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A Comparative Study of Using Digital Twin Spark Ignition System (DTS-i) in Different Fuel Feeding System Used in Motorcycles: A Review

Abhishek Barua[1], Siddharth Jeet[2] and Sasmita Kar[3]
[1,2,3]Department of Mechanical Engineering
Centre for Advanced Post Graduate Studies, BPUT, Rourkela, Odisha, India
Email: rahulbarua69@gmail.com, siddharthjeet7@gmail.com, sasmitakarom@gmail.com

Abstract*—Spark Ignition Engine is widely to power motorcycles. Single spark plug is used in igniting the air-fuel mixture is not so efficient during high speed and heavy loading condition. Moreover, the process of burning of the fuel is also not always instantaneous. However, an alternate solution to it is by making the combustion of fuel as fast as possible. This problem was resolved by introducing the revolutionary twin spark ignition system. By using two spark plugs which spark alternatively at a certain time interval, the diameter of the flame & instantaneous burning of the fuel increased. This system is called DTS-i (Digital Twin Spark Ignition system). Due to DTS-i system it was possible to combine strong performance and fuel efficiency. The improved engine efficiency modes have also resulted in lowered fuel consumption. The efficiency of the small displacement engines was enhanced with increased power output just by increasing the number of fuel igniting element i.e. Spark Plug. Thus a good design and control of the system parameters becomes most essential for optimum performance of an engine. DTS-i offers many advantages over conventional mechanical spark ignition system. This paper reviews the eminent work and researches done for enhancing the performance of Twin Spark Ignition System. Researchers have studied and developed the DTS-i engine on various parameters such as specific fuel consumption, thermal efficiency, exhaust gas emission and engine performance. 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. This paper also reviews the use of DTS-i with different fuel feeding system.

***Index Terms*— Spark-Ignition, DTS-i, Fuel Feeding.**

I. INTRODUCTION

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. Virtually all petrol engines today use an electric spark for ignition.

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II. DIGITAL TWIN SPARK IGNITION (DTS-I)

At the end of compression stroke combustion of fuel takes place and power stroke or expansion stroke is started. By improving the power stroke may change the entire scenario of an engine performance. Bajaj Auto Ltd has done some R&D on the power stroke and invented a new technology named as DTSI (Digital Twin Spark Ignition). In this technology, it uses two spark plug for the combustion of fuel within the engine cylinder. The use of two spark plug increase the burning efficiency of the fuel and produces more power with less amount of fuel. It works on the principle of twin spark produced by the two spark plugs. As compared with the single spark fired engines, in twin spark engines the combustion of the air-fuel mixture takes place at optimal level and it produces more power. Because of the use of twin spark plug, the spark produced is more which burns the fuel more efficiently and rapidly. It results in increase of mileage, power and less emission of exhaust gases. The DTS-i engine produces 26% more power as compared with conventional single spark engines of same capacity. They are Digitally controlled by Electronic Control Unit (ECU) which consist microprocessor chip with pre-programmed data of Ignition Timings for various engine rpm and engine loads. It controls the firing of spark plugs as per the requirement.

II. WORKING OF DTS-I ENGINE

First of all, it is a technology in which two spark plugs are used. Basically, it has two spark plugs at the opposite end of engine cylinder head in 90 degrees; instead of one spark plug which is common in a conventional engine. Two spark plugs produces the spark during the power stroke according to input requirement. According to engine load, RPM and at low-high speed the ECU sends the low and high-frequency pulses to spark plug to perform as per situations. Spark timing of these two spark plugs is controlled digitally. DTS-I engines are known for efficient burning of air-fuel mixer at right time. It has several advantages and disadvantages.

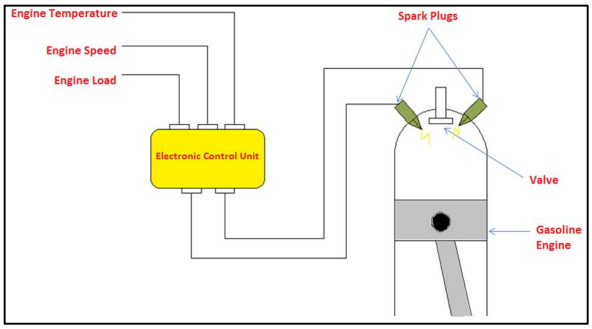

Figure 1. Layout of Twin Spark Ignition System

A. Advantages

- Detonation can be reduced: DTSI engine cannot frequently undergo detonation because complete combustion of air-fuel will not create any disturbance between piston and wall.
- Better fuel efficiency.
- Less emission of exhaust gases.
- Less vibrations and noise due to smooth function.
- Engine breathing performance is easy even at high rpm.
- No overheating issue.
- Complete combustion, no unburnt issue.
- Fast engine response even in winter and cold condition.

B. Disadvantages

- Expensive
- Replacement of both spark plug even one is damage (Reason is series in connection).
- Complex in design.

III. Engine Fuel Feeding System

The main purpose of the fuel feed system is to control the fuel supply to the engine. To supply the fuel from the fuel tank to the engine cylinders, manufacturers use different methods in case of a petrol engine. Types of Fuel Feed systems of a petrol engine are Gravity Feed system, Pressurized Feed system, Vacuum system, Pump Feed system and Fuel injection system. First four out of these fuel feed systems work with carburettor while the fuel injection system uses an injector to supply the fuel to the engine cylinders.

A. Carburettor

The working of the carburettor is simple. The air intake is via the air filter and the fuel intake comes in from the fuel tank. The air and fuel mix together in a set ratio and then passes to the combustion chamber for burning and production of power. Here, when the throttle is twisted, the air flow to the carburettor is increased which causes a swoosh of sucking force and hence the fuel delivery is increase providing acceleration. It has many advantages like easy to operate, cheap to replace, Quick servicing, can be opened up individually without disturbing the engine, on the go tuning and setting possible. It has many limitations like, diaphragm inside is delicate and can tear which will end up to have it replaced, tuning process needs a big screw driver and has to be done physically, there is a certain amount of lag in the process of fuel delivery, old technology, air-fuel mixture ratio is not constant.

B. Fuel Injection (FI)

The working of the Fuel Injection system is more computerized and works on a lot of sensors. The fuel injection nozzle is provided directly in the combustion chamber. The air intake is measured by the air sensor location inside. There is a pressure pump which pressurizes the fuel which allows it to be atomized and hence inside the combustion chamber, the spray is in the form of a mist which allows for complete and cleaner combustion. The fuel supply is controlled by the ECU which is the computer controlling all the electronics of the bike. So when the air supply is increased when the throttle is pulled, the air sensor detects the increase which data is then fed to the ECU so that accordingly the fuel amount to be injected is increased as well. Advantages of Fuel Injection are fuel delivery is optimum and fuel atomizing allows for complete combustion, Increase in fuel efficiency and power output, Acceleration sensitivity increases, air fuel mixture can be changed on the go using different fuel maps pre-loaded on the ECU for variable power outputs. Disadvantages of Fuel Injection are servicing of the FI unit is cumbersome, If there is an ECU failure, the bike will seize to work, It costs a lot and the service and maintenance is costly as well, Producing new Fuel maps needs loads of expertise, Procuring new fuel maps is a costly affair.
Even with all the advantages and disadvantages of both, Fuel injections still have the upper hand over carburettors only because of the quicker response and better power output, and also not to mention that they do help keep the emission levels a lot in check.

IV. Modern Technology in Fuel Feeding System of Motorcycles

A. Swirl Induction

In swirl Induction technology, air-fuel mixture creates "Swirl" into the combustion chamber in the engine, which should aid better burning of fuel. Normally, under these conditions, the quality and concentration of the air-fuel mixture vary from one area to another within the combustion chamber. The combustion chamber having low turbulence spreads the flame that is like a gradually expanding balloon. This results in a slower rate of combustion. Also, it raises the pressure slowly. So, it results in lower efficiency. However, by generating high turbulence inside the combustion chamber; the efficiency of combustion further improves under lean air-fuel mixture conditions. This technology is mainly used in Compression Ignition Engines where it is known as “induction swirl”.
When the combustion takes place under high turbulence, the surface of the inflating flame fragments itself. It forms projections like fingers, increases the surface area. It further improves the combustion. The conventional engines using straight ports have limitations in creating high swirl values due to their geometry. To create more turbulence or swirl, it needs a port configuration that stimulates this process. It was tackled by designing offset ports which created the required degree of the swirl. The offset positioning of the ports generates relatively high swirl and turbulence of the air-fuel mixture in the combustion chamber. Though many automotive manufacturers use this technology, Bajaj Auto Ltd has patented this for their twin spark ignition engines under the name of Digital Twin Spark Swirl Induction (DTS-Si) and is currently use by them

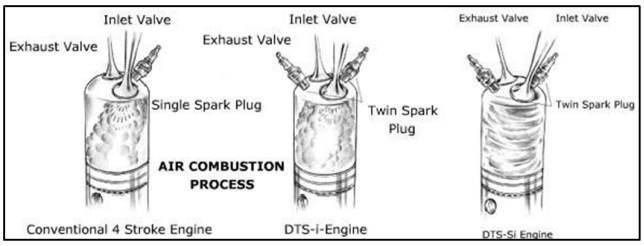

Figure 2. Combustion process in different spark ignition engine

for some low displacement engines since it is giving better results in them only. Because of dual sparking, there will a neat and clean combustion takes place due to that the engine will acquire a good efficiency with complete combustion which results in the smooth running of engine and increase in life span.

B. Tumble Flow Induction

'Tumble flow' means cartwheel motion. In this technology, the air-fuel mixture enters the engine cylinder with a somersault or tumbling action. The advantage of tumble Flow Induction Technology is that it delivers more efficient burning of fuel. Hence, the engine gives more power and better fuel economy with lesser emissions. Technology mainly focuses on the lower speed range of the motorcycle. A motorcycle may never attain the top speed mentioned on its dashboard due to the traffic conditions and engine limitations. However, most of the time, it operates at the average speed of 50-60 km/h. It clearly indicates that, on an average, the bikes typically run at slower engine speeds i.e. between 20-30 km/h.

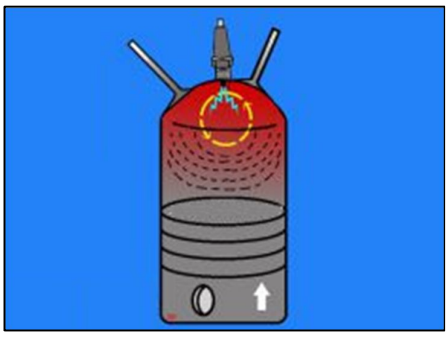

Figure 3. Tumble Flow Induction in single spark ignition engine

Thus, lower engine rpm results in incomplete combustion process. Thereby, it increases the emission from the engine. At low speed, induction process becomes very slow. Hence, the engine does not get enough air to burn the fuel completely. This deficiency increases the need for the improvement of induction. To overcome this issue, automotive engineers developed tumble flow technology. Tumble flow also indicates that the air-flow circulating in the direction of the cylinder axis. Thus, it is beneficial in homogenizing the air-fuel mixture. However, it has little effect on accelerating the combustion process by generating turbulence. So, the tumble flow effectively improves the engine combustion at light load when it completes near the end of the compression stroke. This Technology is yet to be used with twin spark ignition and is currently used by Hero MotoCorp for their 150cc single spark ignition engines under the name of Advanced Tumble Flow Induction(ATFT).

C. Fuel Injection System

In fuel injection system, the conventional carburettor has been replaced by injector which injects fuel in to the engine in a spray form based on the instructions of the Engine Control Unit (ECU) which is a part of the Engine Management System EMS. The Electronic Control Unit (ECU) is microprocessor based and is the brain of the fuel injection system. It processes information sent by various sensors and instantly determines optimum fuelling 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 fuelling & spark timing. The main advantages of Fuel Injection are increased power output for same

displacement, Better low-end torque, Lower fuel delivery & optimisation of spark timing, improved cold start, quick warm-up and excellent response to sudden acceleration, lower emission levels, self-detection and communication of fuel system malfunctioning if any, etc. Currently this technology is patented and used with twin spark ignition by Bajaj Auto ltd under the name Digital Twin Spark Fuel Injection(DTS-Fi).

Figure 4. Bajaj DTS-Fi Technology

V. Related Work

Several researchers have conducted their studies on the Performance of DTS-i engine. 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.

Ref. [1], N. Mitroglou, C. Arcoumanis, K. Mori and Y. Motoyama studied the mixture distribution in a multi-valve twin-spark ignition engine equipped with high-pressure multi-hole injectors.

Ref. [2], Narasimha Bailkeri, Krishna Prasad and Shrinivasa Rao B.R done a comparative study of performance of dual plug and single plug spark ignition engine at different compression ratios. They found that performance of dual plug engine was comparatively better than the conventional single plug ignition engine under all three compression ratios. They also found considerable improvement in thermal efficiency, and reduction in HC and CO emissions in dual plug mode of operation. However, there was a small increase in NOX emission.

Ref. [3], Imran G. Qureshi and Prof. R. J. Jani studied the performance and emission analysis of four stroke twin spark single cylinder SI engine fuelled with gasoline and CNG. They investigated the performance and emission analysis of an engine are by experiment with CNG kit and gas analyser. They found that fuel consumption was reduced in twin spark arrangement for the same power output as compared to single spark using both of the fuel gasoline as well as CNG. Engine emission was also reduced using twin spark plug.

Ref. [4], Narasimha Bailkeri, Krishna Prasad S and Shrinivasa Rao B.R studied the performance of twin plug spark ignition engine at different ignition timings. They developed a new dual ignition engine by introducing two spark plugs at suitable locations and conducted experiments at different load conditions and three different ignition timings. They found that performance of dual plug engine was comparatively better than the conventional single plug ignition engine under all three ignition timings. They also found improvement in performance in power output and thermal efficiency, as well as reduction in BSFC, HC, and CO emission in dual plug mode of operation.

Ref. [5], Devin Nirala, Arun Hathile, Jayesh Raj, Prakash Kumar Sen and Shailendra Kumar Bohidar reviewed twin spark plug performance study on single cylinder S.I. engine with gasoline fuel.

Ref. [6], G.V.N.B.Prabhkar, B.Kiran Babu and K.Durga Prasad they studied about mechatronics used in digital twin and triple spark ignition in four-stroke internal combustion engines of two-wheelers. They found that the application of these technologies would give power with fuel efficiency and harmful emission levels.

Ref [7], Dattatrey Zambre, Gaurav Shintre and Bhagyashri Patil studied the use of mechatronics in Digital Twin Spark Ignition. They found that the application of this technology would give power with fuel efficiency and harmful emission levels.

Ref [8], Arpit Dubey, Akshay Pareta and Pawan Sharma studied multiple spark ignition engines with single spark ignition engines on the basis of engine efficiency and emission characteristics size. They found

considerable performance improvement in power output, increase in thermal efficiency and reduced maintenance due to lower emission of BSFC, HC and CO emission in triple spark plug mode of operation as compared to single and dual spark plug mode of operation.

Ref. [9], Claudio Forte, Gian Marco Bianchi, Enrico Corti and Stefano Fantoni studied the effects of a Twin Spark Ignition System on combustion stability of a high performance PFI engine. They equipped a Ducati high performance engine with a Twin Spark ignition system and evaluated it at full load condition.

Ref. [10], Aditya Patwardhan, Indraneel Ray and Dr Dhananjay R Dolas done a comparative study between DTS-i engine and single spark ignition engine. They have done their study on various parameters such as specific fuel consumption, thermal efficiency, exhaust gas emission and engine performance.

Ref. [11], Hardik Bambhania, Vijay Pithiya and Rajendrakumar Jani studied and compared the performance and emissions of a lean mixed DTS-i spark ignition engine operated on single spark and dual spark. They operated DTS-i engine with single spark and dual spark mode at 2000rpm and 3000rpm with 0, 20%, 40%, 60% and 80% loading condition. They found that brake thermal efficiency for dual spark mode was higher as compared to single spark and there has been decrease in CO and NOx emission but there was increase in HC emission.

Ref. [12], Bhupendra Sahare, Shiva Suryawanshi, Kaushal Kumar Tadge, Shivam Kumar studied the effect of dual sparkplug in two stroke IC engine and found good potential from it by the help of dual spark plug.

VI. Conclusion

It is interesting to observe that most of the researchers have studied the performance of twin spark ignition system under different conditions. Few have tried to compare it with single spark ignition system and with different varieties of fuel. All these researches were showing better results towards minimization of emissions, better fuel economy and maximization of power out. There are many issues with this system like harmful NO_X emission, overheating problem at high speed and loading condition due to faster and continuous burning of air-fuel mixture, maintenance issues etc. Though overheating problem was tackled by introducing liquid cooling arrangement but it adds to the cost of the motorcycle and maintenance of it. When used with fuel injection, it has good power out but to use it in bigger displacement engine, it needs liquid cooling arrangement to tackle overheating which adds to the weight and cost increase of motorcycle. Researches also showed good results when used with 2-stroke engines and it can be developed to be used again by controlling the emission. Twin spark ignition system can be developed to be used in the multi-cylinder engines for better fuel economy and greater power output. It can be also developed to be used with Gasoline Direct Injection(GDI) for optimum response. But it will make the engines more complex, increase manufacturing and maintenance cost. So there are many problems which can be look after and simultaneously many parallel improvement opportunities are present which can help in the development of the Digital Twin Spark Ignition system.

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