EXPERIMENTAL INVESTIGATION OF IN-CYLINDER AIR FLOW IN A DIESEL ENGINE WITH CLOSE COILED AIR INTAKE MANIFOLD

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ABSTRACT

The fluid motion in an internal combustion engine is induced during the induction process and later modified during the compression process. There are various methods to improve the efficiency of engine such as super charging, turbo charging, varying stroke length, varying injection pressure, fuel to air ratio, additional strokes per cycle and so on. In the present work the experimental analysis has been carried out to study the impact of in cylinder swirling flow with closed coil intake manifold using both diesel and Mamey Sapote biodiesel. The swirl motion is created by modifying the inlet manifold. This study presents the comparative measures of brake power, brake specific fuel consumption, brake thermal efficiency, CO, CO_2, HC, NOx and smoke opacity.

Keyword: *Diesel engine, air swirl, emission control. Intake manifold, biodiesel.*

1.0 Introduction

Fossil fuels play a major role in development of any country in the present scenario. Petroleum derived products are the critical sources of energy for fuelling of automobiles for the entire world. But, these fossil fuels are depleting day by day and they are non renewable. It is also assessed that these sources will be depleted in a certain period of time and it is not possible to meet the future requirements. Hence there is a need for development of renewable energy sources to meet the requirements of future and it has become an essential to explore the reasonable substitution of diesel with alternative fuels within the country on a massive production for commercial usage. Alcohols (methanol/ethanol), Liquefied Petroleum Gas(LPG), compressed natural gas (CNG), Hydrogen, fruit & Vegetable seed oils have been tested for suitability on diesel engines in the past few years.The advantage with vegetable oils is air fuel ratio is high in vegetable oil mixture because of oxygen content in the fuel and it is free from sulphur. The calorific value of these oils is almost 90% of the diesel fuel. Vegetable oils are costly than diesel oils in the present market, the viscosity is also one of the serious drawback associated with vegetable oils and this can be reduced by various methods. Those are transesterification, preheating, blending with alcohols /diesel, duel fuelling with liquid and gaseous fuels and use of additives.

Although there is large development in the CI engine in last few decades it is still lagging in the performance in the sense of fuel economy & exhaust emission. It is due to the ineffective use of air in the engine causes improper atomization of the air-fuel mixture results in the poor combustion, which affects the engine performance characteristics in terms of fuel economy and emissions at part load conditions. So to enhance the performance of engine better utilization of intake charge is necessary, different techniques are introduced in form of modification of intake manifold, development of swirl and tumble devices, modification of piston profile for efficient combustion of charge. In this paper different swirl generating devices are analyze and their result is compared with base model without swirl device. Resistance offered by device to flow is prime factor. Since volumetric efficiency of CI engine is always a critical parameter due to numerous component in intake system. Addition of swirl generating device should not develop more resistance to flow. Requirement of swirl is also varying in engine and is not constant at all loading conditions. At cold start conditions and part load conditions engine require slightly rich mixture. Modeling of device is done taken into consideration the fact that it should be able to develop variable swirl while its operation

In-cylinder flow field structure in an internal combustion engine has a major influence on the combustion, emission and performance characteristics. Fluid flows into the combustion chamber of an I.C engine through the intake manifold with high velocity. Then the kinetic energy of the fluid resulting in turbulence causes rapid mixing of fuel and air, if the fuel is injected directly into the cylinder. With optimal turbulence, better mixing of fuel and air is possible which leads to effective combustion. A good knowledge of the flow field inside the cylinder of an I.C engine is very much essential for optimization of the design of the combustion chamber for better performance.

2.0 Literature Survey

It is quite well known that a properly designed intake manifold is vital for the optimal performance of an I.C. Engine. The induction swirl is generated clockwise by the inlet valve port and on compression; this accelerates in the head cavity below the exhaust valve. A more recent work given by Edgar and Ashwani [1] treated the effect of high pressure and temperature. These combined effects act to influence fuel-air mixing, combustion efficiency, flame stability and generation of unwanted emissions. In spite of the huge advancement in the field of internal combustion engines, the problem of mixing air with fuel in a homogenous way is still exist. A homogeneous fuel-air mixture is the mixture in which the fuel particles are surrounded by the air particles with equidistance between the particles based on the air-to-fuel ratio (Ø). Such type of a homogeneous mixture is easy to evaporate burn and be consumed by the engine. As a result, the specific fuel consumption will be reduced as well as the air pollution resulting from incomplete combustion.

Many patents all around the world have been invented in this field and few of them, as examples, will presented here. It is known that Mangion [2] patented a device to improve the mixing process of air and fuel in gasoline engines in which the fuel evaporates inside the intake manifolds through closed tiny tubes inside there. On starting the engine, the high temperature exhaust gases penetrate through the closed tiny tubes causing a rise in its temperature. When fuel-air mixture enters the engine through the intake manifold, the fuel particles that exist in the mixture will collide with the high temperature tiny tubes causing it to evaporate. As a result, the mixing process becomes smoother and the mixture becomes homogeneous for faster burning. The evaporation of this mixture inside the intake manifolds will cause an increase in the mixture volume. As result, the volumetric efficiency of the engine will drop down causing a reduction in the effective efficiency of the engine. One more example from the US patents is the fuel vapor generator [3].

It is in the form of a heat conductive member having an elongated U-shaped passageway formed through it. The member is mounted at the exterior of a carburetor venture. The open inlet end of the passageway extends through the venturi walls and receives atomized fuel from the main fuel nozzle and a portion of the incoming air. This fuel and air mixture is directed through the passageway where it is heated and the fuel is vaporized. The fuel and air are drawn from the passageway and returned into the venture at a location downstream from the main nozzle. A series of mesh screens extending across the passageway and spaced along its length assist in atomizing the fuel and assuring efficient conductions of heat to the entire mixture of fuel and air within the passage way. On the other hand, the Russian prototype [4] which is mainly a carburetor installed on gasoline internal combustion engines, mixes fuel with air at the venture then pushing it into the vertical chamber at the bottom of the carburetor to start a rotational movement inside there. During this process, the mixture will go through another remixing process and becomes more homogeneous before entering the intake manifolds. In such process, the homogeneity of the mixture is an air-flow-speed (engine speed) based process such that the mixture may become homogeneous at a certain speed and may not at another speed because of the change in the mixing time. The faster the engine runs, the shorter the time needed for the mixing process.

This concludes that it is impossible to maintain a homogeneous mixture on all engine-running speeds. Shablin [5], in his invention change this technique into a tangential groove. This design has a problem that the homogeneity is changing during high speeds. One more example from the Russian patents is the work of Yakobov [6]. He inserted an additional device after the carburetor. This new device is provided with inclined grooves with an angle of 14° in order to increase the swirl of the flow, improve the mixing efficiency and decrease the engine pollutions. The problem of this design is the relatively big space that occupied by the device that decrease the volumetric efficiency.

The Australian prototype [7] is another device used to improve the mixing process by installing it directly next to the air filter at the entrance of the intake manifolds. This device converts the straight airflow or the mixture to a swirling airflow by means of blades and holes installed in a tangential position at the device axis. The airflow or the mixture gets into the engine through the blades and the holes and gets out in whirling motion. This airflow then gets mixed with the fuel producing a homogeneous mixture that can burn and evaporate quickly. They claim 15-20% fuel savings, but some old cars have achieved figures higher than 35% fuel savings. This device works efficiently under low engine speeds and is not recommended for high speeds because the centrifugal forces increase as the speed increases causing the fuel particles to accumulate on the intake manifolds' walls which produce an inhomogeneous mixture (in some places the mixture is rich and in some others is lean).

Al-Rousan [8] has invented a device to improve the mixing process in the gasoline engines that operate either by carburetors or indirect injection. This prototype is made of steel of small in size with no moving parts and can be installed without any modifications to the engine and requires no chemical additives. The device will improve the mixing process inside the intake manifolds. Inserted a loop inside the intake manifolds will increase the swirling motion because a big portion of the mixture starts to move around the loop axis that has been called the main stream. Such kind of motion helps in mixing the air and the fuel in a homogeneous way at the exit. The rest of the mixture, that has been called the swirl stream, enters through the device to help controlling its homogeneity. This homogeneous mixture can reduce the specific fuel consumption and reduce the environmental pollution resulting from incomplete combustion at all running speeds.

Rasul and Glasgow [9] have developed a method to increase the performance of an internal combustion engine without any major investment or mechanical parts which requires additional energy to operate is investigated. A convergent-divergent induction nozzle is tested in order to increase the airflow into the engine, which in turn may increase the overall performance. The induction system is applied to the air before the throttle body of a four-cylinder, four-stroke diesel engine connected to an engine dynamometer with airflow and pressure drop measurement facilities. The measurement was done at an engine speed of about 3500 rpm. The results of test show an increase in air flow into the engine, an increase in brake power as well as in mechanical efficiency, which demonstrate that the nozzle type induction can improve the performance of an IC engine.

Saito et al. [10] also found that a re-entrant chamber produces shorter ignition delays, lower fuel consumption, and lower soot and NOx emissions when used with retarded injection timings later studies have suggested that the use of a centrally situated cone, frustum, or other raised crown within the bowl may also have a beneficial effect on performance and emissions [11]. Their studies suggest that it is necessary to consider injection spray angle and injection timing along with chamber geometry, since these three variables strongly interact to determine engine performance [12].

2.1 Effect of Air Swirl in Diesel Engine

Most important function of CI engine combustion chamber is to provide proper mixing of fuel and air in short possible time. For this purpose an organized air movement called air swirl is to be produced to produce high relative velocity between the fuel droplets and air. Swirl is what is taking place when the intake charge exits the intake valve and enters the combustion chamber. As the air enters the combustion chamber and the piston travels down in the bore, it causes a spiraling effect. The air in the spiraling effect actually travels around the bore such as water goes around in a flushing toilet. Swirl, considered as a two-dimensional solid body rotation, persists through the compression and combustion processes. Many researchers have demonstrated that the decay of swirl in an engine cylinder during the compression process is relatively small so that the overall angular momentum of the swirl vortex is almost conserved.

In the present investigation experiments were conducted on DI diesel engine with diesel and B15 (15% of Mamey Sapote biodiesel + 85 % of diesel) on a four stroke, single cylinder water cooled diesel engine. The properties of diesel and Mamey sapote biodiesel are shown in table 2.1

Table No: 2.l Properties of Mamey Sapote oil

Properties	Mamey Sapote oil	Biodiesel
Density at l5^0 C (g/cm^3)	0.887	0.875
Kinematic Viscosity at 40^0 C(mm^2/s)	34.75	4.65
Calorific Value (MJ/Kg)	38.l2	37.2
Flash Point (^{0} C)	l97	l73
Pour Point (^{0} C)	-6	3
Acid Value mg KOH/g	3.79	0.l5
Iodine value g Iodine/ l00 g	65.02	65.28
Specific gravity	0.902	0.87l

3.1 Experimental Setup: The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer as shown in fig: 3.2 and the specifications of the test engine are shown in table 3.1.

Table: 3.1 Engine Specifications

Make and Model	**Research Engine Test setup code 240 PE** **Apex innovations pvt.Ltd.**
Type of Engine	Multi fuel
Number of Cylinders	Single cylinder, Four Stroke
Cooling Media	water cooled,
Rated Capacity	3.5 KW @ 1500 rpm,
Cylinder diameter	87.5 mm
Stroke length	110 mm,
Compression ratio range	12-18
Injection variation	0- 25 ^{o} BTDC
Dynamometer	Eddy current Dynamometer
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Fig: 3.2 Experimental set up with closed coil pipe connecting inlet manifold and air chamber

4.0 Results and Discussion

4.1 Load Vs Brake thermal efficiency:

Brake thermal efficiency of the diesel engine increases with the increase in load on the engine. From fig: 4.1 it observed that at full load B 15 MSO(Mamey Sapote Oil) has the highest brake thermal efficiency which is 29.63%. This is 7.8% higher than the base line engine.

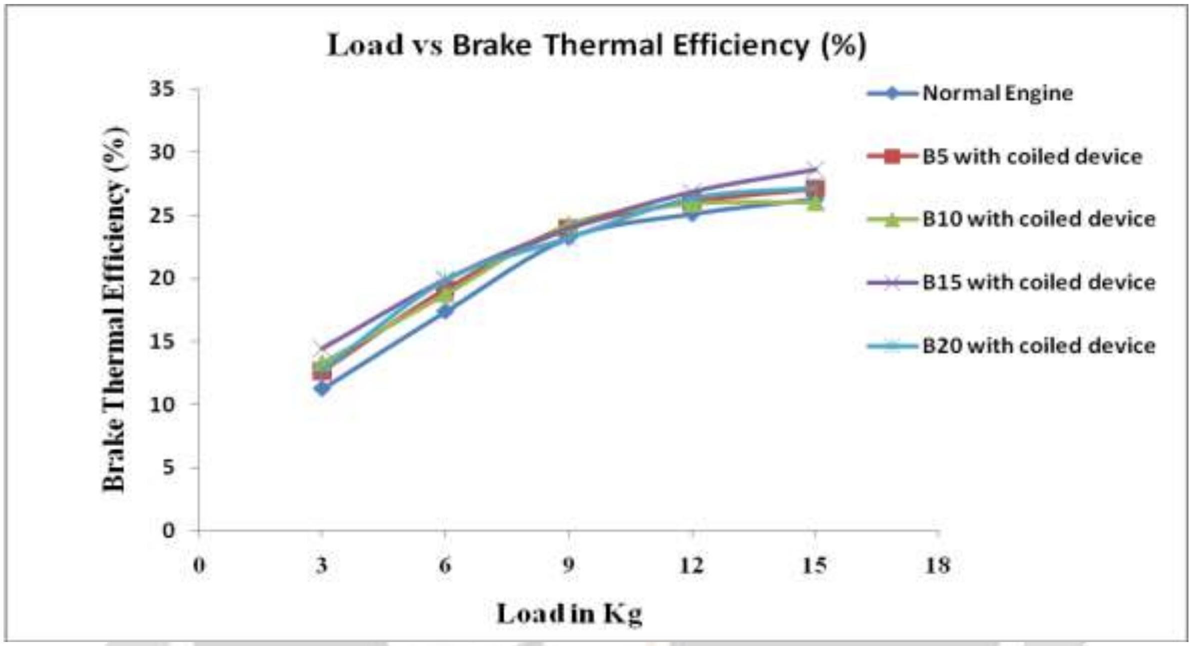

Fig: 4.1 Comparison of brake thermal efficiency with variation of load

4.2 Load versus Brake Specific Fuel Consumption (BSFC)

Brake specific fuel consumption of the engine decreases with the increase in load on the engine. Due to the air swirl generation, there is an increase in the mixture quality of air & fuel in the combustion chamber before the initialization of ignition. Hence the amount of heat released is more, so that the fuel consumption is less for the all blends when compared to the normal engine.Fig:4.2 illustrates that at full load the B15 blend consumes less fuel i.e 0.275 kg/kw-hr. It is observed that in B 15 oil there is a decrease of 6.6 % specific fuel consumption at full load when compared with the base line engine

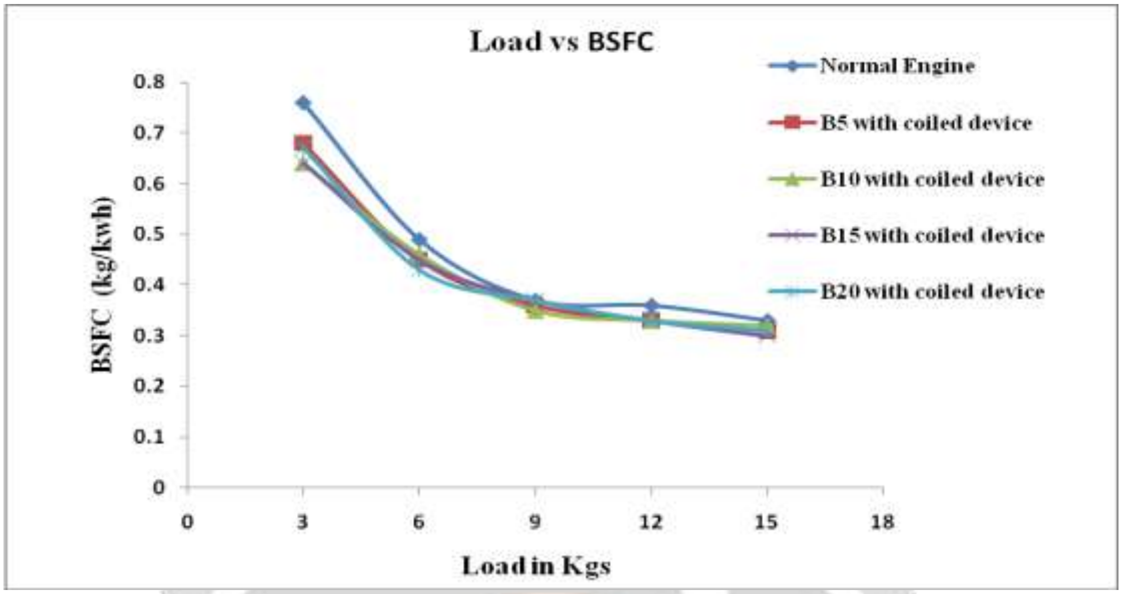

Fig: 4.2 Comparison of brake specific fuel consumption with variation of load

4.3 Load Vs Volumetric efficiency:

The volumetric efficiency decreases with increase of the load. Fig: 4.3 shows that the volumetric efficiency of the diesel engine is more when close coiled intake manifold installed than a base line engine without air swirl device. Due to this the brake thermal efficiency increases with installation of the air swirl device .At low load, the volumetric efficiency is high which is 89.9 % , which is 0.7% higher than without air swirl device.

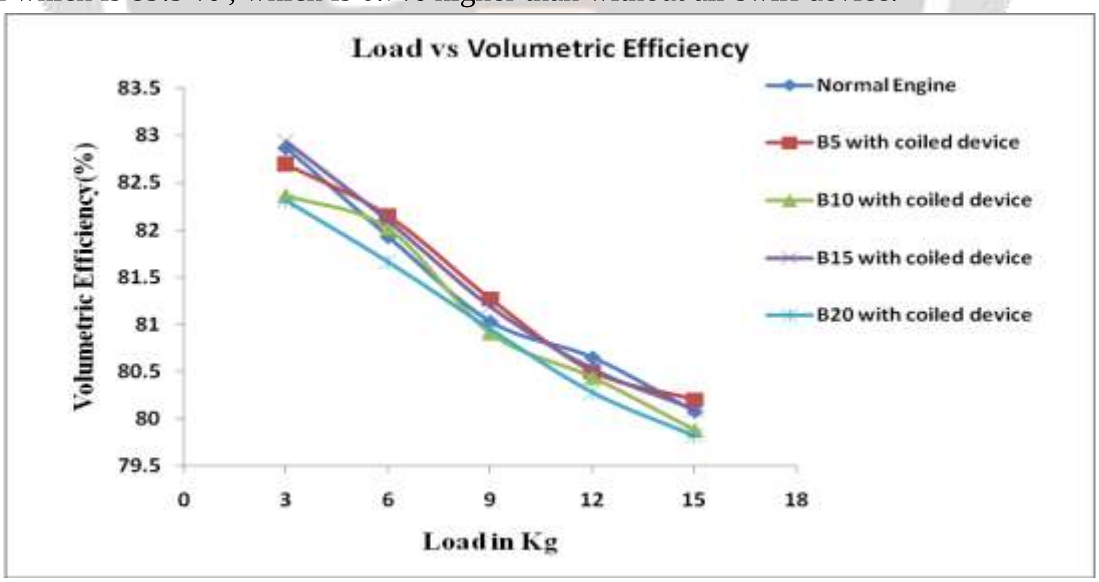

Fig: 4.3 Comparison of Volumetric efficiency with variation of load

4.4. Load vs Hydro Carbons

The biodiesel blends have more oxygen content than that of standard diesel. So, it involves in complete combustion process. The hydrocarbon emissions of the biodiesel blends are lower than the standard diesel due to complete combustion process. When percentage of blends of biodiesel increases, hydrocarbon decreases. Fig: 4.4 illustrate that, at full load the HC emissions are less for 15% MSO , which is 13% less when compared with the base line engine without closed coil intake manifold.

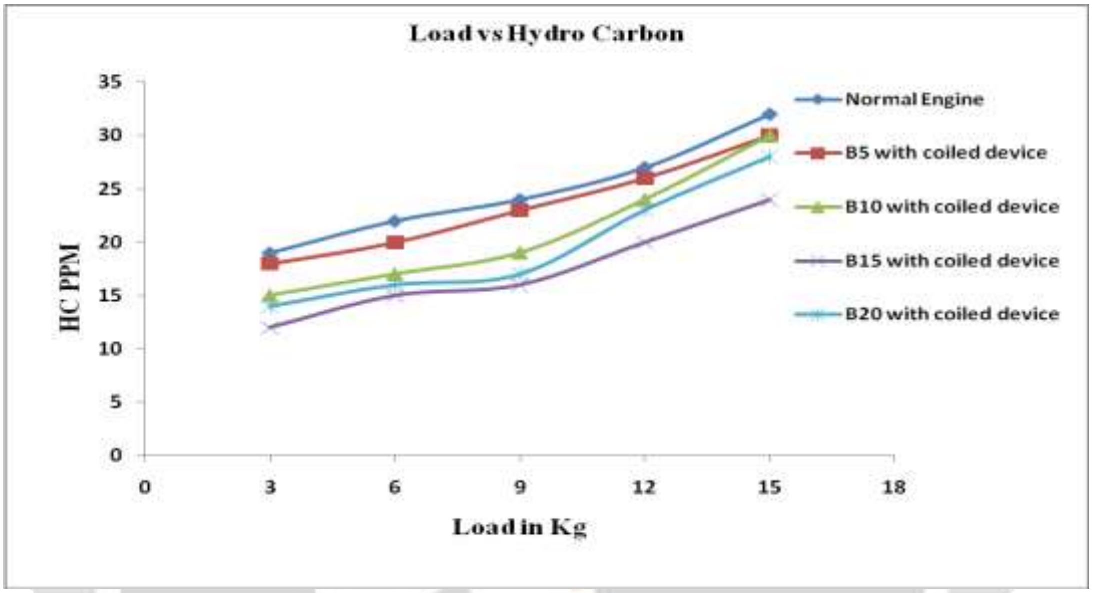

Fig: 4.4 Comparison of Hydrocarbons with variation of load

4.5 Load Vs Carbon monoxide (CO)

The major reason to the CO formation is insufficient time and oxygen for oxidation of CO to CO_2.The carbon monoxide emission depends upon the oxygen content and cetane number of the fuel. As biodiesel has more oxygen content than the diesel fuel the biodiesel blends are involved in complete combustion process. Fig: 4.5 shows that at full load 15 % MSO emits low carbon monoxide (0.08% in volume), which is 17.27% lower than the base line engine without coil intake manifold. The carbon dioxide emission depends upon the complete combustion of the fuel. The biodiesel blends have the 11.5% oxygen content, resulting in complete combustion. Due to the complete combustion of the biodiesel blends, carbon dioxide emission also increases. The carbon dioxide emission using diesel fuel is lower because of the incomplete combustion. The combustion of biodiesel also produced more carbon dioxide but crops are focused to readily absorb carbon dioxide and hence these levels are kept in balance.

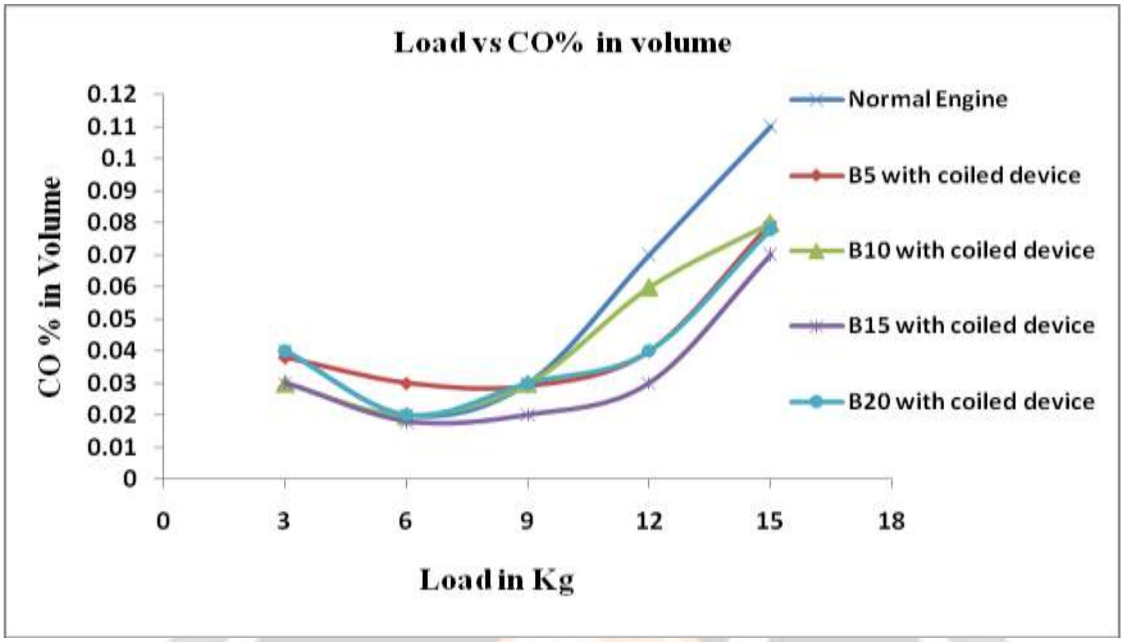

Fig: 4.5 Comparision of Carbon monoxide with variation of load

4.6 Load Vs Oxides of Nitrogen

Nitrogen and oxygen react relatively at high temperature. Therefore high temperature and availability of oxygen are the two main reasons for formation of NOx. When the more amount of oxygen is available, the higher the peak combustion temperature the more is NOx formed. Fig: 4.6 shows that at peak load 15% MSO emits low NOx i.e 550 ppm, which is 12.5% lower than the base line engine without air swirl.

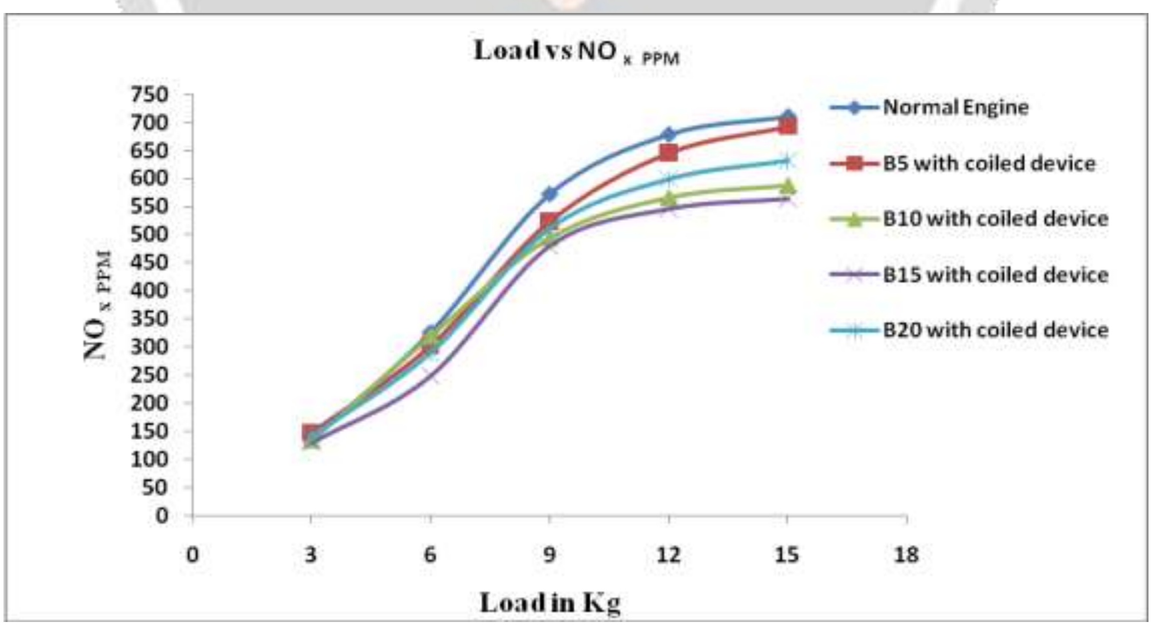

Fig: 4.6 Comparision of Carbon dioxide with variation of load

4.7 Load Vs Smoke Opacity

The amount of soot formed depends upon the fuel ratio and type of fuel. If this soot, once formed finds sufficient oxygen it will burn completely. The size of the soot particles affects the appearance of smoke. Black smoke largely depends upon the air fuel ratio and increases rapidly as the load is increased and available air is depleted. In comparison with diesel, the smoke is less for biodiesel blends at all loads because of complete combustion. For over load the smoke opacity is maximum, which is due to incomplete combustion. Fig: 4.7 shows that at peak load 15% MSO emits less smoke which is13.48% lower than the base line engine without air swirl .

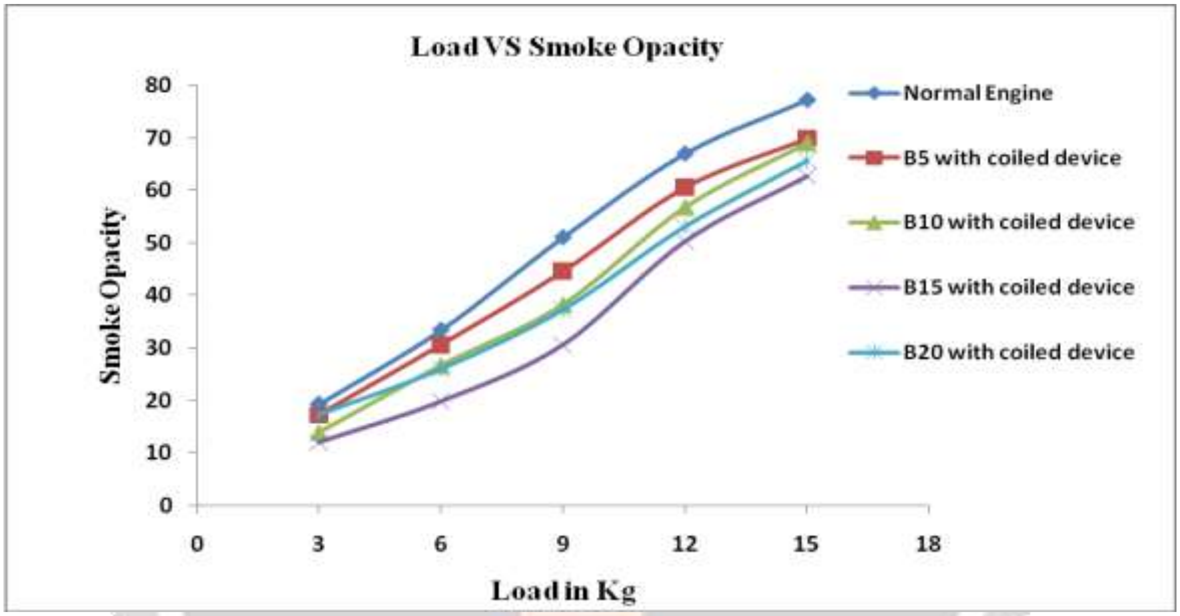

Fig: 4.7 Comparison of NOx with variation of load

5.0 Conclusions

The following conclusions were drawn from the experimental investigation, performance and emission characteristics have been carried out about the single cylinder, 4-stroke, uniform speed diesel engine at a Compression ratio of 18. The combustion along with performance and emission characteristics of single cylinder DI diesel engine fuelled with Mamey Sapote (MSO) biodiesel and its blends have been analyzed with closed coil intake manifold and compared the same with the standard base line engine at full load. Based on the experimental results, the following conclusions are drawn.

- The B 15 MSO(Mamey Sapote Oil) has the highest brake thermal efficiency which is 29.63%.
- The B15 blend consumes less fuel i.e 0.275 kg/kw-hr.
- The HC emissions are less for 15% MSO , which is 13% less when compared with the base line engine.

- The 15 % MSO emits low carbon monoxide (0.08% in volume), which is 17.27% lower than the base line engine.
- The 15% MSO emits low NOx i.e 550 ppm, which is 12.5% lower than the base line engine.
- The 15% MSO emits less smoke which is13.48% lower than the base line engine

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