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Current Status of Direct Fuel Injection in Two Stroke Petrol Engine- A Review

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Abstract; *This paper deals with the revival of 2-stroke petrol engine using direct fuel injection system (DI). The introduction of DI to the engine allows proper mixture of fuel and air, giving complete control of combustion and emissions. As a result of which power output and efficiency increases. Direct fuel injection (DI) has been used before to lower the emissions, but when running at low speed things change and problem of the scavenging and the emission goes up. But still by the direct injection of fuel to the combustion chamber proper fuel-air mixture is obtained and power is increased. Another significant advantage of using direct fuel injection is that it is economical too as it provides a correct estimation of the quantity of fuel required at proper time and providing control over combustion.*

Keywords: *Direct fuel injection, 2-stroke gasoline engine, engine performance parameters, emissions.*

I. Introduction

A two stroke cycle engine is a type of internal combustion engine which completes a power cycle in only one crankshaft revolution or with two strokes of the piston in comparison to a "four-stroke engine", which uses four strokes to do so. This is accomplished by the end of the combustion stroke and the beginning of the compression stroke happening simultaneously and performing the intake and exhaust (or scavenging)functions at the same time. Two-stroke engines often provide high power-to-weight ratio usually in a narrow range of rotational speeds called the "power band", and compared to 4-stroke engines have greatly reduced numberof moving parts and are more compact and significantly lighter. The first commercial two-stroke engine involving in-cylinder compression is attributed to Scottish engineer Dugald Clerk who in 1881 patented his design and his engine is having a separate charging cylinder. The crankcase-scavenged engine, employing the area below the piston as a charging pump, is generally credited to Englishman Joseph Day. Gasoline (spark ignition) versions are particularly useful in lightweight (portable) applications such as chainsaws and small, lightweight and racing motorcycles, and the concept is also used in diesel compression ignition engines in large and weight insensitive applications, such as ships, locomotives and electricity generation. The heat transfer from the engine to the cooling system is less in a two-stroke engine than in a traditional four-stroke, a fact that adds to the overall engine efficiency however traditional 2-strokes have a poor exhaust emissions feature. The working process of 2-stroke petrol engine consists of four strokes, they are suction stroke, compression stroke, power or expansion stroke and exhaust stroke. Two stroke has many advantages astheir performance is always much better due to largely superior power to weight ratio. Further if low emissions and economy advantages of DI are combined with those of the 2-stroke engines it results in better efficiency and less pollution.Also the lower compression ratios automatically provide lower NOx as those are a function of peak combustion temperature.

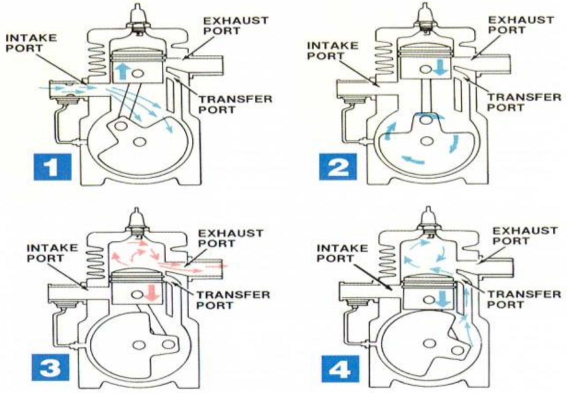

Fig.1: Working process of 2-stroke SI engine

1.1 Direct Fuel Injection

The major advantages of a gasoline direct injection (GDI) engine are increased fuel efficiency and high power output. Emissions levels can also be more accurately controlled with the GDI system. The gains are achieved by the precise control over the amount of fuel and injection timings that are varied according to engine load. In addition, there are no throttling losses in some GDI engines, when compared to a conventional fuel-injected or carbureted engine, which greatly improves efficiency, and reduces 'pumping losses' in engines without a throttle plate. Engine speed is controlled by the engine control unit/engine management system (EMS), which regulates fuel injection function and ignition timing, instead of having a throttle plate that restricts the incoming air supply. Adding this function to the EMS requires considerable enhancement of its processing and memory, as direct injection plus the engine speed management must have very precise algorithms for good performance and drivability.

The engine management system continually chooses among three combustion modes: ultra lean burn stoichiometric and full power output. Each mode is characterized by the air fuel ratio. The stoichiometric air-fuel ratio for gasoline is 14.7:1 by weight (mass), but ultra lean mode can involve ratios as high as 65:1 (or even higher in some engines, for very limited periods). These mixtures are much leaner than in a conventional engine and reduce fuel consumption considerably.

Ultra lean burn or stratified charge mode is used for light-load running conditions, at constant or reducing road speeds, where no acceleration is required. The fuel is not injected at the intake stroke but rather at the latter stages of the compression stroke. The combustion takes place in a cavity on the piston's surface which has a toroidal or an ovoidal shape, and is placed either in the center (for central injector), or displaced to one side of the piston that is closer to the injector. The cavity creates the swirl effect so that the small amount of air-fuel mixture is optimally placed near the spark plug. This stratified charge is surrounded mostly by air and residual gases, which keeps the fuel and the flame away from the cylinder walls. Decreased combustion temperature allows for lowest emissions and heat losses and increases air quantity by reducing dilation, which delivers additional power. This technique enables the use of ultra-lean mixtures that would be impossible with carburetors or conventional fuel injection.

Stoichiometric mode is used for moderate load conditions. Fuel is injected during the intake stroke, creating a homogeneous fuel-air mixture in the cylinder. From the stoichiometric ratio, an optimum burn results in a clean exhaust emission, further cleaned by the catalytic converter.

Full power mode is used for rapid acceleration and heavy loads (as when climbing a hill). The air-fuel mixture is homogeneous and the ratio is slightly richer than stoichiometric, which helps prevent detonation (pinging). The fuel is injected during the intake stroke.

It is also possible to inject more than once during a single cycle. After the first fuel charge has been ignited, it is possible to add fuel as the piston descends. The benefits are more power and economy, but certain octane fuels have been seen to cause exhaust valve erosion.In internal combustion engines, gasoline direct injection (GDI), also known as petrol direct injection or direct petrol injection or spark ignited direct injection (SIDI) or fuel stratified injection (FSI), is a variant of fuel injection employed in modern two-stroke and four-stroke gasoline engines. The gasoline is highly pressurized, and injected via a common rail fuel line directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection that happens in the intake tract, or cylinder port.

Engines with Direct Injection get better mileage by allowing higher compression ratios and leaner mixtures. A high compression ratio is desirable because it allows an engine to extract more mechanical energy from a given mass of air-fuel mixture due to its higher thermal efficiency. This occurs because internal combustion engines are heat engines, and higher efficiency is created because higher compression ratios permit the same combustion temperature to be reached with less fuel

The advantage of a direct-injection 2-stroke engine is reduced weight of the 2-stroke design. As the direct injection system has a mechanism which is less complex than the carburetor assembly consequently making the engine design simpler.

The DI system also helps in eliminating the pollution which is produced by the conventional carbureted engine. As the fuel which is injected in the engine is in controlled amounts, the fuel will burn properly resulting in lower emissions and particulate matter.

The efficiency of a DI engine is comparatively higher, as the fuel amount to be injected is predicted with help of an ECU,an optimum amount of fuel is employed for burning resulting in lower fuel consumption.

Precise control over injection timing can be obtained at varying loads .The DI mechanism can vary its functioning with the change in loads. Ultra lean burn or stratified charge mode is used for light-load running conditions, at constant or reducing road speeds, where no acceleration is required. The fuel is not injected at the intake stroke but rather at the latter stages of the compression stroke. The combustion takes place in a cavity on the piston's surface which has a toroidal or an ovoidal shape, and is placed either in the center (for central injector), or displaced to one side of the piston that is closer to the injector. The cavity creates the swirl effect so that the small amount of air-fuel mixture is optimally placed near the spark plug. This stratified charge is surrounded mostly by air and residual gases, which keeps the fuel and the flame away from the cylinder walls.

Decreased combustion temperature allows for lowest emissions and heat losses and increases air quantity by reducing dilation, which delivers additional power. This technique enables the use of ultra-lean mixtures that would be impossible with carburetors or conventional fuel injection.Stoichiometric mode is used for moderate load conditions. Fuel is injected during the intake stroke, creating a homogeneous fuel-air mixture in the cylinder. From the stoichiometric ratio, an optimum burn results in a clean exhaust emission. Full power mode is used for rapid acceleration and heavy loads (as when climbing a hill). The air-fuel mixture is homogeneous and the ratio is slightly richer than stoichiometric, which helps prevent detonation (pinging). The fuel is injected during the intake stroke.

The direct injection (DI) engines a have good and precise algorithm for better performance and drivability.DI engines also react more quickly to the changes in timing and amount of fuel addition, increasing drivability. Additionally, the vehicle is able to more quickly adjust based on inputs from sensors located downstream from the combustion chamber. Greater control by avoiding detonation and pre-ignition. Because of the ability to control the timing of the injection of fuel into the combustion chamber, it can also be use as controller to avoid pre-ignition and detonation. On current EFI equipped set-ups has always used ignition timing to control the burn sequence, but with direct injection we now have another option of control.

It is also possible to inject more than once during a single cycle. After the first fuel charge has been ignited, it is possible to add fuel as the piston descends. The benefits are more power and economy. The ability to control the injection during the combustion cycle. While all of the fuel used in the combustion process is injected in a port injection type setup, Direct Injection can inject measured amounts of fuel during the combustion cycle to aid in the burn cycle and flame propagation through the firing stroke.

It reduces short circuiting losses during scavenging. Because the fuel amount is ECU controlled so the injected fuel is in requisite amounts so when the pressure waves enters through ports affects the incoming fresh charge less thus resulting in lower fuel losses or decreasing the short-circuiting losses .

The two stroke engine also has its ports open for about ½ of the cycle, making it relatively easy to get plenty of fresh air into the cylinders. Before DI, this was the main cause of the 2-stroke's high emissions, but with DI this now provides an added advantage.

II. Literature Review

The two-stroke petrol engine was very popular throughout the 19th-20th century in motorcycles and small-engine devices, such as chainsaws and outboard motors, and was also used in some cars, a few tractors and many ships. Part of their appeal was their simple design (and resulting low cost) and often high power to weight ratio. The lower cost to rebuild and maintain made the two stroke engine incredibly popular, until the EPA mandated more stringent emission controls in 1978 (taking effect in 1980) and in 2004 (taking effect in 2005 and 2010). The industry largely responded by switching to four-stroke petrol engines, which emit less pollution. Most small designs use petrol lubrication, with the oil being burned in the combustion chamber, causing "blue smoke" and other types of exhaust pollution. This is a major reason why two-stroke engines were replaced by four-stroke engines in many applications. The two-stroke cycle is also used in many diesel engines, most notably large industrial and marine engines, as well as some trucks and heavy machinery, but two-stroke diesels don't burn their lubricating oil and don't have the emission problems of two stroke petrol/gasoline engines [1].The first successful design of a three-port two-stroke Spark-ignition (S.I) engine was patented in 1889 by Joseph Day & Son of Bath. This employed the underside of the piston in conjunction with a sealed crank-case to form a scavenge pump [2].

Douglas and Blair [3] used manually controlled electronic fuel injection system. Various injectionlocations were considered and injection timing and air/fuel ratio varied at each position to determine optimum power and brake specific fuel consumption requirements. Data were presented on performance, efficiency, emissions and relative cost and they concluded that electronically controlled high

pressure injection offers a practical and economical

solution for efficient combustion in a diesel engine . John et al. [4] used four essentials of effective fuel injection, metered quantity of fuel, desired spatial distribution, timing of injection, and complete vaporization prior to the start of combustion. Data

presented include details of spray formation and engine performance and reported dramatic reduction

in fuel consumption and exhaust emissions. The horsepower of the injection engine was nearly the same as that of the carburetor engine while the BSFC was reduced by 25 to 45% and the exhaust HC emission was so reduced that it became closer to that of a four-stroke engine at medium to high loads. At low loads HC emission did not improve due to misfiring.

Emerson et al. [5] characterized the operation of an air-assisted fuel injector. This characterization involved four sets of tests: fuel and air flow calibration; instantaneous measurements of fuel and air solenoid signals, internal pressure in the injector, and poppet lift; photographs of the spray; and droplet sizing. The injector poppet was designed to form a spray of 80° included angle. Nitrogen, instead of air, was used to assist the injection of unleaded gasoline into steady, compressed nitrogen at room temperature. The following conditions were used: nominal fuel flow rates of 10, 20, and 30 mm ^{3} /injection; spray chamber pressures of 0.1, 0.169, and 0.445 MPa; and nominal injections per minute (IPM) of 1600 and 3000. Results showed a linear increase in total fuel mass supplied to the injector as fuel solenoid pulse width was increased, except at the highest IPM and chamber pressure when the total fuel mass tended to level off. The mass of fuel injected showed a linear increase with fuel solenoid pulse width while operating at 1600 IPM, but it tended to level off at 3000 IPM.

Maclnneset al.[6]found that spray width, spray tip penetration, amount of spray found in the head vortex, and chamber fuel distribution are strong functions of the internal design of the fuel injector. Particularly important were the drop size distribution and the direction of the flow at the exit of the nozzle.

Michael M. Schechter et al. [7]described a novel air-forced (AFI) fuel injection system for in-cylinder injection in a 2-stroke engine. The system employed compressed air to force a metered quantity of fuel from the fuel injector internal cavity past a spring loaded poppet valve. As a result, an exceptionally fine atomization was achieved. At the same time, the shape of the air-fuel mixture spray could be varied as might be required by engine operating conditions.

Sung Bin Has et al. [8] considered alcohol fuels for use as automotive fuel which have a defect of high latent heat of vaporization. Therefore, in order to improve vaporization of methanol, the authors had made the fuel vaporizing device to heat the mixture and eliminate the fuel film flow. The study was on the characteristics of vaporization and engine performance according to the change of heating water temperature by means of the fuel vaporizing device. The study showed that as the vaporization of mixture improved, the mixture of methanol became homogenized and the fuel film flow decreased, which resulted in the increase of vaporization rate. And the increase of the vaporization rate improved the engine performance of the alcohol-fueled spark ignition engine.

Ghandhi et al. [9] presented results of experiments performed on a direct-injection two-stroke engine using an air-assisted injector. Pressure measurements in both the engine cylinder and injector body coupled with backlit photographs of the spray provided a qualitative understanding of the spray dynamics from the oscillating poppet system. When the air rail pressure was decreased larger drop sizes were observed.

Ghandhi et al. [10] reported simultaneous fuel distribution images (by shadowgraph and laser-induced fluorescence) and cylinder pressure measurements for a combusting stratified-charge engine with a square cup in the head at 800 RPM and light load for two spark locations with and without swirl. Air-assisted direct-injection occurred from 130°-150° after bottom dead center (ABDC) and ignition was at 148° ABDC. The engine was ported and injection and combustion took place every 6th cycle. The complicated interaction of the squish, fuel/air jet, square cup, spark plug geometry and weak tumble gave rise to a weak cross flow toward the intake side of the engine with no swirl, but toward the exhaust side in the presence of strong swirl, skewing the spray slightly to that side. Ignitability was good, and the combustion repeatable for a spark location on the side that the spray was skewed toward, but misfires were present for a spark location on the side away from which the spray is skewed when an occasionally stronger cross flow excessively leans the mixture at the spark plug. Occasional spray angle broadening was observed in the no-swirl condition, but not in the swirl condition. A high degree of spray broadening resulted in misfires or retarded cycles, but a lesser degree of spray broadening was found to correlate strongly with fast burning cycles as measured by the crank angle location of the peak pressure. The presence of swirl suppressed the broadening of the spray angle and resulted in more repeatable combustion. The cycles with the highest mean effective pressures at each of the configurations did not indicate a unique fuel distribution for optimum performance at this condition. The direct correlation of the shadowgraph and fluorescence images and the pressure measurements has been useful for identifying and understanding the correlation between fuel distribution and atypical combustion events.

Syvertsen et.al. [11] conducted a research project using a single-cylinder, two-stroke research engine at a mid-speed, boat load operating condition. Spray type was the most important factor affecting hydrocarbon emissions, followed by in-cylinder flow-related factors. Injection spray was also most important for nitrogen oxide emissions, carbon monoxide emissions, and efficiency. The dominant mechanism influencing the results was misfire, with other mechanisms present for specific responses.

Ayaz et al. [12] used the concept of making hole in transfer port by direct injection of air stream in two stroke, single cylinder SI engine for eliminating the drawbacks of poor scavenging and relatively high emissions. The variation of BSFC, NOx, smoke and particulate emission with brake power were studied for both scavenging and without scavenging and results of work showed an improvement in the performance and emissions characteristics of engine with scavenging. This was reported as comparative analysis of experimental investigations carried out on a single cylinder 2 strokes S.I. Engine with carburetor, and with and without scavenging.

Loganathan et al. [13] developed and tested an electronically fuel injection system on a 2 stroke SI engine at Indian institute of Technology, Madras. The system was fitted on the intake manifold of a single cylinder; air cooled 2 stroke scooter engines. Tests were conducted at 3000 rpm and 4000 rpm at different throttle position. The optimum injector pulse widths for thermal efficiency, lowest HC emissions and highest power were all different. The maximum brake thermal efficiency, value were 22.6% and 23% at 3000 and 4000 rpm respectively. At a power output of 3kW and 1000 rpm the brake thermal efficiency was about 21% for the carbureted engine. It increased to 23% with the fuel injection system. HC emissions were considerably, lower than the carbureted version at all operating condition and speeds. The engine could work with leaner mixtures with the injection system in general as compared to the carburetor. The maximum power increased with the injection system. The developed system could be used for mapping the engine for the development of software for injection system control.

Govindasamy et al. [14] investigated the performance and emissions of a 2 stroke SI engine fitted with a fuel injection system. The use of strong magnetic charge from the magnet put into the fuel line gave a complete and clean burn so that power was increased with reduced operating expenses. The magnetic flux on the fuel line dramatically reduced harmful exhaust emissions while increasing mileage, thereby saving money and improving engine performance. It increased combustion efficiency and provided higher-octane performance. The experimental results show that the magnetic flux on fuel reduces the carbon monoxide emission up to 13% for base engine, 23% in copper coated (inside the cylinder head) engine and 29% in zirconia coated (inside the cylinder head) engine.

Non supercharged SI engine on LPG with mixture formed by evaporated LPG has lower power by about 8%compared to original petrol engine. This disadvantage was eliminated by Mares Jan et al. [15] by using mixture formed by injection of liquid LPG. The thermodynamic analysis of the indicator diagram showed that the characteristic parameters of the cycle (including parameters of the combustion course) stood practically identical for operation on petrol and on LPG. The experimental results showed that automotive engine with injection of liquid LPG like high-quality variation of the car drive with favorable operating economy and positive ecological effects for environment.

Kumarappa et al. [16] developed an electronic compressed natural gas (CNG) direct injection system to eliminate the short circuiting losses in two stroke spark ignition engines to eliminate high exhaust emissions and improve brake thermal efficiency during idling and at part load operating conditions. The fuel and time maps were generated for the various operating conditions of the engine. For the mapping, the visualization tool was used to estimate the fuel injection time and delivery quantity for required running conditions of the engine. Experiments were carried out at the constant speed of 3500 rpm with a compression ratio of 12:1. The performance and emission characteristics of direct CNG injection system and carbureted engine WEre described. The above studies indicateD the improvement in brake thermal efficiency from 15.2% to 24.3%. This was mainly due to significant reduction in short circuit loss of fresh charge and precise control of air fuel ratio. The pollution levels of HC and CO were reduced by 79.3% and 94.5% respectively compared to a conventional carbureted engine.

Anand et al. [17] characterized, PFI injectors which are suitable for small engines to study the effect of pressure on various spray parameters. Two plate-type PFI injectors were studied: one with two orifices, and the other with four orifices. The nozzle orifice sizes were determined by microscopy. The fuel quantity injected at pressures of 200 kPa, 500 kPa and 800 kPa, were measured by collecting the fuel, for injection pulses of different durations. The spray structure of the PFI sprays was determined by shadowgraphy. A single pulsed Nd:YAG laser in conjunction with fluorescent diffuser optics was used as the light source for shadowgraphy. Backlit images of the spray were obtained at various times after the start of injection using a CCD camera. This was done for sprays at different pressures, and different pulse durations. The spray angle, and spray tip penetration were determined from the processed shadowgraphy images. The backlit images also showed insights into the development of the spray. It was observed that coalescence occurs, with liquid from the orifices merging early on to form a single core.

Tan et al. [18] investigated LPG direct injection from the transfer port of a loop-scavenged two stroke engine. The injector nozzle was placed in an area where it could inject through the transfer port window directly into combustion chamber with minimal fuel spillage into the port and minimal loss of fuel to the exhaust port. Several portions and orientations were simulated to determine the best injector nozzle location and orientation. The simulation results indicated that high fuel trappingefficiency was possible with the proper location of the injector and injection timing. Experimental resultsshowed an 80% reduction in exhaust emissions with the transfer port mounted injector nozzle compared tothe baseline carbureted engine..

Marouf et al. [19] performed the experimental investigations on a single cylinder, two stroke spark ignition engine in the carburetor and gasoline direct injection (GDI) modes. The experiments were conducted on the engine in the carburetor mode up to 80% throttle opening and for different combinations of speed and load. The engine was modified and fitted with an in-cylinder injector in the head. Fuel was supplied through injector with the help of a high pressure DC pump. Experiments for varying speed and load were conducted under in-cylinder injection mode up to 80% throttle opening. It was observed that there is a significant reduction in BSFC, unburnt HC and CO emissions. Also, the power output of the engine had shown an improvement.

Hiltner et al. [20] determined the impact of fuel injection timing in-cylinder fuel distribution. Equivalence ratio maps were acquired by Planar Laser Induced Fluorescence in an optical engine with a production cylinder head. Experimental results were used to determine the injection timing which produced the most uniform fuel distribution for thegiven engine.

Cornel Stan et.al. [21] presented a concept, based on the ram tuned injection. The engine results showed that the engine torque remains in all of the speed range at least at the same level as for the base engines equipped with carburetors, while the bsfc decreased generally by 35-45%. But the most important result was the reduction of pollution - with 80-94% for the HC Emissions and 90% for the CO Emissions respectively.

Johnson et al. [22] described the development and demonstration of an electronic direct fuel injection (EDFI) solution which was applicable to low cost and high production volume engines in several industries. The system was based on the “accumulator” fuel injection operating principle, which involved pressurizing fuel within an injection nozzle and subsequently releasing the pressurized fuel into the combustion chamber on command. This concept provided very short injection duration throughout the dynamic operating range of the engine as well as high injection frequency capability.

Obodeh et al. [23] described the basic exhaust tuning mechanisms with respect to a two-stroke single-cylinder engine. Tuned adjustable exhaust pipe for use on two-stroke motorcycle was designed and tested. The dynamometer used incorporated a flywheel of appropriate moment of inertia to simulate the mass of the motorcycle and rider. The test procedure involved measurement of the flywheel speed during an acceleration phase resulting from opening the throttle. Calculation of the instantaneousflywheel acceleration gave a measure of the torqueand power characteristics. The airflow based valuesof delivery ratio, trapping efficiency and charging efficiency were evaluated from the fuel flow values and the Spindt computation of the exhaust gas analysis. Experimental test results were presented forpower output, specific fuel consumption and engineout emissions. The tuned exhaust system was found to improve fuel economy of the engine by 12%. The major engine-out emissions HC and CO were reduced by a minimum of 27.8% and 10.7%respectively. An improved power output of 15.8%increase was achieved also exhaust noise was reduced.

Fathi et al. [24] studied the effect of the initial charge temperature on the second law terms under the various injection timings in a direct injection spark ignition hydrogen fuelled engine during compression, combustion and expansion processes of the engine cycle. The first law analysis was done by using the results of a three dimensional CFD code. The results showed a good agreement with the experimental data. Also for the second law analysis, a developed in- house computational code was applied. The results revealed that the indicated work availability is more affected by varying hydrogen injection timing in comparison with other second law terms. Also increasing the initial charge temperature caused the heat loss availability and exhaust gas availability to be increased and indicated work availability, combustion irreversibility and entropy generation found be decreased.

Salah et al. [25] conducted the experiments to determine the effect of fuel-injection timings on engine characteristics and emissions of a DI engine fueled with NG-hydrogen blends (0%, 3%, 5% and 8%) at various engine speeds. Three injection timings namely 120°, 180° and 300° CA BTDC with a wide open throttle at relative air–fuel ratio, $\lambda = 1.0$ were selected. The ignition advance angle was fixed at 30° CA BTDC, while the injection pressure was fixed at 1.4 MPa for all the cases. The tests were firstly performed at low engine speed of 2000 rpm to determine the engine characteristics and emissions. The results showed that the engine performance (e.g. Brake Torque, Brake Power and BMEP), the cylinder pressure and the heat release have the highest values at the injection timing of 180° CA BTDC, followed by the 300° CA BTDC and the 120° CA BTDC. The NOx emission was found to be highest at the injection timing of 180° CA BTDC. The THC and CO emissions were found to decrease while the CO_2 emission increased with the advancement in the injection timing. The addition of a small amount of hydrogen to the natural gas was found to increase the engine performance, enhance combustion and reduce emissions for any selected injection timings. Secondly, the tests were carried out at variable engine speeds (i.e. 2000 rpm–4000 rpm) in order to further investigate the engine performance. The injection timings of 180° and 300° CA BTDC with CNG–H_2 blends were only selected for comparisons. The injection timing of the 300° CA BTDC was discovered to yield better engine performance as compared to the 180° CA BTDC injection timing after a cutoff engine speed of approximately 2500 rpm.

III. Conclusion

The following conclusions were drawn from the present review:

1. The development in electronic fuel injection system has made it possible to overcome the level of pollution and improvethe performance of engine in term of parameters like fuel consumption. It has eliminated the short circuiting losses completely.

2. The fuel consumption and emission in two stroke SI engine can be reduced by optimizing theparameters like air-fuel ratio, bore-stroke ratio, delivery ratio andprocesses like combustion and scavenging energy in combustion chamber.
3. The optimization of injection timing greatly reduces the specific fuel consumption and exhaust emission due to better control over the air fuel ratio.
4. The use of injector, fuel pump, crank angle encoder and ECU with various series can replace the carburetor and its various disadvantages.
5. The use of DI system can improve atomization whichleads to proper burning of fuel and have less pollution andbetter efficiency.
6. The use of fuel injection systems can very well control amount of fuel injected. Hence the working of fuel can be reduced as compared to conventional two stroke engines.

IV. Future Scope

The development of direct injectionsystemin 2-stroke engine is beneficial in numerous fields like agricultural, heavy duty works and applications where the operating conditions vary with load. The scarcity of fossil fuels has urged the use of alternative fuels which are less costly and less harmful to the environment. As biofuels are eco-friendly, their use in direct injection engines can lead to additional advantages in the time of high price of petroleum based fuels. The biofuels like ethanol, methanol, butanol and their blends with petrol can be successfully used in direct injection engines. With the use of biofuels in direct injection engines, the pollution can be reduced and efficiency can be increased.

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