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STUDY OF DIGITAL TRIPLE SPARK IGNITION ENGINE

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Abstract

Nowadays, it has become a fashion for the people especially living in urban areas to ride a vehicle, which gives more power output. Now the companies even want to launch such vehicles that attract the young generation. A conventional four stroke spark ignition internal combustion engines employed a spark plug for igniting the air-fuel mixture. However, engine with single spark plug yield wastage of unburnt air-fuel mixture, so power output and fuel efficiency of engine decreases. Because in actual practice, perfect combustion is not at all possible due to various losses in the combustion chamber as well as design of the internal combustion engine. Therefore, an alternate solution to it is by increasing the number of spark plug for efficient burning of the air-fuel mixture.

This work deals with the study of Digital Triple Spark Ignition (DTS-i) system for a four stroke internal combustion engine. In addition, this system provides optimal combustion of air-fuel mixture at part load conditions. This helps to achieve more power, better fuel efficiency, lesser emissions and overall smooth functioning of the engine.

Key words:-*Digital Triple Spark Ignition (DTS-i), spark plug, optimal combustion, power, fuel efficiency, emissions, etc.*

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1. INTRODUCTION

Owing to various factors such as losses in combustion chamber and design of internal combustion engine, the perfect combustion is not possible in internal combustion engine. At the same time, the process of burning of air-fuel mixture in combustion chamber is not instantaneous. Hence, it is required to increase combustion rate process as fast as possible. This is achieved by using multiple spark plugs instead of single spark plug. By using multiple spark plugs the diameter of flame is increased. Because spark plugs are fired alternatively at a certain time interval and allowed for burning of air-fuel mixture instantaneously. Such type of system is called Digital Spark Ignition system.

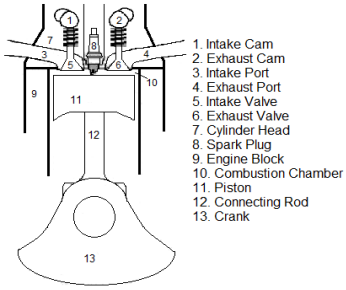

Fig. 1.1:- Four Stroke Single Spark Ignition Engine

Fig. 1.1 indicates the schematic diagram of four stroke single spark ignition engine, which consists of following four strokes:

1. Suction stroke
2. Compression stroke
3. Expansion stroke
4. Exhaust stroke

Each of these strokes consists of 180^0 rotation of crankshaft and hence a four-stroke cycle has completed through 720^0 of crank rotation. Thus, for one complete cycle there is only a one power stroke, while the crankshaft turns by two revolutions.

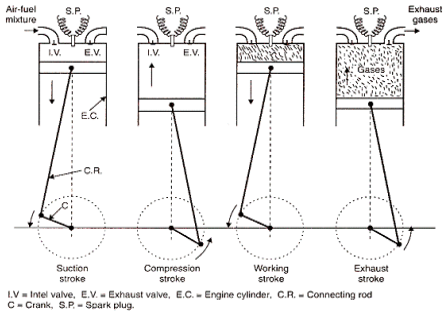

Fig. 1.2:- Working of Four Stroke Spark-Ignition Engine

Fig. 1.2 indicates the working of four stroke spark-ignition engine is based on Otto cycle as shown in fig. 1.3. It is the thermodynamic cycle most commonly found in automobile petrol engines. It consists of the intake stroke, which is performed by an isobaric expansion, followed by an adiabatic compression stroke. Through the combustion of fuel, heat is added in a constant volume (isochoric) process, followed by an adiabatic expansion process power stroke. The cycle is closed by the exhaust stroke, characterized by isochoric cooling and isentropic compression processes.

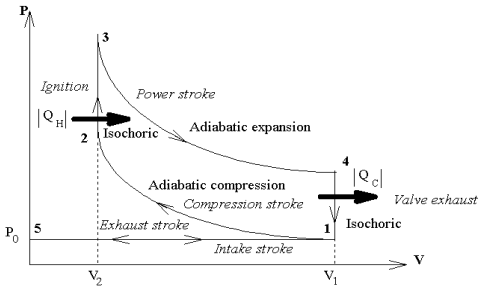

Fig. 1.3:- Otto Cycle

Limitations of Four Stroke Single Spark Engine:-

1. Incomplete combustion.
2. Burning of fuel is not instantaneous.
3. Lower fuel efficiency.
4. Higher emissions.

Rapid combustion is the basic requirement for knock free operation of S.I engine. Improved trade off between efficiency and NO_X emissions is the greater tolerance towards EGR or excess air, reduction in cycle-by-cycle fluctuations of engine power, which can improve vehicle drivability and greater knock resistance, thereby allowing fuel economy with higher compression ratios. Multiple ignition system is one of the techniques to achieve rapid combustion. Multiple spark plugs 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. Several experimental studies were made in the area of dual ignition engines regarding optimization of spark plug location and to prove their efficient operation at part loads, extended lean misfire limit and relatively clean burning compared with single spark ignition systems. A conventional four stroke engine has a single spark plug located at one end of the combustion chamber and hence the combustion is inefficient leading to sub optimal mileage and sub optimal performance & can even have problems with oil flow. Hence, there was a requirement to change engines design, ignition, production and quality to achieve the following objectives:

- Uniform power delivery in all operating conditions.
- A high degree of drivability.
- First rate standards of reliability and long service life.

The digital twin spark engine readily increased the power output without compromising the mileage of the vehicle and reduced percentage of pollutants fumes. Later on, some more modifications were made in Digital Twin Spark Ignition (DTS-i) engine to convert it into Digital Twin Spark-Swirl Ignition (DTS-Si) engine which included a new way of introducing air fuel mixture in combustion chamber.

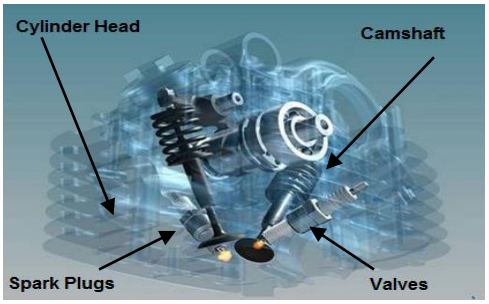

Fig. 1.4:- Digital Twin Spark Ignition Engine

According to the research and development wing of the Bajaj auto DTS-Si engine is a second generation engine whereas the latest engine launched Bajaj autos it considered as the third generation engine. This engine has been given the name of DTS-i triple spark engine which was launched under the model name of Pulsar 200NS. This triple spark engine consists of three spark plugs two of them are the planet or subordinate spark plugs whereas third spark plug acts as the main spark plug. This engine has the capacity of creating a complete combustion and giving the maximum output with considerable fuel efficiency

2. LITERATURE REVIEW

Several researchers were conducted their studies on the Performance of SI Engine ignition systems and DTS-i engine. Effect of parameters like fuel consumption, emissions, torque, load capacity, etc on performance of engine has been analyzed.

Prabhkar et al. [1] conducted study on the conventional engines which employed a single spark plug for igniting the air-fuel mixture. But however for more effective burning of the mixture in order to increase the power output and reduce the wastage of this mixture as unburnt, 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. [2] highlighting 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 which employed a single spark plug for igniting the air-fuel mixture. But however for more effective burning of the mixture in order to increase the power output and reduce the wastage of this mixture as unburnt, 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. [3] carried experimental work 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 was conducted at different load conditions and at three different compression ratios. The results were compared with that of a single plug operation. The results had shown that performance of dual plug engine was 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 BSFC, HC, and CO emissions in dual plug mode of operation. However, there was a small increase in NO_X emission. Effect of compression ratio in dual plug engine system had 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 knocks at higher compression ratios.

A Ramtilak et al. [5] discussed designed and developed of Digital Twin Spark Ignition (DTS-i) system. In this concept for small bore four stroke engines with two valves. Two spark plugs placed diametrically opposite to each other in the combustion chamber fire simultaneously igniting the charge. The benefit of this concept is improved fuel economy, better drivability, and reduced engine on an emissions. The DTS-i concept helps the products meet the India 2005-emission standard without the use of secondary air injection and exhaust after treatment. The power, torque and specific output per litre were increased, while the fuel consumption and emissions were reduced due to the rapid combustion brought about by the twin spark plugs. 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 three plugs are employed the flame front travels from three points in the cylinder and the effective distance to be travelled by each flame is reduced. The concept of triple plug spark ignition was under consideration for more than last three decades.

3. WHAT IS DIGITAL TRIPLE SPARK TECHNOLOGY?

Here, DTS-i Stands for "Digital Triple Spark Ignition". Three spark plugs provide unprecedented performance and efficiency. Also the fast and optimal combustion at part load conditions results in better fuel efficiency and ensures lower emissions. The ignition of triple spark engine is controlled electronically by the Electronic Control Unit (ECU) based on the load, engine rpm and engine temperature. Combustion in a triple spark engine is 27% and 50% faster as compared to twin spark and single spark engine respectively.

This technology, for the first time in INDIA was implemented by BAJAJ on their product Pulsar 200NS. According to Bajaj, these plugs gain an advantage in low-rpm riding condition where it extracts the best economy compared to KTM Duke 200 in similar conditions it gives as much as 10-13kmpl more, however the difference vanishes at higher rpm and high speed.

At the heart of the new Pulsar is its cutting-edge engine which sets new benchmarks in performance, emission and incidentally also fuel efficiency. The Digital Twin Spark-ignition (DTS-i) technology launched in 2003 marked a unique first in the history of Indian Motoring. The new Pulsar takes this technology altogether to another level with a Single Over Head Camshaft (SOHC) four valve triple spark engine controlled by an advanced Electronic Control Unit for an absolutely unmatched performance.

Fig. 3.1:- Digital Triple Spark Ignition Engine

4. CONSTRUCTIONAL DETAIL

The construction of digital triple spark engine is same as that of the conventional four stroke engine. It consists of following parts:

1. Piston
2. Cylinder
3. Crankshaft
4. Connecting Rod
5. 3-Sparkplugs
6. 2- Inlet Ports And 2- Exhaust Ports
7. 2- Inlet Valves And 2- Exhaust Valves

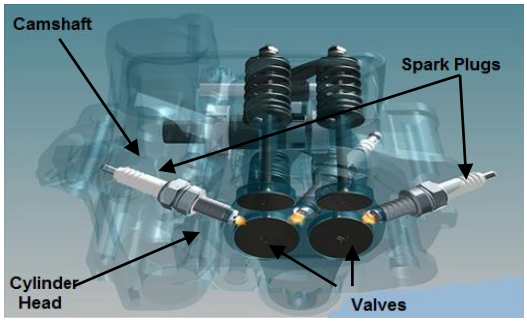

Fig. 4.1:- Engine With Three Spark Plugs

In engine construction, to make use of three spark plugs, the pulsar engine houses a pent roof combustion chamber

which in turn allows housing three spark plugs in the engine chamber. Out of the three plugs, the primary plug is the centre one and is mounted in an angle and enters the chamber at the top-centre. The other two secondary plugs are mounted below, which is opposite to each other and one of them being vertically underneath the primary plug.

5. WORKING

The working of digital triple spark engine is very similar to four stroke engine, but only modification done is that use of three spark plugs instead one spark plug. Fig. 5.1 indicate digital triple spark engine which consist of three spark plugs located at various location in the combustion chamber. Out of the three plugs, the primary plug is the centre one and is mounted in an angle and enters the chamber at the top-centre. The other two secondary plugs are mounted below, which is opposite to each other and one of them being vertically underneath the primary plug in the combustion chamber, which require less time to reach the farthest position of the combustion chamber and optimize the combustion chamber characteristics.

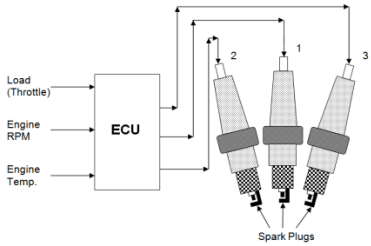

Fig. 5.1:- Working Of Digital Triple Spark Engine

It consists of two inlet valves and two outlet valves and three spark plugs. The two inlet valves allow the air fuel mixture to flow freely to the combustion chamber. The two outlet valves allow the exhaust gases to be released smoothly. This helps the engine breathe easily even at high rpm. The secondary plugs fires a bit after the primary one has fired and the timings are controlled by the Electronic Control Unit (ECU) based on the load, engine rpm and engine temperature as shown in fig 5.1. The ECU uses different ignition maps for different riding conditions to ensure that the flame propagation in the combustion chamber is optimal. As for cruising, ECU response calmly and during top speed the ECU response is faster than usual. This configuration helps in delaying the ignition timing almost by 15^0 TDC yet resulting in optimal combustion. Combustion in a triple spark engine is 27% and 50% faster as compared to twin spark and single spark engine respectively.

As a result, with use of digital triple spark ignition system following benefits can be achieved:

1. A remarkable improvement in thermodynamic efficiency and hence a considerable increase in the amount of power available.
2. More effective combustion at low load and at idling speed.
3. A sizeable reduction in specific fuel consumption.
4. A reduced exhaust emission.
5. Less chance of ignition system failure as failure of either circuit will not stop the engine, which can still work with single spark ignition.

5.1 TRICS III

Throttle Responsive Ignition Control System 3rd generation (TRICS III) is shown in fig. 5.1.1. It is a means of controlling the ignition by operating the throttle. Depending on the needs of the rider whether it be cruising, acceleration or maximum speed, the ignition requirements constantly change. Based on a particular amount of throttle opening, the magnetic field generated by the magnet opens or closes the reed switch. The reed switch is connected to the digital CDI, which signals the CDI to change/switch, the desired ignition advance timing maps. This helps in achieving a good balance between drivability and optimum ignition spark advance, resulting in an almost perfect ignition spark advance for every throttle opening and engine rpm.

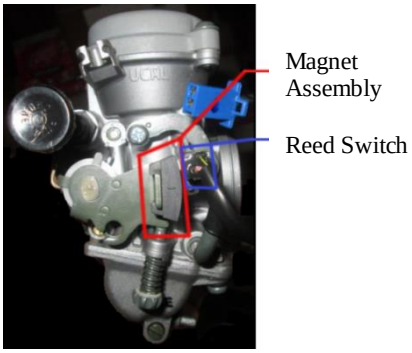

Fig. 5.1.1:- TRICS III

5.2 IGNITION WITH A DIGITAL C.D.I.

A Digital CDI with an 8 bit microprocessor chip handles the spark delivery. The programmed chip's memory contains an optimum ignition timing maps for any given engine rpm, thereby obtaining the best performance characteristics from the combustion chamber. Working together with the TRICS III system, it delivers optimum ignition timing for varying load conditions.

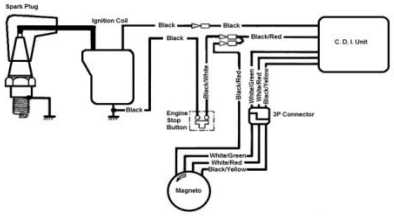

Fig. 5.2.1:- Ignition with a Digital C.D.I.

6. COMBUSTION COMPARISON

Fig 6.1 illustrates comparison for combustion process in single spark, twin spark and triple spark engine. It is observed that in spite of 15^0 later ignition timing in the triple spark system the combustion ends in advance of the others i.e. twin spark and single spark engine. Combustion in a triple spark engine is 27% and 50% faster as compared to twin spark and single spark engine respectively. This

results in more power, better fuel efficiency, lesser emissions and overall smooth functioning of engine.

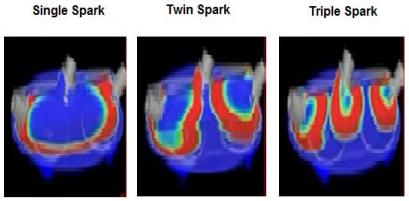

Fig. 6.1:- Combustion Comparison

7. ADVANTAGES

1. Easier starting.
2. Superior running with minute vibrations and noise.
3. Less emission.
4. More output power and fuel efficiency.
5. Less prone to plug fouling.
6. Smooth working even at higher rpm.
7. No issues on cold air intake.
8. No chances of engine knocking.

8. DISADVANTAGES

1. Costlier technology.
2. Complications in its design.
3. Fault in ECU can lead to malfunctioning of engine.
4. Requires high cooling (liquid cooled).
5. Failure in cooling system can cause severe damage to engine and Heavier engine compared to twin spark and single spark engines.

9. APPLICATIONS

This technology, for the first time in INDIA was implemented by BAJAJ AUTO on their product Pulsar 200NS (2012).Also, it is used in Pulsar AS200 (2015); Pulsar RS200 (2015); Bajaj Dominar 400 (2017); etc.

10. FURTHER MODIFICATIONS

10.1 Digital Triple Spark-Swirl Ignition Engine

Fig. 10.1.1 indicates working of swirl ignition engine. It is observed that due to the offset position inlet valve is very much helpful in achieving the swirl motion of the charge while it enters the combustion chamber. As the charge is in swirl motion the spark spreads very quickly in the combustion chamber and hence helps in obtaining the complete combustion of the air fuel mixture.

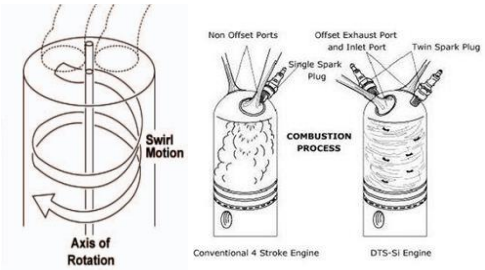

Fig. 10.1.1:- Working of Swirl Ignition Engine

11. CONCLUSION

The application of these technologies in the present day automobiles will give the power bikes with fuel efficiency. Since these technologies also minimize the fuel consumption and harmful emission levels, they can also be considered as one of the solutions for increasing fuel costs and increasing effect of global warming. Combustion in a triple spark engine is 27% and 50% faster as compared to twin spark and single spark engine respectively. This results in more power, better fuel efficiency, lesser emissions and overall smooth functioning of engine.

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