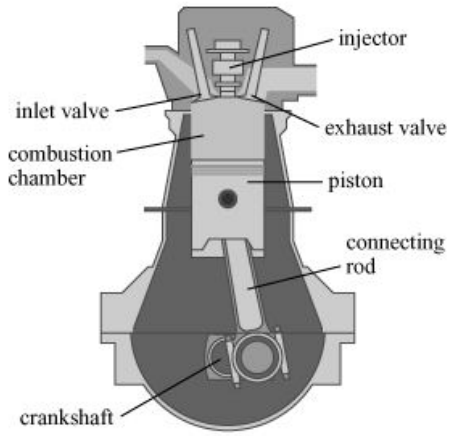

Fig -2: Compression ignition engine

5 Working

5.1 Working of Spark Ignition (SI) engine

Spark ignition (SI) engine is of divided into two types based on number of strokes, they are two stroke and four stroke engines. Most of these are four-stroke cycle engines, meaning four piston strokes are needed to complete a cycle. But in two stroke engines the cycle is completed in two piston strokes.

5.2 Principle of a four stroke Spark Ignition (SI) engine

The principle used in a four-stroke petrol engine is commonly known as Otto Cycle. It states that there would be one power stroke for every four strokes. Such engines use a spark plug which is used for the ignition of the combustible fuel used in the engine. Most of the cars, bikes and trucks use four stroke engines. In every cycle there is an adiabatic compression, addition of heat at constant volume, an adiabatic expansion and the release of heat at constant volume. The P-V diagram for a 4-stroke engine is as follows:

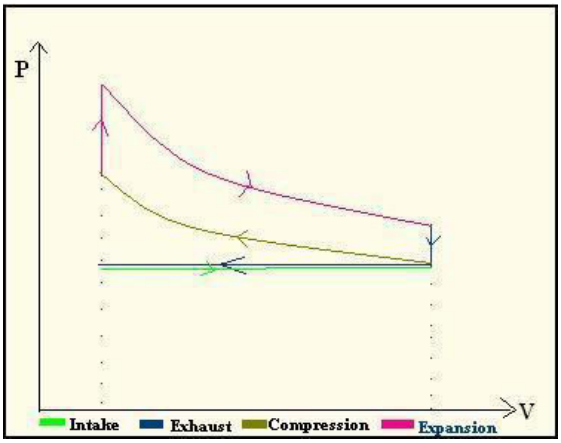

Fig -3: P-V Diagram of four stroke engine

In four stroke SI engine, the cycle of operations is completed is completed in four strokes of piston. Each stroke has a 180^o of crankshaft rotation and hence a four-stroke cycle is completed by 720^o of crank rotation. An ideal four stroke SI engine has the following strokes.

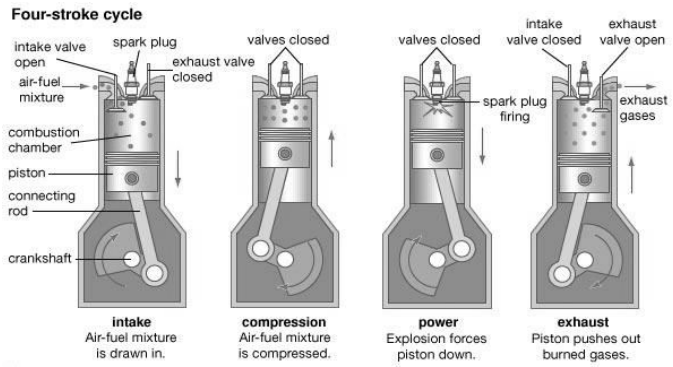

Fig -4: Four stroke cycle

1. **Suction or Intake stroke:**The suction stroke starts when piston is at top dead Centre (TDC) and move towards bottom dead Centre (BDC). The inlet valve is opened and exhaust valve is closed. The Fuel air-mixture is drawn by the suction created in the cylinder by the downward motion of piston. The suction stroke ends when piston reaches BDC and inlet valve is closed.
2. **Compression stroke:** It starts when the piston moves upwards towards TDC by the return stroke compressing the charge in the cylinder. Both inlet and exhaust valves are closed in this stroke. The entire charge is compressed into the clearance volume by the piston. At the end of the stroke, the charge is ignited with the help of spark plug placed on the cylinder head. In ideal engines, the burning process is approximated as heat added at constant volume. During combustion of fuel, the chemical energy of fuel is converted to heat energy increasing the temperature up to 2000^o Celsius. The pressure is also increased considerably.
3. **Expansion or Power stroke:** In this stroke, the piston moves towards the BDC due to the high pressure of the burnt gases. Both inlet and exhaust valves are closed in this stroke. In this stroke, power is produced among the four strokes. Both pressure and temperature increase during power stroke.
4. **Exhaust stroke:** At the end of expansion stroke, the inlet valve is remained closed and exhaust valve is opened due to which pressure of burnt gases reduces to atmospheric level. As the piston moves towards TDC, the remaining burnt gases are forced out of the cylinder. Exhaust valve is closed as the piston reaches TDC.

5.3 Principle of a two stroke Spark Ignition (SI) engine

A cycle completed in two strokes of piston rather than four strokes is called as two stroke cycle engine. In this engine, suction and exhaust strokes are eliminated and instead of valves, ports are used. The exhaust gases are driven out from cylinder by a charge of fuel entering the cylinder at the end of working stroke.

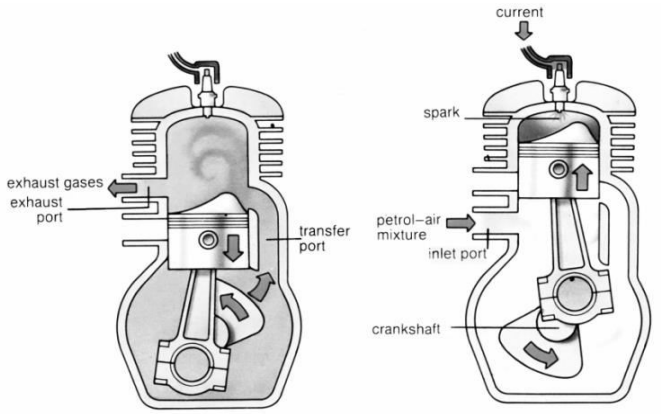

Fig -5: Two stroke cycle

1. **Down Stroke:** First the piston is moved downwards from TDC to BDC to let the fresh air enter into the combustion chamber. The fresh air-fuel mixture gets into the combustion chamber through crankcase. Crankshaft rotation – 180°
2. **Up Stroke:** The piston is moved upwards from BDC to TDC. The fuel-air mixture gets compressed & spark plug ignites the mixture. As the mixture gets expanded, the piston moves down. During up stroke, the inlet port is opened. While this inlet port is opened, the mixture gets sucked inside the crankcase. When the mixture is pushed up into the combustion chamber during the previous up stroke, a partial vacuum is created as no mixture is left behind in the crankcase. This mixture is ready to go into the combustion chamber during down stroke but remains in the crankcase until the piston goes up till TDC. Crankshaft rotation – 360°. Thus, two strokes get completed along with one power cycle.

5.4 Working of Compression Ignition (CI) engine

The basic construction of four stroke CI engine is same as that of four stroke SI engine except that, instead of spark plug used in SI engine, a fuel injector is used in CI engine. In CI engine, only air is taken into the cylinder during suction stroke. The injector supplies high pressure atomized fuel into the engine cylinder. It works on the principle of diesel cycle.

5.5 Principle of a four stroke Compression Ignition (CI) engine

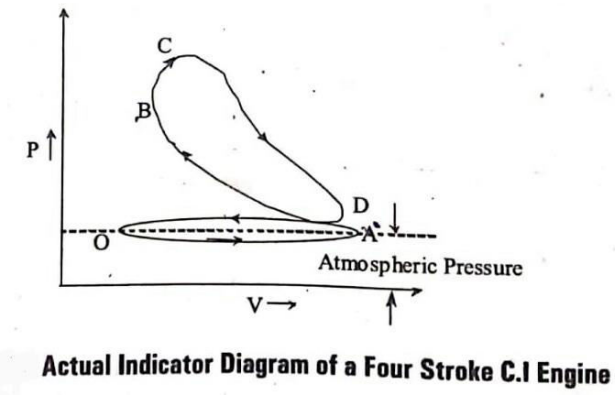

Fig -6: P-V Diagram of four stroke compression ignition engine

The principle used in a four-stroke Diesel engine is commonly known as diesel cycle. It is also known as constant heat addition cycle. The Diesel cycle is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected.

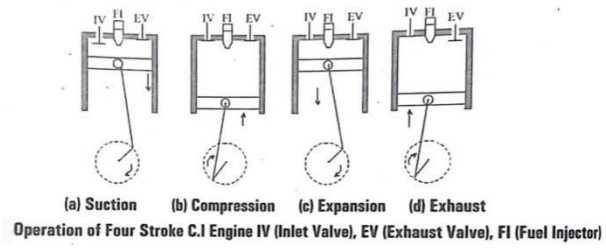

Fig -7: Four stroke cycle of compression ignition engine

The sequence of operation of four stroke engine is as follows

1 **Suction stroke:** During this process, piston moves from TDC to BDC position, performing intake stroke. At this time, the inlet valve is open and the exhaust valve is in closed position. Due to these downward movements of the piston, partial vacuum is created inside the cylinder. Due to this vacuum, a metered quantity of air enters into the engine cylinder. The process is shown by curve O-A.

2 **Compression stroke:** During compression stroke, the piston moves from BDC to TDC resulting in compression of air present in the cylinder. At this time, both the inlet and exhaust valves are in closed position. Due to this, the volume of charge in the cylinder reduces the compression ratio, usually ranges from 12 to 24. Therefore, compression increases the pressure and temperature of the air. The pressure of the air after compression will be about 35

bar and the temperature ranges from 600° Celsius to 700° Celsius. During compression stroke, work is done by the piston on the air inside the cylinder. This process is represented on indicator diagram by curve A-B.

Before the end of compression stroke, fuel injector injects the fuel in the form of fine atomized spray. Due to this, the fuel ignites has the temperature of the air is too high to self-ignite the fuel. This increases the pressure inside the cylinder rapidly. It is represented on the indicator diagram by curve B-C.

3 **Expansion stroke:** As the piston reaches TDC position, the ignited mixture tends to expand. The expansion causes the piston to move downwards. At this time, both inlet and exhaust valves are in closed position. During this process, work is done on the piston by expanding gases resulting in power stroke. Due to this, both temperature and pressure reduces as shown in the indicator diagram by curve C-D.

4 **Exhaust stroke:** After expansion stroke, the piston tends to raise I.e. moves upwards from BDC to TDC. At this time, the exhaust valves opens and the inlet valve is in closed position. This upward movement of the piston forces the burnt gases through the exhaust valve. It is represented in the indicator diagram by the curve D-O. This completes the cycle and repeated for the effective running of engine.

6 Differences between SI and CI engines

The Table below shows some important differences between Spark ignition engine (SI) and Compression ignition engine (CI).

Table -1: Difference between Spark ignition and compression engines.

S.no	Parameter	SI Engine	CI Engine
1	**Definition**	It is an engine in which the spark is used to burn the fuel.	It is an engine in which heat of compressed air is used to burn the fuel.
2	**Thermal efficiency**	High thermal efficiency.	Less thermal efficiency.
3	**Compression ratio**	Low compression ratio.	High compression ratio.
4	**Fuel used**	Petrol is used as fuel.	Diesel is used as fuel.
5	**Operating cycle**	It operates on Otto cycle.	It operates on Diesel cycle.
6	**Constant parameter during cycle**	Constant volume cycle.	Constant pressure cycle.
7	**Method of ignition**	Spark plug is used to produce spark for the ignition.	Heat of compressed air is used for the ignition.
8	**Pressure generated**	Low pressure is generated after combustion.	High pressure is generated after combustion.
9	**Engine Speed**	High speed engines.	Low speed engines.
10.	**Emission of hydrocarbons**	Fewer Hydrocarbons are emitted.	More hydrocarbons are emitted.
11	**Intake**	Air + fuel.	Only air.
12	**Weight of engine**	Si engine has less weight.	CI engine are heavier.
13	**Noise production**	It produces less noise.	It produces more noise.
14	**Starting**	The starting of SI engine is easy.	The starting of CI engine is difficult.
15	**Fuel supply**	Carburetor	Injector
16	**Maintenance cost**	Low	High
17	**Volume to power ratio**	Less	High
18	**Cost of engine**	Less cost	High cost
19	**Vibration problem**	Less	Very High

7 Applications

Internal combustions engines like SI and CI engines are widely used in many places like

1. Automotive: cars, motorcycles, scooters, tractors, bikes etc.
2. Locomotives
3. Aircrafts
4. Marine: Outboard, inboard, ships and motor boats.
5. Power generators: portable (Domestic) and fixed (peak power).
6. Agriculture: Tractors,pump sets.
7. Earthmoving: Dumpers, Tippers, mining equipment etc.
8. Home use: Lawnmowers, Snow blowers etc.

8 Conclusions

Compression ignition (CI) Engine or diesel engine produces better output or efficiency than spark ignition engine because of the property of the fuel Diesel is not a volatile fuel, which means, it burns gradually during the power stroke. Now, that helps in thorough combustion of the air-fuel mixture. Additionally, diesel engines run of lean mixture (air>fuel) which helps in burning the fuel properly due to the higher oxygen content in the combustion chamber and by boosting the engine with a turbocharger or a supercharger, efficiency can be further improved.

Diesel engines compared to petrol engines have a longer stroke length which gives the air-fuel mixture just enough time to burn evenly as well. Another valid point is that, Compression ratio is directly proportional to thermal efficiency. Now, diesel engines have higher compression ratio (16:1 to 22:1) than petrol engines (7:1 to 12.5:1) which improves the combustion efficiency significantly. Thus, enhancing the overall efficiency of an engine. But Diesel produces more CO_2 emissions per liter of fuel burnt, about 17% more than Petrol.

In automotive, typically a diesel car has about 25% more mileage than an equivalent capacity petrol car, because the diesel burns much slower than petrol and also diesel fuel is more energy rich than petrol. It has 38.8 Mega Joules of energy per litter whereas the petrol has only 34.8 Mega Joules of energy per litter. The compression ratio of diesel engine 16:1 to 22:1, whereas in petrol engine the compression ratio is 7:1 to 12.5:1, which means more chemical energy is converted into mechanical energy in diesel engine due to high compression ratio. Thus, a diesel engine has more efficiency and gives more mileage than petrol or SI engines.

Diesel engines have better mechanical advantage than petrol engines and can develop higher torque. Since, more torque is generated at lower rpm in diesel engine; the car can easily drive away without increasing the engine speed too much and thereby increases fuel economy. Maintenance cost is more in diesel engine than compared to petrol engine.

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