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COMPARATIVE STUDY OF DIFFERENT INTERNAL COMBUSTION ENGINES

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ABSTRACT

This article compares the differences between the both types of internal combustion engines, with respect to their working principles. The most prominent difference between Spark Ignition (SI) and Compression Ignition (CI) engines is the type of fuel used and the process of mixing the fuel for effective combustion. The SI engine uses carburetor as a means of mixing the air and fuel in equal proportion while compression engines uses injector. Single spark ignition engines fail to carryout complete combustion in automobiles due to various losses in combustion chamber and other design parameters. Thus the process of combustion is not at all instantaneous and therefore alternate solution to it is by burning the fuel as quickly as possible by using two spark plugs instead of one. An internal combustion (IC) engine has a predominant role in a low power generation. One of the best methods to improve the engine performance and reduce the exhaust emission in a SI engine is by using introduction of twin spark into the combustion chamber. Objective of this paper is to compare both types of internal combustion and the twin spark engine. On applying the twin spark plug in gasoline engine the combustion could be made proper and the specific fuel consumption could be made to decrease.

Keywords*: Spark ignition, Compression ignition, internal combustion engines; Twin spark.*

I. INTRODUCTION

The term spark-ignition (SI) engine refers to internal combustion engines, generally petrol engines, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. This is in contrast to compression-ignition (CI) engines, typically diesel engines, where the heat generated from compression is enough to initiate the combustion process, without needing any external spark (William & Donald, 2007). The diesel engine (also known as a compression-ignition engine) is an internal combustion engine in which ignition of the fuel that has been injected into the combustion chamber is initiated by the high temperature which a gas achieves when greatly compressed (adiabatic compression). This contrasts with spark-ignition engines such as a petrol engine or gas engine which use a spark plug to ignite an air-fuel mixture. A S.I. engine is a device which transforms the chemical energy of a fuel into thermal energy to produce mechanical work. In a spark-ignition engine a sufficiently homogeneous mixture of vaporized fuel, air and residual gases is ignited by a single intense and high temperature spark between the spark plug electrodes. DTS-i has two Spark plugs located at opposite ends of the combustion chamber and hence fast and efficient combustion is obtained. The benefits of this efficient combustion process can be felt in terms of better fuel efficiency and lower emissions. The ignition system on the Twin spark is a digital system with static spark advance and no moving parts subject to wear. It is mapped by the integrated 4 digital electronic control box which also handles fuel injection and valve timing. It features two plugs per cylinder. This innovative solution, also entailing a special configuration of the hemispherical combustion chambers and piston heads, ensures a fast, wide flame front when the air-fuel mixture is ignited, and therefore less ignition advance, enabling, moreover, relatively lean mixtures to be used. This technology provides a combination of the light weight and twice the power offered by two-stroke engines with a significant power boost, i.e. a considerable "power-to-weight ratio" compared to quite a few four stroke engines. Moreover, such a system can adjust idling speed & even cuts off fuel feed when the accelerator pedal is released, and meters the enrichment of the air-fuel mixture for cold starting and accelerating purposes if necessary, it also prevents the upper rev limit from being exceeded. At low revs, the over boost is mostly used when overtaking, and this is why it cuts out automatically. At higher speeds the over boost will enhance full power delivery and will stay on as long as the driver exercises maximum pressure on the accelerator.

II. LITERATURE REVIEW

Several researchers have conducted their studies on the Performance of Engine ignition systems and effect of parameters like fuel consumption, emissions, torque, load capacity etc has been analyzed. Number of reviews has been taken below to complete the present study. Prabhkar et al. (2014) carried the study on the conventional engines employed a single spark plug in its engine for igniting the mixture of fuel and air. But to have more effective burning of the mixture in order to increase the power output and reduce the wastage of this mixture as unburnt, the number of spark plug was doubled for efficient burning of the mixture. Two spark plugs helped in igniting the fuel from two directions rather than one, as in conventional engines. This new technology was termed as "Twin Spark Ignition System". Although this technological trend proved to be sufficient, a new well-improvised ignition system was given birth and named as "Triple Spark Technology" involving the use of three spark plugs rather than one or two. Syed Moizuddin et al. (2014) highlighted the improvisation in the working of a two-wheeled four stroke internal combustion engines. The efficiency of these small engines were improved with increased power output just by increasing the number of fuel igniting element i.e. Spark Plug. Conventional engines employed a single spark plug in its engine for igniting the mixture of fuel and air. But to have more effective burning of the mixture in order to increase the power output and reduce the wastage of this mixture as unburnt, the number of spark plug was doubled for efficient burning of the mixture. Two spark plugs helped in igniting the fuel from two directions rather than one, as in conventional engines. This new technology was termed as "Twin Spark Ignition System". Although this technological trend proved to be sufficient, a new well-improvised ignition system was given birth and named as "Triple Spark Technology" involving the use of three spark plugs rather than one or two. Narasimha et al. (2013) conducted experimental investigation on multiple spark plug engines. A new dual spark ignition engine has been developed by introducing two spark plugs at different locations and the experiments are conducted at different load conditions and at three different compression ratios. The results are compared with that of a single plug operation. The results have shown that performance of dual plug engine is comparatively better than the conventional single plug ignition engine under all three compression ratios. The results have shown considerable improvement in thermal efficiency, and reduction in HC and CO emissions in dual plug mode of operation. However, there is a small increase in NOX emission. Effect of compression ratio in dual plug engine system has not been investigated in detail so far with respect to engine performance and exhaust emissions. Optimum compression ratio which gives the best performance with respect to the above parameters due to ill effects of combustion knock at higher compression ratios. Imran and Jani investigated the effects of twin spark using CNG fuel in SI engine. The performance and emission analysis of an engine are investigated by experiment with CNG kit and gas analyzer. From this study the fuel consumption is reduce in twin spark arrangement for the same power output as compare to single spark using both of the fuel gasoline as well as CNG. Engine emission is considerably reduced using twin spark plug. Multiple ignition system is one of the techniques to achieve rapid combustion. Multiple spark plug engines often use the initiation of flame propagation at two or more number of points in the combustion chamber depending on the number of spark plugs employed. If two plugs are employed the flame front travels from two points in the cylinder and the effective distance to be travelled by each flame is reduced. The concept of dual plug spark ignition is under consideration for more than last three decades.

III. KEY FACTORS DISTINGUISHING IC ENGINES

A. Cycles of Operation

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 as was described for the four-stroke engine. It consists of the same four major steps: Intake, compression, power and exhaust. 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.

B. Quality and variety of fuels

Setright (2011), maintained that petrol/gasoline engines are limited in the variety and quality of the fuels they can burn. Older petrol engines fitted with a carburetor required a volatile fuel that would vaporize easily to create the necessary air-fuel ratio for combustion. Because both air and fuel are admitted to the cylinder, if the compression ratio of the engine is too high or the fuel is too volatile (with too low an octane rating), the fuel ignites under compression, as in a diesel engine, before the piston reaches the top dead center. This pre-ignition causes a power loss and over time causes major damage to the piston and cylinder walls. The need for a fuel that is volatile enough to vaporize but not too volatile (to avoid pre-ignition), this means that petrol engines will only run on a moderate range of fuels. There has been some success at dual-fuel engines that use petrol and ethanol, petrol and propane, and petrol and methane (Suzuki, 1997). In diesel engines, a mechanical injector system vaporizes the fuel directly into the combustion chamber or a pre-combustion chamber (as opposed to a Venturi jet in a carburetor, or a fuel injector in a fuel injection system, vaporizing fuel into the intake manifold or intake runners as in a petrol engine). This forced vaporization means that less-volatile fuels can be used. More crucially, because only air is inducted into the cylinder in a diesel engine, the compression ratio can be much higher as there is no risk of pre-ignition provided the injection process is accurately timed. This means that cylinder temperatures are much higher in a diesel engine than a petrol engine, allowing less volatile fuels to be used (Suzuki, 1997)

C. Fuel flammability

Diesel fuel has low flammability, leading to a low risk of fire caused by fuel in a vehicle equipped with a diesel engine. In fact, diesel engines are often used than the petrol (gasoline), because the fuels spark-ignition engines releases combustible vapors which can lead to an explosion if it accumulates in a confined space such as the bottom of a vessel. Ventilation systems are mandatory on petrol-powered vessels.

D. Introduction of fuel in the engine

During the pistons' suction stroke in SI engines a mixture of air and fuel is injected from the cylinder head portion. The air-fuel mixture is injected via the carburetor which controls the quantity and the quality of the injected mixture. In the case of CI engines, diesel 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 fuel in SI 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 (Singal, 2012)

E. Thermal Efficiency

Thermal efficiency is the ratio of the useful work produced to the total energy supplied. According to Singer, Charles Joseph; Raper, Richard, (1978) petrol engines can have thermal efficiencies ranging between 12% 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. However, such a comparison does not take into account that diesel fuel is denser and contains about 15% more energy by volume. Although the calorific value of the fuel is slightly lower at 45.3 MJ/kg (mega joules per kilogram) than petrol at 45.8 MJ/kg, liquid diesel fuel is significantly denser than liquid petrol. This is significant because volume of fuel, in addition to mass, is an important consideration in mobile applications. Adjusting the numbers to account for the energy density of diesel fuel, the overall energy efficiency is still about 20% greater for the diesel version. While a higher compression ratio is helpful in raising efficiency, diesel engines are much more efficient than gasoline (petrol) engines when at low power and at engine idle. Unlike the petrol engine, diesels lack a butterfly valve (throttle) in the inlet system, which closes at idle. This creates parasitic loss and destruction of availability of the incoming air, reducing the efficiency of petrol engines at idle. In many applications, such as marine, agriculture, and railways, diesels are left idling and unattended for many hours, sometimes even days. These advantages are especially attractive in locomotives (Ransome-Wallis, 2001). Even though diesel engines have a theoretical fuel efficiency of 75%, in practice it is lower. Engines in large diesel trucks, buses, and newer diesel cars can achieve peak efficiencies around 45%, and could reach 55% efficiency in the near future. However, average efficiency over a driving cycle is lower than peak efficiency. For example, it might be 37% for an engine with a peak efficiency of 44%.

F. Twin Spark Benefits

In case of twin spark, two spark-plugs fire at the same time. These are simultaneous firing and swirl of the air-fuel mixture results in complete combustion. This action is digitally controlled by the DTS-I System (namely the twin spark plugs, TRICS III and intelligent CDI). Power and torque requirements constantly change, depending on whether the rider is cruising, accelerating or is at high speeds/max speed. Throttle Responsive Ignition Control

System - III is an intelligent system which can quickly adapt ignition timing to suit different riding characteristics. The Intelligent Capacitor Discharge Ignition contains a microprocessor, which continuously senses different speeds and load on engine and responds by altering ignition timing.

G. Ignition Processes

Internal combustion engines require ignition of the mixture, either by spark ignition (SI) or compression ignition (CI). Before the invention of reliable electrical methods, hot tube and flame methods were used. **Spark Ignition Process** generally relies on a combination of alternator or generator and lead–acid battery for electrical power. The battery supplies electrical power for cranking, and supplies electrical power when the engine is off. The battery also supplies electrical power during rare run conditions where the alternator cannot maintain more than 13.8 volts. Gasoline internal combustion engines are much easier to start in cold weather than diesel engines they can still have cold weather starting problems under extreme conditions. **Diesel engines** rely solely on heat and pressure created by the engine in its compression process for ignition. The compression level that occurs is usually twice or more than a gasoline engine. Diesel engines take in air only, and shortly before peak compression, spray a small quantity of diesel fuel into the cylinder via a fuel injector that allows the fuel to instantly ignite.

IV. EMISSIONS

Emission standards are requirements that set specific limit to the amount of pollutants that can be released into the environment. Many emission standard focus on regulating pollutants released by automobiles and other powered vehicles. They can also regulate emissions from industry, power plants, small equipments such as lawn movers and diesel generators. According to Singer, Charles Joseph; Raper, Richard (2013), since the diesel engine uses less fuel than the petrol engine per unit distance, the diesel produces less carbon dioxide (CO_2) per unit distance.

Pollution

Diesel exhaust is well known for its characteristic smell; but this smell in recent years has become much less because the sulfur is now removed from the fuel in the oil refinery. Diesel exhaust has been found to contain a long list of toxic air contaminants. Among these pollutants, fine particle pollution is perhaps the most important as a cause of diesel's harmful health effects. The products of combustion coming out of the exhaust system are more noticeable with diesel engines, particularly if any of the injection equipment components are out of tune. It is questionable which are the more harmful: the relatively invisible exhaust gases from the petrol engine, which include nitrogen dioxide or the visible smoky diesel, exhaust gases.

Noise

The distinctive noise of a diesel engine is variably called diesel clatter, diesel nailing, or diesel knock. According to Manbw.com (2008), diesel clatter is caused largely by the diesel combustion process; the sudden ignition of the diesel fuel when injected into the combustion chamber causes a pressure wave. Diesel fuels with a higher cetane rating modify the combustion process and reduce diesel clatter. A combination of improved mechanical technology such as multi-stage injectors which fire a short "pilot charge" of fuel into the cylinder to initiate combustion before delivering the main fuel charge, higher injection pressures that have improved the atomization of fuel into smaller droplets, and electronic control (which can adjust the timing and length of the injection process to optimize it for all speeds and temperatures), have partially mitigated these problems in the latest generation of common-rail designs, while improving engine efficiency (Anyebe, 2009).

V. PERFORMANCE

Torque

Diesel engines produce more torque than petrol engines for a given displacement due to their higher compression ratio. Higher pressure in the cylinder and higher forces on the connecting rods and crankshaft require stronger, heavier components. Heavier rotating components prevent diesel engines from revolving as high as petrol engines for a given displacement. Diesel engines generally have similar power and inferior power to weight to petrol engines. Petrol engines must be geared lower to get the same torque as a compared to diesel, but since petrol engines revolves higher, both of them will have similar acceleration. Comparing engines based on (maximum) torque is just as useful as comparing them based on (maximum) rpm.

Power

In diesel engines, conditions in the engine differ from the spark-ignition engine, since power is directly controlled by the fuel supply, rather than by controlling the air supply. The average diesel engine has a poorer power-to-weight ratio than the petrol engine. This is because the diesel must operate at lower engine speeds and because it needs heavier, stronger parts to resist the operating pressure caused by the high compression ratio of the engine and the large amounts of torque generated to the crankshaft. A petrol engine of similar size cannot put out a comparable power increase without extensive alterations because the stock components cannot withstand the higher stresses placed upon them. Since a diesel engine is already built to withstand higher levels of stress, it makes an ideal candidate for performance tuning at little expense. However, it should be said that any modification that raises the amount of fuel and air put through a diesel engine will increase its operating temperature, which will reduce its life and increase service requirements. These are issues with newer, lighter, high-performance diesel engines which are not "overbuilt" to the degree of older engines and they are being pushed to provide greater power in smaller engines (Hardenberg, 1999)

Forced induction

The addition of a turbocharger or supercharger to the engine greatly assists in increasing fuel economy and power output, mitigating the fuel-air intake speed limit for a given engine displacement. Boost pressures can be higher on diesels than on petrol engines, due to the latter's susceptibility to knock, and the higher compression ratio allows a diesel engine to be more efficient than a comparable spark ignition engine. Because the burned gases are expanded further in a diesel engine cylinder, the exhaust gas is cooler, meaning turbochargers require less cooling, and can be more reliable, than with spark-ignition engines (Singer, Charles Joseph; Raper, Richard, 2013). Poor power and narrow torque bands have been addressed by superchargers, turbochargers, (especially variable geometry turbochargers), intercoolers, and a large efficiency increase from about 35% for IDI to 45% for the latest engines in the last 15 years.

Reliability

For most industrial or nautical applications, reliability is considered more important than light weight and high power. The lack of an electrical ignition system greatly improves the reliability of CI engine. The high durability of a diesel engine is due to its overbuilt nature, a benefit that is magnified by the lower rotating speeds in diesels. Diesel fuel is a better lubricant than petrol and thus, it is less harmful to the oil film on piston rings and cylinder bores; it is routine for diesel engines to cover 400,000 km (250,000 mile) or more without a rebuild (Ricardo, 2011). Due to the greater compression ratio and the increased weight of the stronger components, starting a diesel engine is harder than starting a gasoline engine of similar design and displacement. According to Nunny, (2007) the pony engine heated the diesel to aid in ignition and used a small clutch and transmission to spin up the diesel engine. Even more unusual was an International Harvester design in which the diesel engine had its own carburetor and ignition system, and started on petrol.

VI. CONCLUSION

There is reduced risk of fire accident due to low volatility of diesel fuel and the long intervals between overhauling and servicing also reduces cost of maintenance in CI engines. There is also higher thermal efficiency, greater volumetric efficiency and injection equipments are more reliable and stable in CI than the electrical ignition system in SI engines. The CI engines has less harmful effect of exhaust products, could run without battery which makes it more economical as compared to its size due to high compression ratio. Spark ignition and compression ignition are totally different mechanical technologies that are used in internal combustion engines. Though, both the spark ignition technology which are called spark ignition (SI) engines, and the other which are known as compression ignition (CI) engines, operates in similarity in some cases using the same principles of operation. It can also be concluded that the application of twin spark technologies in the present day automobiles will give powerful bikes with fuel efficiency. Since these technologies also minimize the fuel consumption and harmful emission levels, they can be considered as one of the solutions for increasing effect of global warming.

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