IJAAR PUBLISHING® DOI: 10.46654
International Journal of Advanced Academic Research (Sciences & Technology) | ISSN: **2488-9849**
Vol. 1, Issue 2 (November, 2015) | www.ijaar.org

A DETAILED EVALUATION OF INTERNAL COMBUSTION AUTOMOTIVE ENGINES

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ABSTRACT

This study is focused on the performance evaluation of internal combustion automotives such as spark ignition and compression ignition engines. Specifically, the study examined the working principles of spark ignition and compression engines, the performance of spark and compression ignition engines and the type of fuel used by both engines. It was concluded that diesel engines consumes less fuel than spark engines, it is more reliable, noisier in operation and safer in terms of fire accident. Furthermore, the study revealed that spark ignition engines produces more speed, less expensive and quieter in operation. However, the study recommended that the injector should be used with petrol in order to improve its speed and also, injectors should be properly mounted on its seating to avoid vibration and noise.

Keywords: Automotive, Compression ignition, Engines, Spark ignition, Internal Combustion.

INTRODUCTION

The quest for easy and faster means of achieving goals and objectives necessitates the introduction of an alternative means to the manual force earlier used by ancient generations. This is one of the reasons why machines and engines were introduced. According to oxford dictionary (2015), machine is any device with several parts, using mechanical power to perform a particular task. Most machines functions with engines. In automobile industries for instance, the basic function of an engine is to convert chemical energy (the fuel) into mechanical energy and to produce usable power and torque (this is the ability to turn the driving wheels and move the vehicle). There are two classes of engine, namely; external engine and internal engine. The former is a kind of engine that fuel is generated away from the engine, for example, steam and locomotive engines. The later is the kind of engine that fuel is heated inside the engine cylinders and heat liberated by combustion is converted wholly into mechanical energy (Olisa, 2000). The common types include; spark ignition engines and compression ignition engines.

The term spark ignition is used to describe the system with which the air-fuel mixture inside the combustion chamber of an internal combustion engine is ignited by a spark. It is a process that uses an electrical field induced in a magneto or coil. The field builds too many thousands of volts and then is collapsed via a timed circuit. The resulting surge of current travels along a wire and terminates at the spark plug inside the combustion chamber. An electrical spark occurs as the charge tries to jump the precision gap at the tip of the spark plug at exactly the moment a precisely metered mixture of fuel and air has been thoroughly compressed in the combustion chamber. The resulting controlled explosion delivers the power to turn the reciprocating mass inside the engine. This type of engine is known to be very light, economical and the production of high speed. However, this type of engine has its weakness that relegates it to the back bench for some persons.

Compression ignition engine is a type of internal-combustion engine, such as a diesel, in which ignition occurs as a result of the rise in temperature caused by compression of the mixture in the cylinder. Ignition is achieved by spraying diesel into highly compressed air (Wodi, 2005). This type of engine was previously used mainly for heavy duty vehicles due to its ability to produce high torque that is required to power these types of vehicles. However, this type of engine has its own irregularities that make it impossible for some persons to prefer using it. Basically, due to the irregularities of these engines some persons prefer one to the other while some prefer the other.

Today, it is notable that these two engines are the common types of engines in automobile industries. It is either spark ignition or compression ignition. Therefore, it will be very pertinent to be familiarized with the operations of these engines to remedy the ignorance associated with their operations. It is on this background that the researcher decided to compare the performance of spark and compression ignition engines in an automobile layout.

STATEMENT OF PROBLEM

The invention of car as a means of transportation in the world has eased the stress of travelling from one part of a country to another. It has also contributed in transferring goods from one place to another. This is a very useful product that the world cannot comfortably do without. Ever since its invention, the automobile industry has been going through one transformation to another ranging from; restructuring of automobile bodies to design of engines. Notable among the engine designs that are common today is the internal combustion engines, such as; spark ignition and compressed ignition engines (Wodi, 2005). These

engines have their strength and weakness which makes them preferred by some users and disliked by the other. This is one of the reasons why people find it very difficult to select engine type when they want to purchase a car. There is always a problem of selecting the engine that is efficient, has high speed, economical, cheap, reliable, and so on. This confusion brings some desperate buyers into the hands of those that can dupe them or lure them into buying a car that cannot satisfy their taste and wants. Basically, it will be very necessary to have knowledge about the weakness and strength of the engine designs that are common in automobile industries.

PURPOSE OF STUDY

The purpose of the study is to compare the performance of spark ignition and compressed ignition engines in an automobile layout. Specifically, the study will examine the following;

- The working principle of spark ignition engine
- The working principle of compressed ignition engine
- The performance of spark ignition engine
- The performance of compression ignition engine.

INTERNAL COMBUSTION ENGINE

An internal combustion engine (ICE) is a heat engine where the combustion of fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit (Wikipedia, 2015). According to Olisa (2000), an internal engine is a kind of engine where air-fuel combustion takes place inside the engine cylinders and the heat liberated by combustion is converted wholly into mechanical energy.

In an internal combustion engine (ICE), the ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work. The engine consists of a fixed cylinder and a moving piston. The expanding combustion gases push the piston, which in turn rotates the crankshaft and ultimately, through a system of gears in the power train and finally drives the vehicle's wheels.

CONSTRUCTIONAL FEATURES OF INTERNAL COMBUSTION ENGINE

A brief description of the parts of an internal combustion engine is given below.

1. Cylinder

The cylinder of an IC engine constitutes the basic and supporting portion of the engine power unit. Its major function is to provide space in which the piston can operate to draw in the fuel mixture or air (depending if it is spark ignition or compression ignition), compresses it, allow it to expand and thus generate power. The cylinder is usually made of high-grade cast iron. In some cases, to give greater strength and wear resistance with less weight, chromium, nickel and molybdenum are added to the cast iron.

2. Piston

The piston of an engine is the first part to begin movement and to transmit power to the crankshaft as a result of the pressure and energy generated by the combustion of the fuel. It converts the rotary motion of the crankshaft to a linear or reciprocating motion through the gudgeon pin. The piston is closed at one end and open on the other end to permit direct attachment of the connecting rod and its free action. The materials used for pistons are grey cast iron, cast steel and aluminium alloy. However, the modern trend is to use only aluminium alloy pistons in the tractor engine. According to Olisa (2000), the main functions of piston are as follows:

I. It acts as a gas tight plunder which moves up and down the cylinder.
II. It transmits force to the crankshaft through the connecting rod during power stroke.
III. Forms a guide and a bearing for the small end of connecting rod.
IV. It takes the side thrust caused by angularity of the crank pin and connecting rod assembly.

3. Piston Rings

Piston rings are made of cast iron with chromium-plated outer face. It is splited to enable the ring to be assembled onto the piston.Functions of piston rings according to Olisa (2000) includes;

I. To transfer heat from the piston crown to the cylinder
II. To maintain a gas tight seal between the piston and the cylinder walls
III. It prevents lubricating oil from passing out to combustion chamber.

4. Piston Pin

The connecting rod is connected to the piston through the piston pin. It is made of case hardened alloy steel with precision finish. There are three different methods to connect the piston to the connecting rod.

5. Connecting Rod

The con-rod connects the piston to the crankshaft. Its action converts the linear movement of the piston into the rotary movement of the crankshaft. The end connecting the piston is Known as small endand the other end is known as big end.

6. Crankshaft

This is connected to the piston through the connecting rod and converts the linear motion of the piston into the rotational motion of the flywheel.

7. Valves

Valves used in the internal combustion engines controls the flow of gases into and out of the cylinders and combustion chamber at the appropriate time. Four types of valve construction are used in the internal combustion engines; poppet, slide, sleeve and rotary (Olisa, 2000). However, poppet valve is more commonly used. High tensile alloy steel is used in making valves.

8. Camshaft

The valves are operated by the action of the camshaft, which has separate cams for the inlet, and exhaust valves. The cam lifts the valve against the pressure of the spring and as soon as it changes position the spring closes the valve. The cam gets drive through eitherthe gear or sprocket and chain system from the crankshaft. It rotates at half the speed of the camshaft.

9. Flywheel

The flywheel stores up energy and assists in carrying the engine over its three idling strokes (induction, compression and exhaust).

TYPES OF INTERNAL COMBUSTION ENGINE

There are two kinds of internal combustion engines currently in production: the spark ignition gasoline engine and the compression ignition diesel engine.

1. Spark ignition engine

This is the more commonly known of the two major types of internal combustion engines (Wodi, 2005). This refers to the type of engine where the combustion process of air-fuel mixtures is ignited by a spark from spark plug. They are commonly referred to as "gasoline engines" in American, and "petrol engines" in Britain and the rest of the world (Wikipedia, 2015). However, these terms are not preferred since spark ignition engines can (and increasingly are) run on fuels other than petrol/gasoline, such as auto gas LNG, methanol, ethanol, bio-ethanol, compressed natural gas (CNG), hydrogen, and (in drag racing) nitro methane (Wikipedia, 2015).

2. Compression ignition engine

This is the other popular internal combustion engine which does not require spark plugs and distributor to initiate the combustion as in the spark ignition engine (Wodi, 2006). Furthermore, Wodi (2006) stated that ignition is achieved by spraying diesel into highly compressed air. When the air in the cylinder is compressed to about 1/16 of its volume, it attains a temperature high enough to cause an explosion when diesel is sprayed into it.

The first man who had invented the engine with ignition from compression was E. Steward. He was interested in engines that can work without spark plugs. In Stewards engines the air was blown into the combustion chamber unfortunately, Steward has not come into mind to test the efficiency of that type of engines. Developing the concept of "economy-type heat-engines", Rudolph Diesel in 1890 invented the engine much more efficient due to high compression ratio. In Rudolph Diesel type of engine, heat generated from compression is enough to initiate the combustion process without needing any external spark.

However, the working cycle of both spark ignition and compression ignition engines may be two strokes or four strokes. A four stroke spark ignition engine is an Otto cycle engine. It consists of the following four strokes: suction or intake stroke, compression stroke, expansion or power stroke, exhaust stroke. Each stroke consists of 180 degree rotation of crankshaft rotation and hence a four stroke cycle is completed through 720 degree of cranks rotation. Thus, for one complete cycle there is only one power stroke while the crankshaft turns by two revolutions.

WORKING PRINCIPLES OF FOUR STROKES SPARK AND COMPRESSION IGNITION ENGINES

For engines to work properly, it has to perform some cycle of operations continuously. The principle of operation of the spark ignition (SI) engine was invented by Nicolaus, A. Otto in the year 1876; hence SI engine is also called the Otto engine (Zeleznik & Mcbribe, 2011). The principle of working of compression ignition engine (CI) was found out by Rudolph Diesel in the year 1892, hence CI engine is also called diesel engine.

However, the principle of working of both SI and CI engines are almost the same, except the process of the fuel combustion that occurs in both engines. In SI engines, the burning of fuel occurs by the spark generated by the spark plug located in the cylinder head. The fuel is compressed to high pressures and its combustion takes place at a constant volume. In CI engines the burning of the fuel occurs due to compression of the fuel to excessively high pressure which does not require any spark to initiate the ignition of fuel. In this case the combustion of fuel occurs at constant pressure. Both engines can work either on two strokes or four strokes.

THE OPERATION OF FOUR STROKE CYCLES

1. Suction (intake) stroke

This is the first stroke of the engine. During this stroke the piston is moved downward from Top Dead Centre by means of crankshaft which is rotated by electric motor. This movement increases the size of combustion space thereby reducing the pressure inside the cylinder as against the higher pressure of the outside atmosphere. This forces the air into combustion space through suction valve. The exhaust valve remains closed in this stroke while the piston moves downward towards Bottom Dead Center (BDC).

During the piston's suction stroke in the SI engines, a mixture of air and fuel is injected from cylinder head portion of the cylinder. The air-fuel mixture is injected via the carburettor that controls the quantity and the quality of the injected mixture. In CI engines, fuel is injected into the combustion chamber towards the end of the compression stroke. The fuel starts burning instantly due to the high pressure. To inject diesel in CI engines, a fuel pump and injector are required. In CI engines, the quantity of fuel to be injected is controlled but the quantity of air to be injected is not controlled.

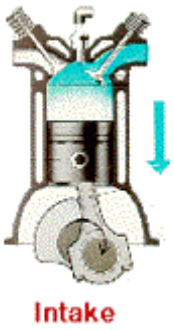

Figure 1

2. Compression Stroke

This is the second stroke of the engine. It is gotten from the word compress. The air-fuel mixture is compressed during the upward movement of the piston in spark ignition. While in compression ignition the air is compressed to a very high pressure. The pressure of the compressed gas increases, thereby preparing the gas for combustion. Combustion takes place a little before the end of compression phase. This is made possible through the initiation of spark by the spark plug for spark ignition, while in compression ignition the spark is initiated by the injector (Olisa, 2000 &Wodi, 2006). Combustion increases the temperature of the gas. During this stroke suction and exhaust valve remain closed while the piston moves upward.

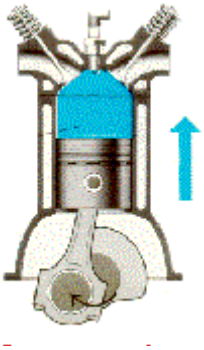

Figure 2

3. Power stroke

This is the third stoke of the engine. At the end of the compression stroke a spark occurs at the sparking plug or at the spray of fuel by the injector. This ignites the mixture which burns very radically heating the gas to a very high temperature which also raise its pressure. This forces the piston down the cylinder. During this stroke, the piston moves downward while the two valves remains closed.

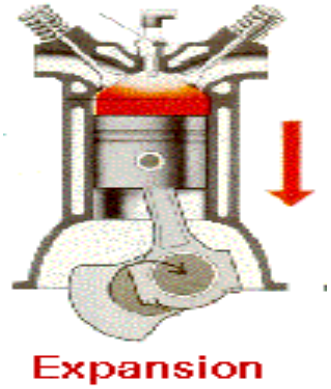

Figure 3

4. Exhaust stroke

This is the fourth stoke of the engine. As the piston begins to rise after reaching BDC during the power stoke, the exhaust valve opens and the spent gases are forced out of the cylinder.

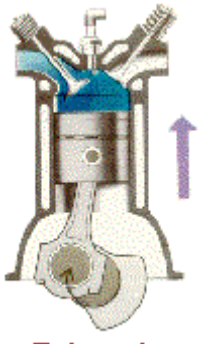

Figure 4

The cycles of suction, compression, power and exhaust operates on a continuous basis all the time the engine is running. As can be seen the complete cycle of the operations of a stroke engine occupies two complete revolutions of the crankshaft. The SI engines draw into the cylinder a mixture of petrol and air which is compressed and burnt while the compression ignition draws air into the cylinder.

DIFFERENCE BETWEEN SPARK AND COMPRESSION IGNITION ENGINES

S/No	Spark Ignition	Compression Ignition
1	air- petrol mixture is suck into the cylinder during the suction stroke	only air is suck into the cylinder during sucking stroke.
2	spark plug is used	employs an injector
3	power is produced by park plug (ignition)	power is produced by compression
4	occupies less space	occupies more space
5	works on the principle of Otto cycle	work on diesel engine cycle
6	more running cost	less running cost

COMPARISON OF THE PERFORMANCE EVALUATION OF SPARK AND COMPRESSION IGNITION ENGINES

This is discussed under the following; fuel economy, power and torque, reliability, pollution, safety, start up and maintenance.

- **Fuel economy**

The chief comparison to be made between the two types of engines is how effectively each engine can convert the liquid fuel into work energy. Different engines are compared by their thermal efficiencies. Thermal efficiency is the ratio of the useful work produced to the total

energy supplied. Spark engines can have thermal efficiencies ranging between 20% and 30%. The corresponding diesel engines generally have improved efficiencies between 30% and 40%. Both sets of efficiency values are considerably influenced by the chosen compression ratio and design.

- **Power and torque**

The spark engine is usually designed with a short stroke and operates over a much larger crankshaft speed range than the diesel engine. This enables more power to be develop towards the upper speed range in the spark engine which is necessary for high road speeds, however, a long stroke diesel engine has improved pulling torque over a relatively narrow speed range, this being essential for the haulage of heavy commercial vehicles.

- **Reliability**

Due to their particular process of combustion, diesel engines are built sturdier, tend to run cooler and have only half the speed range of the most spark engines. These factors make the diesel engine more reliable and considerably extend engine life relatively to the spark engines.

- **Pollution**

Diesel engine tends to become noisy and vibrate on their mountings as the operating pad is reduced. The combustion process is quieter in spark engine and it runs smoother than the diesel engine. There is no noisy injection equipment used on the spark engine unlike that necessary on the diesel engine. The products of combusting coming out of the exhaust system are more noticeable with diesel engines, particularly if any of the injection equipment components are out of the tune.

- **Safety**

Unlike spark, diesel fuels are not flammable at normal operating temperature, so accidents are minimized.

- **Cost**

Due to their heavy construction and injection equipment, diesel engines are more expensive than spark ignition engines.

- **Start up**

Starting a SI engine is much easier than starting a CI engine because of high compression ratio.

- **Maintenance cost**

Maintenance cost of SI engines is low when compared to CI engines because of the high fatigue stress that is caused in CI engines.

CONCLUSION

The following conclusions were made:

- The principle of working of both SI and CI engines are almost the same, except the process of the fuel combustion that occurs in both engines.
- Both engines can work either on two strokes or four strokes.
- Diesel engines generally have improved efficiencies therefore; it consumes less fuel than spark engines.
- Spark ignition engines produces more speed than diesel engines.
- Diesel engine is more reliable.
- Diesel engine runs noisier than spark engines.
- Diesel engine is safer in terms of fire accident.
- Spark ignition engine is less expensive in terms of purchase and maintenance.

RECOMMENDATIONS

The following recommendations were made:

- Injectors should be used with petrol instead of diesel. This will increase the speed of the engine.
- The injectors should be properly mounted to prevent vibration.

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