

Recent trends in Four-Stroke Internal Combustion Engines of Two-Wheelers

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ABSTRACT: This paper deals with highlighting the improvisations in the working of a two-wheeled four stroke internal combustion engines. The efficiency of these small engines were enhanced 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. A detail about this trend in IC engine is discussed below.



Fig. 1 Magneto Ignition System

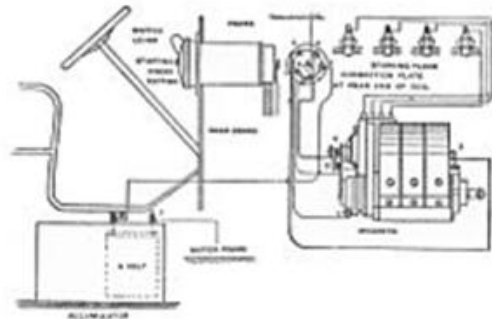


Fig. 2 Switchable System

I. INTRODUCTION

Conventional Single Spark Plug Ignited Four-Stroke Engine

An ignition system is a system for igniting a fuel-air mixture. Ignition systems are well known in the field of internal combustion engines such as those used in petrol (gasoline) engines used to power the majority of motor vehicles, but they are also used in many other applications such as in oil-fired and gas-fired boilers, rocket engines, etc.

The first ignition system to use an electric spark was probably Alessandro Volta's toy electric pistol from the 1780s. Virtually all petrol engines today use an electric spark for ignition.

Magneto Ignition Coil

The simplest form of spark ignition is that using a magnet. The engine spins a magnet inside a coil, or, in the earlier designs, a coil inside a fixed magnet, and also operates a contact breaker, interrupting the current and causing the voltage to be increased sufficiently to jump a small gap. The spark plugs are connected directly from the magneto output.

Early magnetos had one coil, with the contact breaker (spark plug) inside the combustion chamber. In about 1902, Bosch introduced a double-coil magneto, with a fixed sparking plug, and the contact breaker outside the cylinder. Magnetos are not used in modern cars, but because they generate their own electricity they are often found on piston-engine aircraft engines and small engines such as those found in mopeds, lawnmowers, snow blowers, chainsaws, etc. where a battery-based electrical system is not present for any combination of necessity, weight, cost, and reliability reasons.

Switchable systems

The output of a magneto depends on the speed of the engine, and therefore starting can be problematic. Some magnetos include an impulse system, which spins the magnet quickly at the proper moment, making easier starting at slow cranking speeds. Some engines, such as aircraft but also the Ford Model T, used a system which relied on non rechargeable dry cells, (similar to a large flashlight battery, and which was not maintained by a charging system as on modern automobiles) to start the engine or for starting and running at low speed. The operator would manually switch the ignition over to magneto operation for high speed operation.

To provide high voltage for the spark from the low voltage batteries, a 'tickler' was used, which was essentially a larger version of the once widespread electric buzzer. With this apparatus, the direct current passes through an electromagnetic coil which pulls open a pair of contact points, interrupting the current; the magnetic field collapses, the spring-loaded points close again, the circuit is reestablished, and the cycle repeats rapidly. The rapidly collapsing magnetic field, however, induces a high voltage across the coil which can only relieve itself by arcing across the contact points; while in the case of the buzzer this is a problem as it causes the points to oxidize and/or weld together, in the case of the ignition system this becomes the source of the high voltage to operate the spark plugs.

1.1.3 Battery and Coil-operated ignition

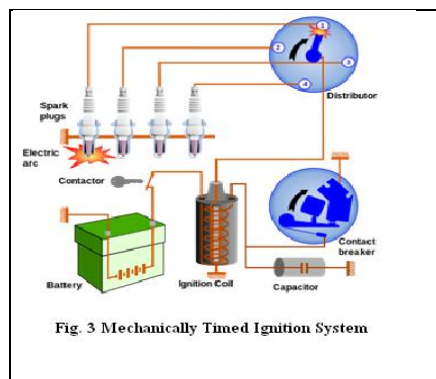
With the universal adaptation of electrical starting for automobiles, and the concomitant availability of a large battery to provide a constant source of electricity, magneto systems were abandoned for systems which interrupted current at battery voltage, used an ignition coil (a transformer) to step the voltage up to the needs of the ignition, and a distributor to route the ensuing pulse to the correct spark plug at the correct time.

The first reliable battery operated ignition was developed by the Dayton Engineering Laboratories Co. (Delco) and introduced in the 1910 Cadillac. This ignition was developed by Charles Kettering and was a wonder in its day. It consisted of a single coil, points (the switch), a capacitor and a distributor set up to allocate the spark from the ignition coil timed to the correct cylinder. The coil was basically a transformer set up to step up the low (6 or 12 V) voltage supply to the high ignition voltage required to jump a spark plug gap.

The points allow the coil to charge magnetically and then, when they are opened by a cam arrangement, the magnetic field collapses and a large (20 kV or greater) voltage is produced. The capacitor has two functions: 1) it absorbs the back EMF from the magnetic field in the coil to minimize point contact burning and maximize point life; and 2) it forms a resonant circuit with the primary coil of the ignition coil transferring further energy to the secondary side until the energy is exhausted. The Kettering system became the primary ignition system for many years in the automotive industry due to its lower cost, higher reliability and relative simplicity.

Modern Ignition Systems

The ignition system is typically controlled by a key operated Ignition switch. Mechanically timed ignition



Most four-stroke engines have used a mechanically timed electrical ignition system. The heart of the system is the distributor. The distributor contains a rotating cam driven by the engine's drive, a set of breaker points, a condenser, a rotor and a distributor cap. External to the distributor is the ignition coil, the spark plugs and wires linking the distributor to the spark plugs and ignition coil.

The system is powered by a lead-acid battery, which is charged by the car's electrical system using a dynamo or alternator. The engine operates contact breaker points, which interrupt the current to an induction coil (known as the ignition coil).

Electronic Ignition

The disadvantage of the mechanical system is the use of breaker points to interrupt the low-voltage high-current through the primary winding of the coil; the points are subject to mechanical wear where they ride the cam to open and shut, as well as oxidation and burning at the contact surfaces from the constant sparking. They require regular adjustment to compensate for wear, and the opening of the contact breakers, which is responsible for spark timing, is subject to mechanical variations. In addition, the spark voltage is also dependent on contact effectiveness, and poor sparking can lead to lower engine efficiency. A mechanical contact breaker system cannot control an average ignition current of more than about 3 A while still giving a reasonable service life, and this may limit the power of the spark and ultimate engine speed.

Electronic ignition (EI) solves these problems. In the initial systems, points were still used but they handled only a low current which was used to control the high primary current through a solid state switching system. Soon, however, even these contact breaker points were replaced by an angular sensor of some kind - either optical, where a vanes rotor breaks a light beam, or more commonly using a Hall effect sensor, which responds to a rotating magnet mounted on the distributor shaft. The sensor output is shaped and processed by suitable circuitry, then used to trigger a switching device such as a thruster, which switches a large current through the coil.

Now the development in these conventional ignition systems started. This began with the entry of ignition system involving two spark plugs, i.e. "Digital Twin Spark Ignition (DTS-i)" system.

II. TWIN SPARK IGNITION ENGINES

Alfa Romeo Twin Spark (TS) technology was used for the first time in the Alfa Romeo Grand Prix car in 1914. In the early 1960s it was used in their race cars (GTA, TZ) to enable it to achieve a higher power output from its engines. And in the early and middle 1980s, Alfa Romeo incorporated this technology into their road cars to enhance their performance and to comply with stricter emission controls.

The orthodox single cylinder, four-stroke, spark ignition engine is generally equipped with a single spark plug. The fresh charge (air – fuel mixture) that entered the cylinder during the suction stroke is compressed during the compression stroke resulting in the increase of pressure and temperature of the charge. The spark plug, usually situated at one end of the combustion chamber, ignites the air-fuel mixture and the ensuing flame spreads like a slowly inflating balloon. There is an inevitable delay for this inflating balloon to reach the furthest part of the combustion chamber. So, there are pockets of poor combustion within the chamber and, overall, the combustion is slow and inefficient.

When it comes to higher capacity engines the distance to be traveled by the flame front is further increased resulting in the still slower combustion.

The Digital Twin Spark Ignition technology takes care of this slower combustion problem in a simple but a novel way. The cylinder head is equipped with two spark plugs, instead of the usual one. By generating two sparks at either ends of the combustion chamber, (approximately 90° to the valve axis) the air-fuel mixture gets ignited in a way that creates two flame fronts and, therefore, a reduction in flame travel of the order of 40 per cent is achieved. A fast rate of combustion is achieved leading to faster rise in pressure. The obvious outcome of this is more torque, better fuel efficiency and lower emissions. An electronic device (microprocessor) controls the firing order of these twin spark plugs.

The fresh charge that entered the cylinder during the suction stroke is compressed during the compression stroke. Then a spark will be ignited by one of the twin spark plugs and the flame front begins to expand like an inflating balloon. In the mean while another spark will be ignited by another spark plug as per controls of the microprocessor. The flame front also begins to expand like an inflating balloon. Therefore the areas that are not covered by the first flame front will be covered by second flame front resulting in the complete & rapid combustion of the fuel. However, this technology even though proved as a successful one all bike-manufacturing companies are not incorporating this technology in their models. Their idea is this faster rate of combustion can be achieved by employing a single spark plug with differential sparking cycles.

2.1 Advances of DTS-I Technology

DTS-i.e. Engine can be further tuned to deliver exhilarating performance or exceptional mileage. The further advances of DTS-I technologies are:

Digital Twin Spark – Swirl Induction (DTS - Si) and Digital Twin Spark – Fuel Injection (DTS - Fi)

Digital Twin Spark - Swirl Induction (DTS - SI):

The DTS-I technology is the parent technology for this latest DTS-Si technology. Even though a faster rate of combustion is achieved by incorporating the DTS-I technology, there is a chance for further improvement of rapid combustion process at lighter loads. When there is a sufficient or heavy load on the engine, the 4 – stroke cycle completes at a faster rate resulting in the faster combustion because of the twin sparks produced by the twin plugs. But when there exists a lighter load on the engine, the 4 – stroke cycle will not complete at a faster rate. Therefore even the incorporation of twin spark plugs cannot aid the faster combustion i.e. still a better rate of combustion can be achieved at lighter loads.

Combustion efficiency in lean Air-Fuel mixture conditions can be further improved by generating high turbulence in the combustion chamber. Combustion chambers having low turbulence give rise to propagation of a flame front, which is akin to that of a gradually expanding balloon. This results in a slower rate of combustion and thus slower rate of pressure rise. End result is lower efficiency. When high turbulence is generated and combustion takes place, the surface of the ballooning flame front fragments itself, with projection like fingers, which increases its surface area, thereby improving combustion further.

Here comes the Swirl Induction concept, which is meant for producing higher turbulence in the combustion chamber. Swirl Induction is nothing but imparting a swirling motion to the fresh charge that enters the combustion chamber. This can be done by making slight modifications in the ports positioning of engine.

The DTS-Si engine will have two spark plugs but it differs from the parent DTS-I engine in the design of position of the ports. The straight ports used in conventional engines have limitations in generating high swirl values due to their geometry. One of the ways to generate more swirl is to have a port configuration that promotes this phenomena. An offset port configuration was arrived upon and optimized to generate the required swirl numbers. Incorporated in the new engine, this results in a swirling motion of the incoming charge, which decays itself into turbulence as the piston moves in the Induction and Compression strokes. This results in the Air-Fuel mixture being more thoroughly mixed and spread around the combustion chamber. Sparks provided by the twin spark plugs ignite this highly turbulent and compressed Air-Fuel mixture, leading to a flame front with high surface area, resulting in a rapid rise of pressure due to rapid combustion. The values of turbulence achieved now, are substantially higher than that of a straight port cylinder head, such as in DTS-i. A combination of DTS-i and Swirl induction thus provides extremely rapid combustion, resulting in high efficiency.

2.2.2 Digital Twin Spark – Fuel Injection (DTS - Fi):

DTS – Fi is another advancement of the parent DTS – i technology. This technology is the combination of both DTS– i and fuel injection. This technology is meant for increasing the fuel efficiency in power bikes.

Generally in conventional 4-stroke engines, which use petrol as fuel, makes use of carburetor, which mixes the fuel and fresh air in required ratio and supplies the same to the combustion chamber. The process is similar for all loads. But the fuel consumption will be more when there is a heavy load on the engine and it is less when there is a light load on the engine. It is impossible for a conventional carburetor to take care of the fuel supply for these varying loads. Therefore there is a need for some intelligent device that controls the fuel supply according to the varying loads.

That so wanted intelligent device is nothing but the Electronic Control Unit (ECU). The Electronic Control Unit is a microprocessor based system and can be regarded as the brain of the fuel injection system. It processes information sent by various sensors and instantly determines optimum fueling and spark timing for various engine-operating conditions. The ECU contains detailed information of the engine's characteristics from which it picks the necessary data for commanding both fueling & sparks timing.

III. DIGITAL TRIPLE SPARK IGNITION

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 DTS-i (Digital Twin Spark-ignition) 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 SOHC 4-valve Triple Spark engine controlled by an advanced Electronic Control Unit for

an absolutely unmatched performance. To support this exhilarating heart-pumping performance the bike comes with liquid cooling and a six speed gear box.

The Pulsar 200NS chassis comprises a pressed steel perimeter frame and a Rectangular tube section swing arm delivering over three times the lateral stiffness of a P220 frame. These deliver outstanding high speed handling and cornering stability. The centrally located muffler and the unique gas filled Nitrox mono suspension further improve the ride and handling of the bike due to low & centralized CG position. The Pulsar design character has evolved with the performance & dynamics. It's become stronger, more aggressive with a street fighter stance. The look just begs you to ride it. Once astride, the sporty Speedo console, triple-tree clip-ons, the signature clips and the illuminated switches evoke the design, fit and finish so far exclusively reserved for much more expensive super sports bikes. The new 200cc Pulsar is probably the most stunning sports bike in its class oozing raw muscular appeal.

To make use of 3 spark plugs, the pulsar engine houses a pent roof combustion chamber which in turn allows housing 3 spark plugs in the engine chamber. Out of the three plugs, the primary plug is the center one and is mounted in an angle and enters the chamber at the top-center. The other two secondary plugs are mounted below, each opposite each other and one of them being vertically underneath the primary plug. The secondary plugs fires a bit after the primary one has fired and the timings are controlled by the ECU depending on various parameters like throttle position, engine revs, load on engine and many other stuffs. According to Bajaj, these plugs gain a advantage in low-rev riding condition where it extracts the best economy.

IV. CONCLUSION

Hence it can be concluded that the application of these technologies in the present day automobiles will give the present generation what they want i.e. 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.

The use of these technologies ensures rapid combustion of the fuel in the combustion chamber, lower emissions and thereby an increase in the fuel efficiency. Better low end torque, Lower fuel delivery and optimization of spark timing, improved cold start, quick warm up and excellent response to the sudden acceleration, Lower emission levels, Self detection and communication of fuel system malfunctioning if any are also some of the important advantages of these technologies. We can hope for still better technologies, which can achieve still better results because there is no end for innovation.

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