

Experimental investigation of in-cylinder air flow to optimize number of helical guide vanes to enhance DI diesel engine performance using mamey sapote biodiesel

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Abstract: The current research work investigates the influence of helical guide vanes in to the intake runner of a D.I diesel engine operating by the high viscous Mamey Sapote biodiesel to enhance in-cylinder suction air flow features. Helical guide vanes of different number of vanes are produced from 3D printing and placed in the intake manifold to examine the air flow characteristics. Four different helical guide vane devices namely 3, 4, 5 and 6 vanes of the same dimensions are tested in a D.I diesel engine operating with Mamey Sapote biodiesel blend. As per the experimental results of engine performance and emission characteristics, it is found that 5 vanes helical guide vane swirl device exhibited in addition number of increased improvements such as the brake power and brake thermal efficiency by 2.4% and 8.63% respectively and the HC, NO_x, Carbon monoxide and, Smoke densities are reduced by 15.62%, 4.23%, 14.27% and 9.6% at peak load operating conditions as collate with normal engine at the same load. Hence this investigation concluded that Helical Guide Vane Devices successfully enhanced the in-cylinder air flow to improve better addition of Mamey Sapote biodiesel with air leading in better performance of the engine than without vanes.

1. Introduction

Owing to importance regarding the energy safety since fewer Petroleum reserves are accessible on the globe, rapid rate of exhaustion of crude oil, limited source of fossil fuels have led to escalation prices of oil and drastic changes in environment, attention is focused on utilization of alternative fuels, such as vegetable and fruit seed biodiesel blends in compression ignition engines. The vegetable seed oils are converted into biodiesel by transesterification process. It consist of mono alkyl esters of long chain fatty acids. Main drawbacks of biodiesel when compared to diesel are poor thermo physical characteristics such as, high viscosity, low heating and low volatility [1]. Due to the above reasons many investigations reports poor outcomes of the diesel engine operating with alternative fuel. Fazal. et.al [2] examined the various analysis on performance & emission tests run on biodiesel from different literatures. They understood that the Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC) and oxides of Nitrogen (NO_x) were increased mostly, on the other hand Brake Power (BP), Unburned hydrocarbon (UBHC) and Carbon Monoxide (CO) emissions were lowered [3]. Owing to high viscosity of biodiesel creating it less level to vaporize, diffuse: the reduction in carbon monoxide and emissions were owing to the rich oxygen present in the biodiesel that helps in better combustion [4]. Based on the facts, it is observed that the vaporization and combustion phenomena of biodiesel which is injected in to the cylinder need to be improved to enhance the performance and



reduce the emission characteristics.

Many investigators across the globe conducted the experiments by blending of biodiesel at different proportions or preheating the biodiesel to reduce the viscosity or alter the fuel injection approach or attempt all these methods to enhance the performance & emissions of compression ignition engine [5]. Though, still there is a scope for enhancement particularly by increasing the in-cylinder air flow into the engine cylinder to improve the mixing of fuel and air.

Based on literature review no research has been done by other investigators to enhance the in-cylinder air circulation to enhance the performance of compression ignition engines operating with high viscous Mamey Sapote biodiesel. Hence, in this present work experiments were conducted to get the affect of helical guide vanes in enhancing turbulence features to enhance the evaporation and combustion phenomena to enhance the performance & emission features of the diesel engines operating with biodiesel. Compression ignition engines need homogeneous mixture for effective combustion, which is possible with the supply of swirling air and turbulent fuel sprayed into the engine cylinder [6]. Biodiesel requires additional turbulence and air swirl to enhance the air fuel mixing. Thus the main objective of the current research work is inserting fixed helical guide vane swirl devices in the intake manifold to enhance the mixing of high viscous Mamey Sapote biodiesel and air.

Guide vanes are fixed vanes inserted in the intake manifold to deflect the air flow as a result well organized intake turbulent air flow can be created with more kinetic energy and air velocity during the suction stroke and will be continued until the ignition.. This process was investigated effectively to enhance the engine performance and decrease the emissions, when adopted on different types of SI engines [7] however; no research has been done on a compression ignition engine working with Mamey Sapote biodiesel. Hence an attempt is made by inserting helical guide vane swirl devices in the intake manifold to decrease complicated modifications to a normal diesel engine. In the helical swirl guide vane design four parameters are considered: Vane angle, number of vanes, vane height and device length. To create the effective turbulence, all the parameters require optimizing to enhance the engine performance and reduce the emissions, since some investigators reported in the literature that over design of the device leads to obstruction in the direction of the flow of air instead of enhancing [8]. Though, this investigation has restricted in the optimization of number of vanes and all other parameters are remains constant [9][10]. The various helical guide vane models are tested by conducting the experiments with Mamey Sapote biodiesel on DI diesel engine. Earlier to that similar experiments are conducted on the same engine without helical guide vanes run by diesel and Mamy Sapote biodiesel.

2. Helical Guide Vanes Fabrication

In the present investigation four helical guide vanes are modeled in CREO software. The model is shown in Figure:2.. Based on the four parameters the devices are modeled: helix angle, vane numbers, and height of the vane and length of swirl device. Among the four parameters vane angle, height of the vane and length of swirl device kept constant and the number of vanes are changed from device to device viz 3, 4, 5 and six numbers of vanes. The models are fabricated with the aid of 3 D Printing. The fabricated helical guide vane models photographs are shown in the Fig: 2.1. The dimensions of the produced helical guide vanes are presented in the Table: 2.1.

Table 2.1 Specifications of Helical Guide Vane swirl devices

Element	Dimension
Major Outer Radius (R)	24 mm
Guide vane (L)	60 mm
Thickness of the vane	2 mm
Pitch	106 mm
Height of the vane	8 mm
Guide vane helical angle(θ)	350
Guide vane number	3 Vanes, 4 Vanes, 5 Vanes and 6 Vanes

**Figure 2.1 Modeled Helical Guide vane swirl devices & produced from 3 D Printing**

3. Testing Methodology

The specification of the experimental test engine is presented in the Table 3. The engine is shown in the figure 3. The tests began with starting the normal engine without inserting the guide vanes in the intake manifold operating with diesel fuel. After the diesel engine attains the standard rpm and the engine working temperature, 3kg load was applied by regulating the load regulator. After the diesel engine attained the working temperature at this load, the necessary engine and emission data were recorded. The similar method was repeated for other loads of 6kg, 9kg, 12kg and 15 kg, .respectively. After carrying out the experiments, the engine was permitted to run in no load condition, before the fuel was changed to Mamey Sapote biodiesel blend (B15). Same process for taking the readings, when the engine was operate with diesel was repeated when operate with biodiesel blend without guide vanes. This test provided the standard readings before the helical guide vanes are inserted in the inlet manifold. After the standard readings the diesel engine was permitted to stop in biodiesel mode. The helical guide vanes were inserted into the inlet manifold one after the other, and the same method was adopted to collect the readings. Before the end of each experiment the engine is allowed to operate with diesel to wash out the biodiesel in the fuel lines. This was repeated every time

Table 3.1 Specification of Engine Cylinder

Make and Model	Research Engine Test setup
Type of Engine	Multi fuel
Number of cylinders	Single cylinder, Four Stroke
Cooling Media	Water cooled
Rated capacity	3.5 Kw @ 1500 r.p.m
Cylinder diameter	87.5 mm
Stroke length	110 mm
Compression ration range	12-18
Injection variation	0 – 25 ° BTDC
Dynamometer	Eddy current dynamometer

**Fig: 3.1 Experimental Setup**

4. Results and Discussion

This segment presents the effect of helical guide vanes on DI diesel engine operating with Mamey Sapote biodiesel and finding the optimum number of vanes for the models. For presentation of the test results the standard data for diesel and biodiesel were represented as diesel, B15 (15% of Biodiesel + 85% of diesel) and the guide vanes with biodiesel are named as HG1 (3 vanes), HG2 (4 vanes), HG3 (5 vanes) and HG 4 (6 vanes) respectively.

4.1 Performance Parameters

4.1.1 Brake Power: The graphs of brake power against applied loads for diesel, Mamey Sapote blend and all helical guide vane models are plotted in Fig: 4.1. From the figure the brake power is improved when the load on the engine is increased. The same tendency was observed in other associated work [11]. The brake power was more for the diesel when compared to biodiesel, this is owing to the lower calorific value of Mamey Sapote biodiesel collated to conventional diesel fuel as described before [12].

4.1.2 Brake Thermal Efficiency: The distinction of brake thermal efficiency with engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.2. Based on the figure, it is observed that the brake thermal efficiency of B15 is lower than the diesel. However, with the insertion of helical guide vane in the intake manifold there is better combustion efficiency due to the proper mixing of air and fuel. The brake thermal efficiency of the engine is observed to be maximum with five vane helical guide swirl device. Therefore, an ultimate basis of optimized swirl generation in the combustion chamber. This investigation observed that an increase in 8.63% at full load when compared with normal engine for Five vane helical guide swirl device.

4.1.3 Brake Specific Fuel Consumption: The curves of brake specific fuel consumption verses engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.3. From the figure, the brake specific fuel consumption was lowered when the load on engine was increased. The Five vane helical guide swirl device showed the minimum consumption when compared with other devices. This is mainly due to the improved combustion of fuel in the combustion chamber.

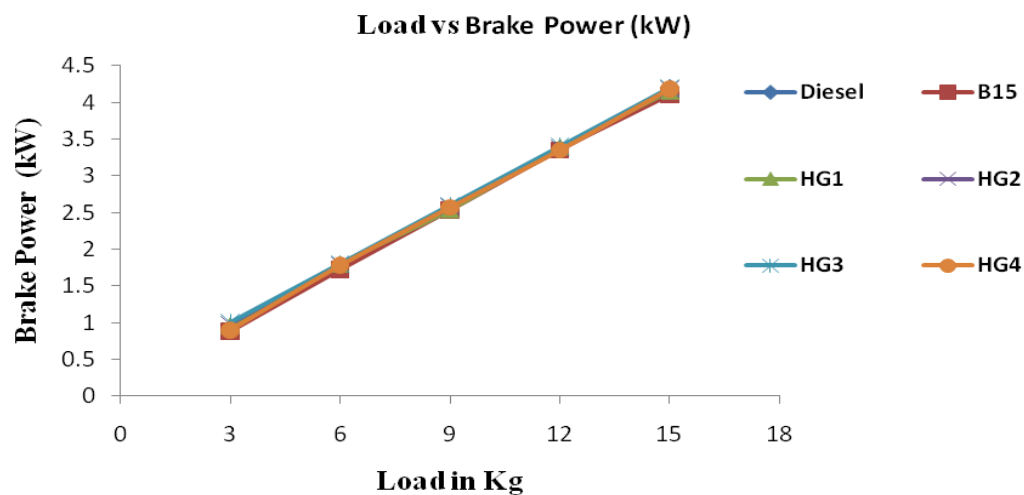


Figure: 4.1 Comparison of brake power with engine Load

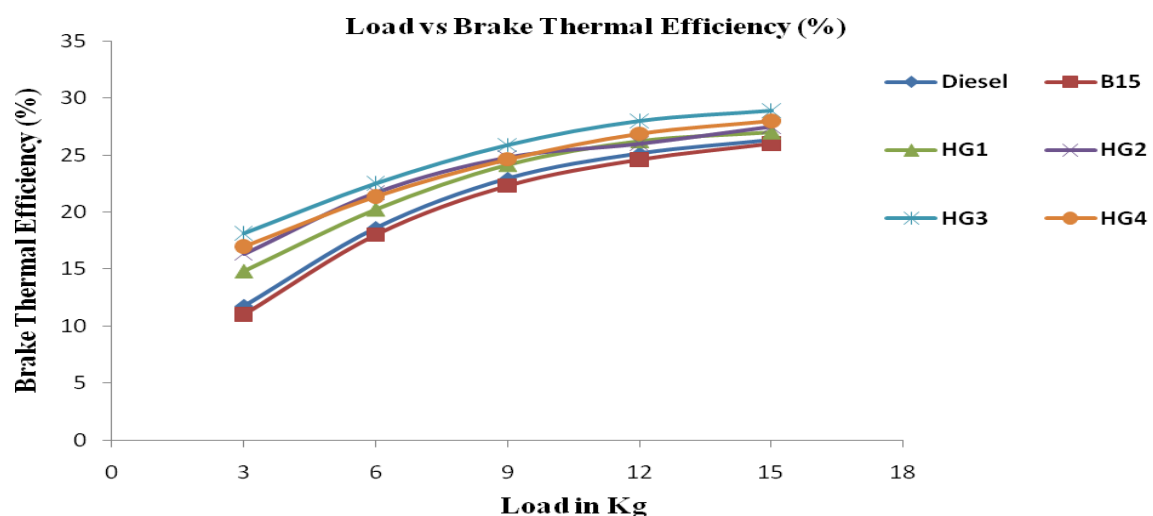


Figure: 4.2 Comparison of brake thermal efficiency with engine load

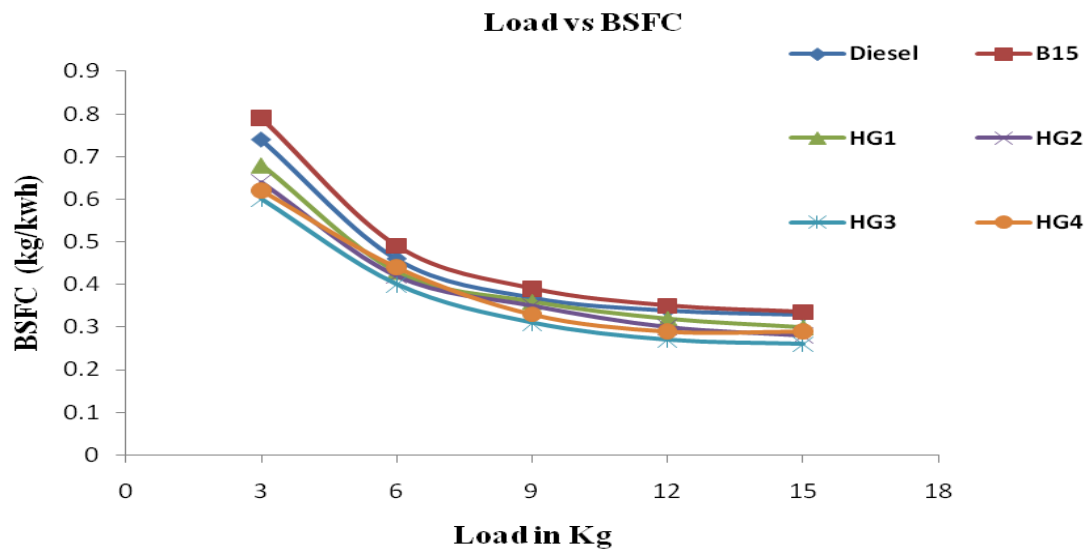


Figure: 4.3 Comparison of brake specific fuel consumption with engine load

4.2 Emission Parameters

4.2.1 Unburned Hydro Carbons: The curves of unburned hydro carbons against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.4. Due to the poor air fuel mixing and the smaller combustion period unburnt hydro carbons are emitted from the engine. From the figure, it is observed that hydrocarbon emissions increased when engine load enhanced. In Five vane helical guide swirl device the hydrocarbon emissions are lower when compared with the other devices and found that 15.62% emissions lower than the normal engine at full load.

4.2.2 Oxides of Nitrogen: The curves of Nitrogen oxides (NO_x) against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.5. From the figure, it is found that with increase of engine load NO_x emissions are also increased. Owing to the lower calorific value of Mamey Sapote blend the maximum temperature attained in the cylinder is less when compared with diesel. Due to this reason the formation of Nitrogen oxides are less when compared with the diesel. The five vane swirl device emits low NO_x when compared to all other devices, and observed that it emits 3.94% lower than the normal engine at full load

4.2.3 Carbon monoxide: The curves of Carbon monoxides (CO) against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.6. Due to the poor air fuel mixing, poor combustion in the engine cylinder leads to creation of carbon monoxide. It is observed from the figure, when engine load is increased, accordingly the carbon monoxide emissions were increased. The emissions in the first half load slightly increased and the remaining load range drastically increased. The same trend was observed on other related research works [13]. In the Five vane helical guide swirl device emits low CO when compared to all other devices, and found that 14.27% lower than normal engine at full load.

4.2.4 Carbon dioxide: The curves of Carbon dioxides (CO₂) against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.7. From the figure, it is observed that the carbon dioxide emissions increase with increase in engine load. Due to the

swirl devices better mixing of fuel and air which leads to better combustion efficiency, hence enhanced carbon dioxide emission from all the devices. For Five vane guide swirl device CO₂ emission is very high when compared with other devices, which is 7.24% higher than the normal engine at full load.

4.2.5 Smoke Density: The curves of smoke density against engine loads for diesel, Mamey Sapote blend and all helical guide vane devices plotted in the Fig: 4.8. Smoke generation mainly depends on air flow circulation into the engine cylinder, from the figure, smoke density increases with increase on engine load. The five vane helical guide vane device emits less smoke when compared with other devices, and found that 9.6% lower than the normal engine at full load.

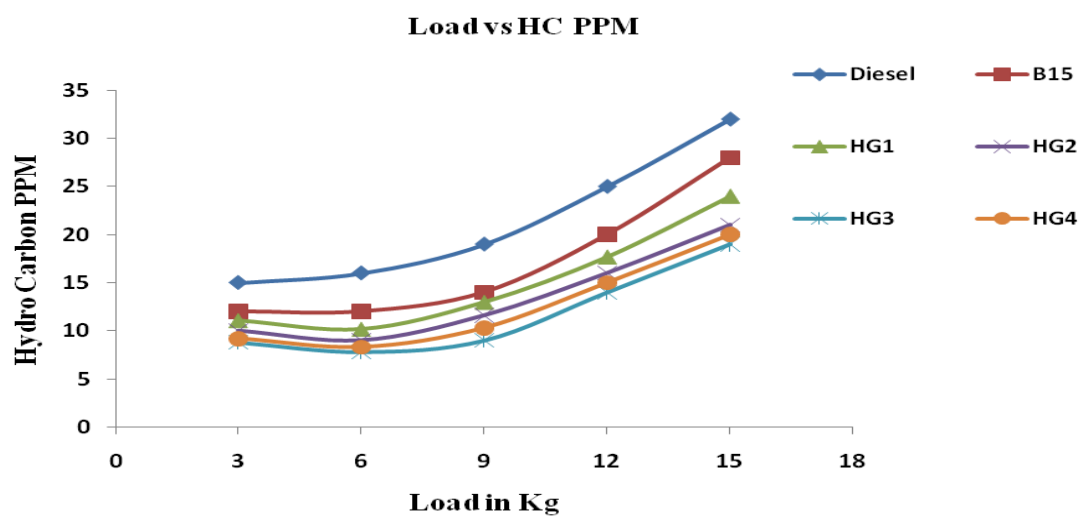


Figure: 4.4 Comparison of Hydro Carbons with engine load

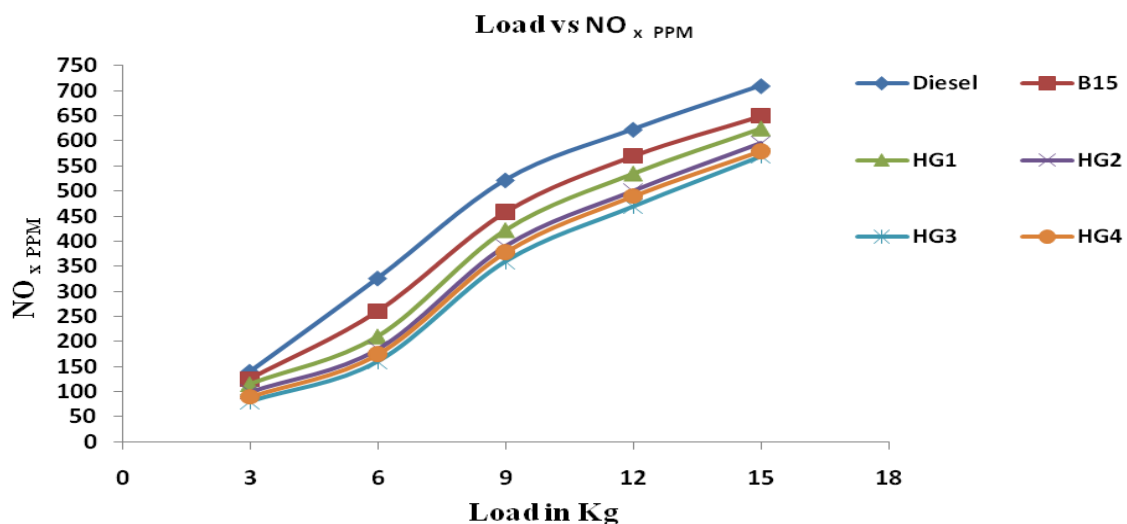


Figure: 4.5 Comparison of NO_x emissions with engine load

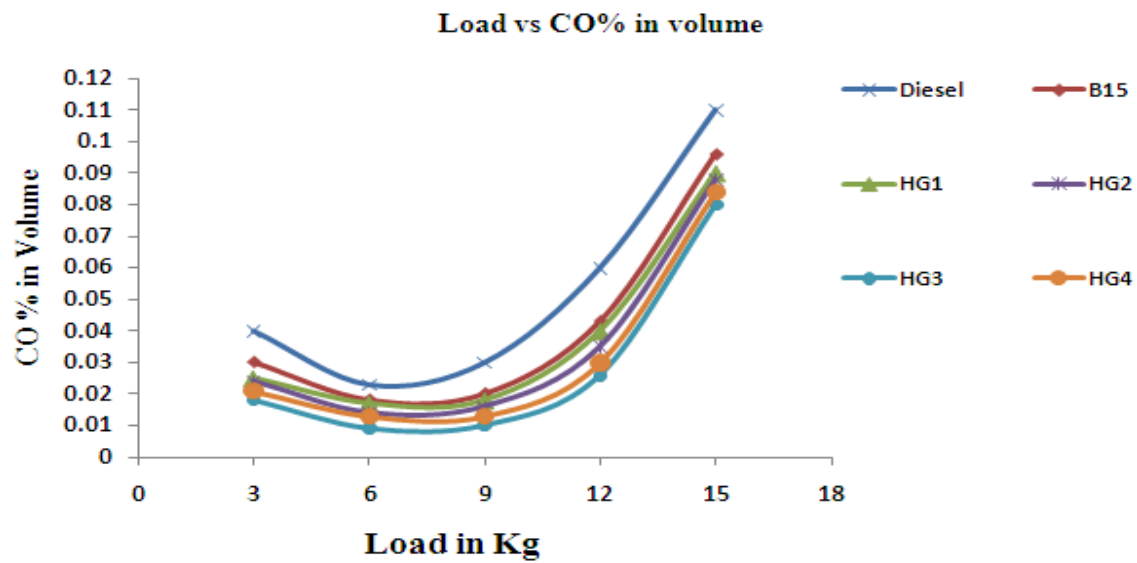


Figure: 4.6 Comparison of Carbon monoxide emissions with engine load

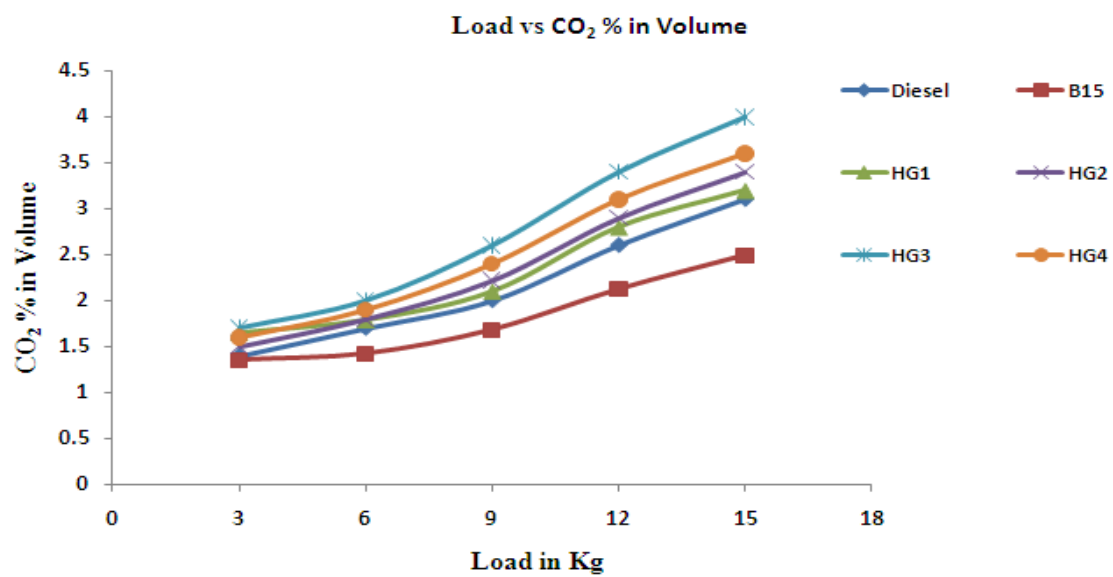


Figure: 4.7 Comparison of Carbon dioxide emissions with engine load

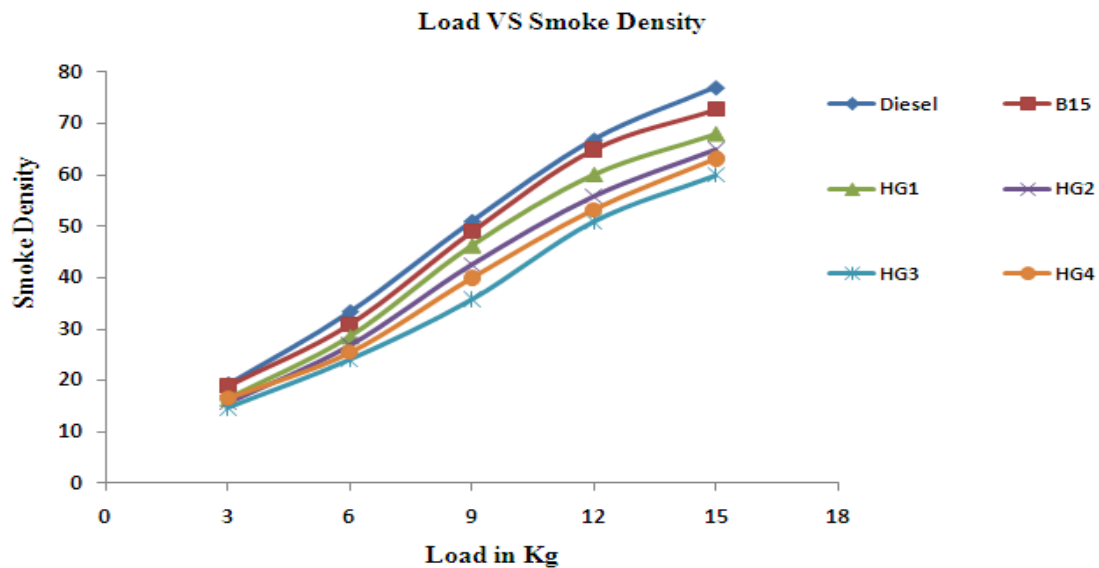


Figure: 4.8 Comparison of Smoke densities with engine load

5. Conclusion

Experiments for performance & emission characteristics are conducted on a single cylinder, 4-stroke, uniform speed DI diesel engine at a compression ratio of 18. The following conclusions are drawn based on the engine operating on B15 blends with various number of Helical Guide Vane Swirl devices Viz., HG1, HG2, HG3 and HG4. All parameters are compared at full load with normal diesel engine.

- The BP is increased 0.48 % for HG3 when compared with normal engine.
- The brake thermal efficiency is increased by 8.63 % for HG3 when compared with normal engine
- The brake specific fuel consumption is decreased by 7.6 % for HG3 when compared with normal engine
- . Hydro Carbon emissions are decreased by 15.62% for HG3 when compared with normal engine
- Nitrogen Oxide emissions are decreased 4.23% for HG3 when compared with normal engine
- Carbon Monoxides are decreased 14.27 % for HG3 when compared with normal engine
- Carbon Dioxides are increased by 7.4 % for HG3 when compared with normal engine
- Smoke Densities are decreased by 9.6 % for HG3 when compared with normal engine

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