International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 5617-5628

http://www.ripublication.com

Studies on Performance and Emission Characteristics of a Single Cylinder Diesel Engine With Shrouded Inlet Valve Using Diesel and Pongamia Methyl Ester Blend as Fuel

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Abstract

An experimental study was carried out on 5.9 kW single cylinder direct injection diesel engine with eddy current dynamometer. The research paper investigates the performance and emission characteristics of diesel and pongamia pinnata methyl ester blends in base engine and shrouded inlet valve engine. The inlet valve was fabricated with 15 mm height and 180º angle of shroud to conduct the tests. The brake thermal efficiency for the blends B30 and B40 indicate better performance over diesel for both configurations. However the brake thermal efficiency of B10 and B20 blends are comparable to that of diesel fuel. The brake specific energy consumption was increased in all blends for low load conditions and it showed reverse effect at high load conditions as compared to diesel and it was slightly more in the shrouded configured engine. The emission levels of Carbon monoxide, Carbon dioxide, Hydrocarbon and smoke are less in biodiesel blends than diesel in both configurations but increase with increase in load. These emission levels are slightly higher in the shrouded inlet valve engine when compared with the base engine for the diesel fuel as well as the blends of biodiesel due to shroud resistance. The Oxides of nitrogen emission increase with increase in exhaust gas temperature for the blends from zero to full load due to complete combustion in base engine. The shrouded configured engine shows reverse trend on exhaust gas temperature as well as Oxides of nitrogen from the base engine and it is an indication of incomplete combustion. The implementation of swirl by shroud portion shows negative effect on performance and emission levels in base engine as well as shrouded configured engine due to less air entrainment with the fuel droplet. It was concluded that B30 and B40 biodiesel blends are the better substitute fuel for fossil diesel in both engine configurations.

Key Words: Biodiesel, Diesel engine, emission, performance and Shrouded valve

Introduction

The objective of this study was to analyze the biodiesel blends and to replace the diesel fuel partially by biodiesel to overcome the energy crisis and also to investigate the performance of shrouded inlet valve engine with the blends.

Biodiesel has the tendency to emit higher smoke emission. Many researchers recommended shrouded valve is a swirl improver and smoke emission reduces with diesel fuel. Here in the research work, shrouded valve is used to improve the swirl movement and to reduce the smoke emission. Researchers have done considerable amount of numerical analysis to obtain the flow

pattern during the intake process in petrol and diesel engines. It was reported only about the swirl pattern inside the combustion chamber, swirl ratio, and tumble ratio using the CFD tool.

Research work was carried out on flow analysis using CFD in a diesel engine with the inserted guide vane swirl and tumble device (GVSTD) [1] in the intake port. It was concluded that 4 vanes of 2.5 mm height and 35° twist angles led to least resistance of air flow and improved the turbulent kinetic energy during the combustion period than without vanes running with bio diesel.

The pongamia plant is easy to cultivate, grows fast, drought resistant and is easy to extract non edible oil from its seeds. Cultivation of the plant improves rural economy especially in agriculture. The viscosity of vegetable oil is shown as a negative factor to use it in a diesel engine. The viscosity is several times greater than diesel and leads to many problems in pumping and atomization which have been solved by transesterification process to improve the engine performance. The karanja methyl ester [2] can be replaced with diesel fuel up to 40% and the blend gives lesser CO, smoke and NO_x emission without sacrificing the power output. The brake specific fuel consumption increases in less percentage in lower blends and it shows reverse trend in higher blends than diesel.

The efforts are made to investigate the blends of pongammia methyl ester [3] and diesel in diesel engines. It was reported that the biodiesel blends can be used up to certain extent to get a better performance and lesser emissions and concluded that up to 40% biodiesel by volume replacement is possible to run the diesel engine without sacrificing the power output. The performance and emission analysis was conducted with the jetropha methyl ester [4] and its blends. It was concluded that the brake thermal efficiency was slightly lesser for biodiesel blends than diesel and the emission levels of CO, HC and smoke are less except NO_x.

The neem methyl ester and its blends [5] are tested in a diesel engine to assess the performance, combustion and emission levels and it was reported that the lower blends (B10 and B20) gave better performance and less emission levels except NO_x whereas higher blends (B30, B50, and B100) were identified with lesser performance than diesel. The experimental study was carried out with the karanja methyl ester and their blends [6] and reported with comparable performance with diesel fuel, less emission levels of CO, HC and smoke than diesel, whereas NO_x emission shows the negative trend

The effect of swirl [7] are discussed on performance and emission in detail for the angle of masking 50º, 70º, 90º with Honge oil methyl ester and its blends. It was reported that angle of masking increases the brake thermal efficiency increases and the emission levels of smoke, HC and NO_x are decreased due to better mixing of fuel with air. It was also reported that there is no enhancement in performance as well as in emissions with 120º angle of masking due to incomplete combustion.

The effect of swirl on combustion and emission are analyzed in a single cylinder diesel engine with throttle mechanism [8]. It was reported that the excess swirl spoil the combustion process leads to higher smoke and fuel consumption, but less NO_x emission level.

The experimental investigations on combustion, performance and emission are very limited in this region with diesel, biodiesel and their blends. The pongamia methyl ester was chosen for the present study to analyse the performance and emission characteristics of diesel and biodiesel blends in diesel engine with and without shroud. The shrouded inlet valve was fabricated to carry out the test runs and the model was made to visualize the flow pattern [1] inside the combustion chamber with the help of FLUENT software. The detailed experimental investigations were carried out on a single cylinder diesel engine with and without shroud on inlet valve using diesel and biodiesel blends.

Test Set Up and Testing Procedure

A single cylinder, four stroke, naturally aspirated, water cooled diesel engine coupled with an eddy current dynamometer was selected for the experimental investigation. The specification of the engine is given in Table 1. The schematic diagram of the experimental set-up was shown in Figure 1. The inlet valve was made with shroud portion on its top for the angle of 180^0 to generate swirl inside the combustion chamber. The technical drawing of the normal and shrouded inlet valve is shown in Figure 2. The shrouded portion was used for the experimental study is 15 mm height with 180^0 angle of shroud. The tests were carried out with and without shroud at various load conditions using diesel and blends of biodiesel (B10, B20, B30 and B40). Each test was conducted by starting the engine with diesel fuel only and after warm up, it was switched over to biodiesel blends. At the end of the test, the fuel was replaced by diesel and the engine was kept running for a while before shut-down to flush out the biodiesel from the fuel line and the injection system. The fuel consumption was taken for each test run after the engine attained steady state operation. An exhaust gas analyzer (AVL Di-Gas 4000) was used to measure CO, CO_2, HC and NO_X emissions. Smoke emission was measured with the help of a smoke meter (AVL 437). The engine tests were carried out thrice for all five selected fuels and the average data was taken into account for further investigation.

Table 1 Engine Specification

Make	: Kirloskar
Type	: Single cylinder, water cooled
Maximum power	: 5.9 kW at 1800 rpm
Bore × Stroke	: 87 × 110 mm
Compression ratio	: 17.5:1
Injection pressure	: 200 bar
Fuel injection timing	: 23º b TDC
Loading device	: Eddy current dynamometer

Results and Discussion

Performance Characteristics

The brake thermal efficiency of diesel engine was discussed with respect to various load conditions for the diesel and biodiesel blends and also it was compared with the results obtained from shrouded inlet valve engine configuration.

Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power is shown in Figure. 3. for the diesel engine with and without shroud for the different biodiesel blends. It can be observed that there was an increasing trend of brake thermal efficiency for all the blends with increase in load due to reduction in heat loss [2]. The reduction in brake thermal efficiencies was obtained for diesel (4.76%) and the blend B10 (0.01%), B20 (7.54%), B30 (1.03%) and B40 (5.83%) in shrouded inlet valve engine at higher brake power. It was observed that by comparing both configurations, the shrouded inlet valve configured engine showed inferior brake thermal efficiency than the base engine due to shroud resistance to the air entry. It reduce the air entrainment with the fuel droplet and increase the in-cylinder heat transfer, resulting in lower mean gas temperature that leads to lesser brake thermal efficiency.

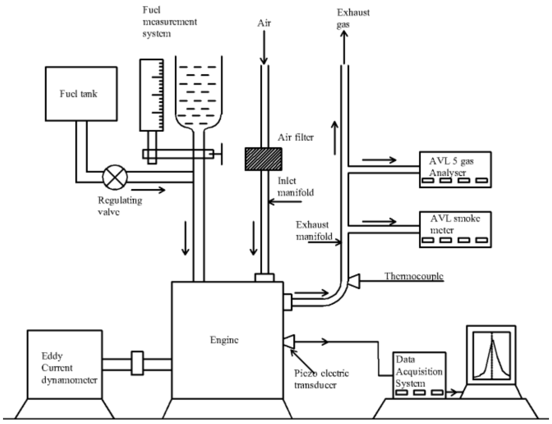

Figure 1. Experimental setup

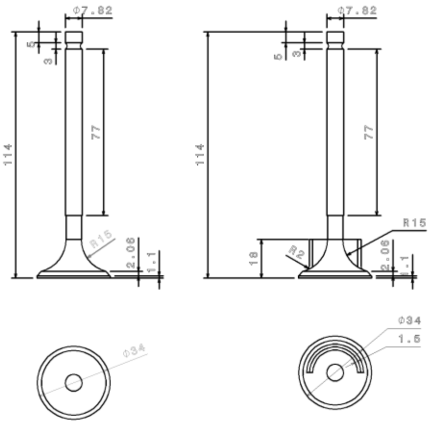

Figure 2. Normal and Shrouded inlet valve

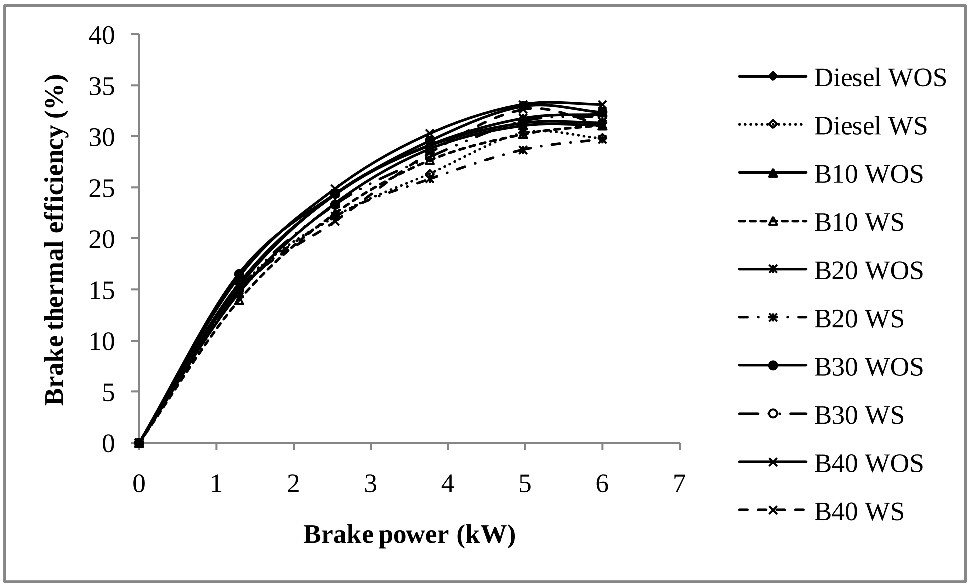

Figure 3. Variation of BTE with Brake power for Diesel and Biodiesel blends

Emission Characteristics

The trend of CO, CO_2, HC, and smoke and NOx emission level is analyzed for the load variations. These emission characteristics are compared with the results obtained for shrouded inlet valve engine.

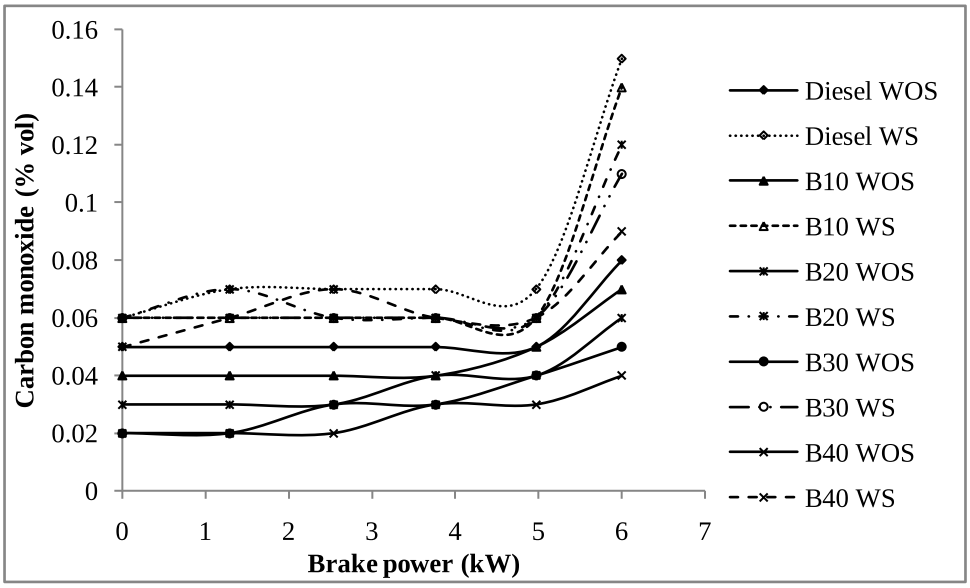

Figure 4. Variation of CO with Brake power for Diesel and Biodiesel blends

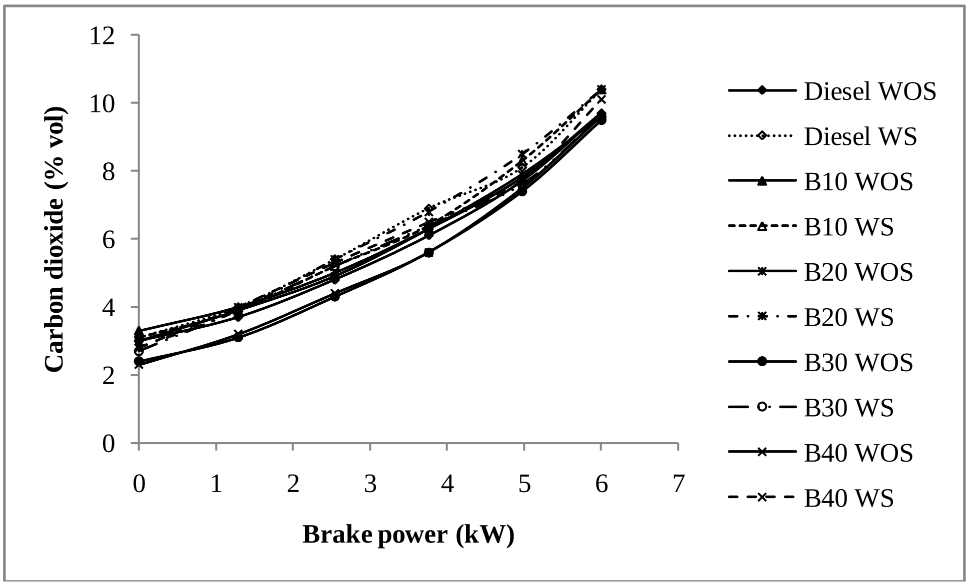

Figure 5. Variation of CO_2 with Brake power for Diesel and Biodiesel blends

Carbon monoxide Emissions

The observed CO concentration is very small in all blends compared with the diesel for all brake powers and it is shown in Figure.4. The lower biodiesel blends contain oxygen high enough for complete combustion. The higher blends suppress the combustion process due to its viscosity [3] and lead to slight increase in CO emission at high loads. Due to incomplete combustion the increase in trend is observed for CO concentration in shroud configured engine for all the blends as compared to the base diesel engine.

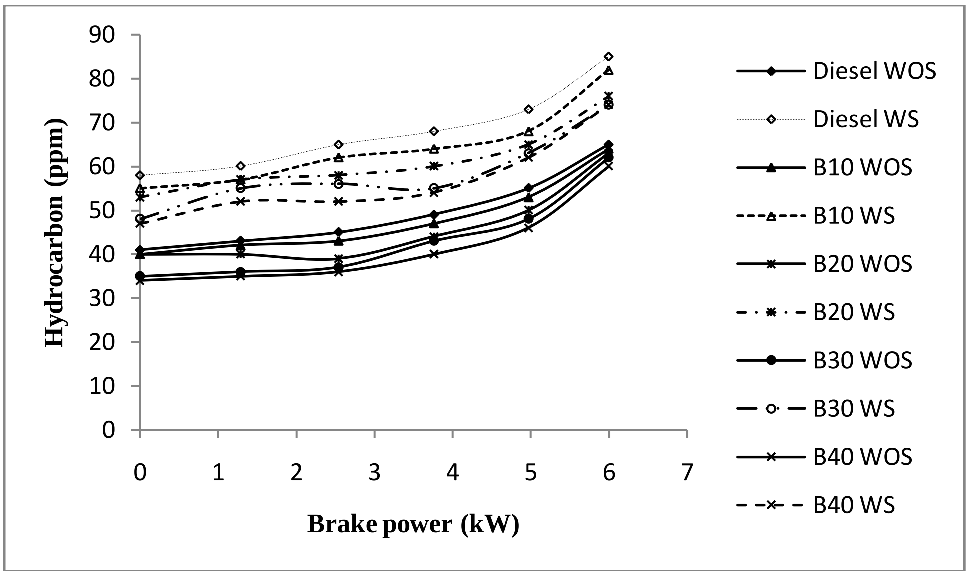

Figure 6. Variation of HC with Brake power for Diesel and Biodiesel blends

Carbon dioxide Emissions

The CO_2 emission increases with increasing brake power for all the blends and is shown in Figure.5. The emissions are slightly lower [6] than diesel at B30 and B40 blends for low load whereas at higher loads the CO_2 emission is the same as that of diesel fuel. This can be attributed to the presence of oxygen in the fuel which results in better combustion. CO2 emission is slightly higher at lower blends (B10 and B20) at all loads except at high load where CO2 emission compares well with the base diesel engine. The same trend is also found in shroud configured engine and the blends (B30 and B40) emit less CO_2 emission than the base diesel engine.

Hydrocarbon Emissions

It is seen from the Figure.6 that HC values are lesser for biodiesel blends compared with the diesel fuel. The higher cetane number and availability of oxygen in the fuel lead to better combustion that helps to decrease [4] the hydrocarbon emission. The HC emissions are found to increase with increasing brake power for all blends. By considering the shroud configured engine the HC emission is less for blends than diesel at all brake powers. It is found to be higher than the base engine for all blends due to less oxygen content interns of shroud resistance [7] in the intake air and more fuel injected which leads to incomplete combustion.

Exhaust Gas Temperature

The exhaust gas temperature increases with increasing in brake power for all the biodiesel blends in both configurations as shown in Figure.7. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. It is also seen that as the biodiesel substitution in diesel is increased, the exhaust gas temperature increases [4] due to oxygen availability in the biodiesel. Biodiesel blends produce a greater value of exhaust temperature when compared with the diesel for both engine configurations from zero to full load condition. It is decreased in a shrouded configuration engine when compared with base engine emission levels due to ignition delay that leads to incomplete combustion [6].

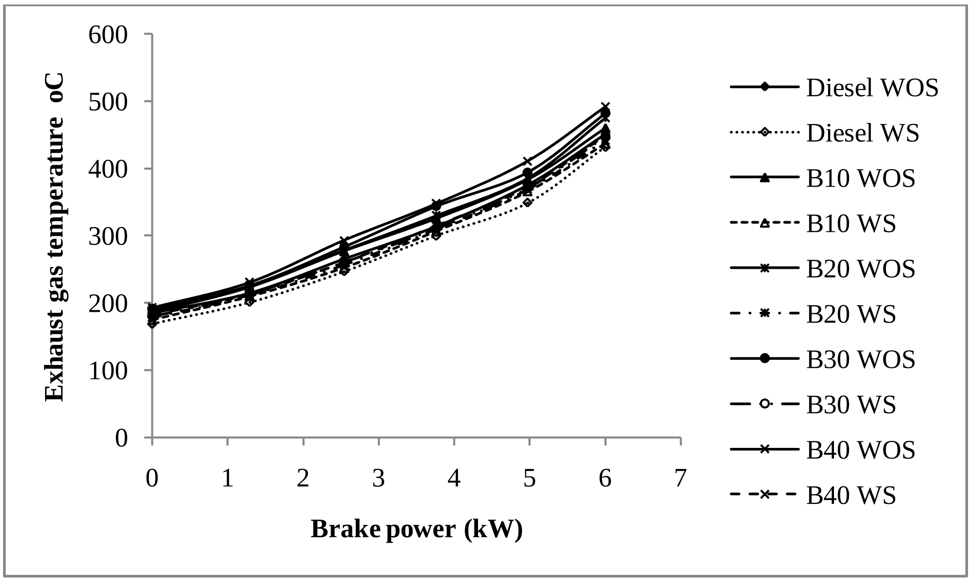

Figure 7. Variation of Exhaust gas temperature with Brake power for Diesel and Biodiesel blends

Oxides of Nitrogen Emissions

The Figure.8 shows that the increasing trend of NOx emission [5] for all blends with respect to brake power. An upward trend in NOx emission is observed by increasing the content of biodiesel in diesel. The important factor for the formation of NOx is due to a high combustion temperature in the engine cylinder and the oxygen concentration. The shrouded configuration engine has lower NOx emission value than the base engine for all blends due to shroud resistance. It reduces air entrainment [8] with the fuel droplet inside the combustion chamber that leads to lower NO_x emission.

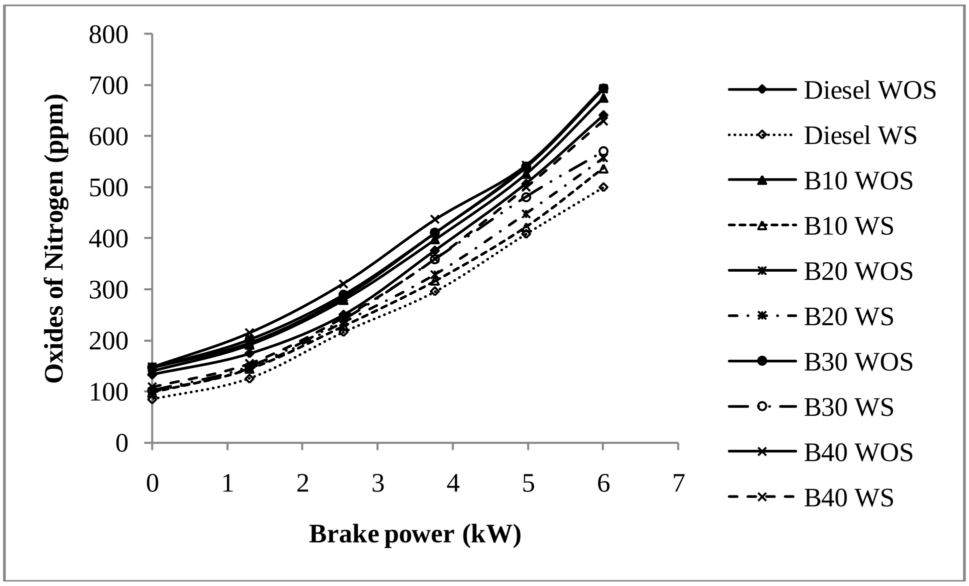

Figure 8. Variation of NO_x with Brake power for Diesel and Biodiesel blends

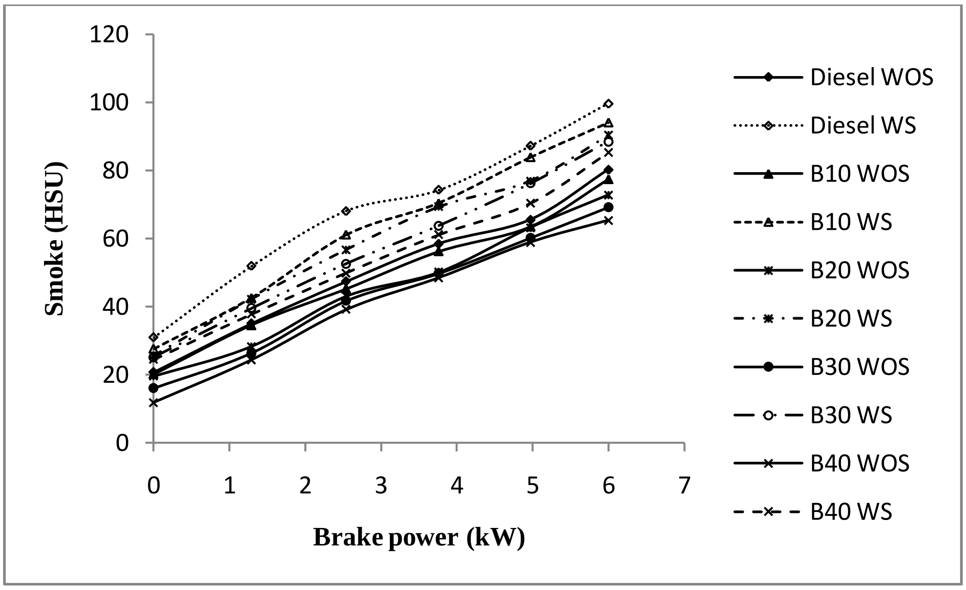

Figure 9. Variation of Smoke with Brake power for Diesel and Biodiesel blends

Smoke Emissions

The reduction in smoke can be achieved by the presence of less carbon content and more oxygen concentration [5] with biodiesel blends as compared to diesel, which was shown in Figure.9. The smoke is mainly generated in fuel rich zone at high temperature, the addition of oxygenated biodiesel blends leads to an improved combustion. The observed smoke emission is higher [8] in the shrouded configuration engine than the base diesel engine for all fuel blends due to less availability of oxygen in the intake air.

Conclusion

An experimental investigation was carried out in the single cylinder diesel engine with and without shroud configuration at the inlet valve using diesel and biodiesel blends. The following conclusion can be drawn from the experimental data.

The brake thermal efficiency of the engine was increased than diesel by increasing the content of biodiesel in diesel. The B30 and B40 blends gave significantly better results than diesel for both engine configurations. The brake specific energy consumption was increased in all blends for lower brake power and it showed reverse effect at higher brake power as compared to diesel and it was slightly more in the shrouded configured engine.

The CO, CO_2, HC and smoke were less for the biodiesel blends than diesel in base engine configuration. These emission levels were slightly higher in the shrouded engine for all test fuels. An oxide of nitrogen emission depends on exhaust gas temperature and it increases for the blends from zero to full load in base engine due to complete combustion. The shrouded configured engine shows reverse trend from the base engine and it is due to incomplete combustion.

The brake thermal efficiency of the engine was almost closer with the base engine for the different fuel blends in both engine configurations and lesser oxides of nitrogen was observed from shrouded configured engine. It was concluded that B30 and B40 biodiesel blends are the better substitute fuel for fossil diesel in both engine configurations. The shrouded engine configuration showed slightly inferior performance than the base diesel engine.

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Abbreviations:

bTDC	-	Before Top Dead Centre
BTE	-	Brake Thermal Efficiency
WS	-	With shroud
WOS	-	Without shroud
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
HC	-	Hydrocarbon
NO_x	-	Oxides of Nitrogen
%vol	-	Percentage of volume
ppm	-	Parts per million
HSU	-	Hartridge smoke unit

Auto Biography

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