Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 6, Issue 09, September -2019

EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF THERMAL BARRIER COATED DIESEL ENGINE WITH AME

R.Bharathiraja, [1] R.Ashok, [2] V.Sharun, [3]

Mechanical Engineering, Panimalar Institute of Technology

Abstract — *It is a known fact that the conventional fossil fuel will exist for a few more years. This is due increase in the vehicle's population and the industrial applications day by day. Also, these fuels are responsible for the air pollution by emitting gases that are harmful for any living being. In general, internal combustion engine emits the unburnt hydrocarbons, Cox, NOx gases also, little quantity of particulate matter and smoke that has to be under control. In that case, vegetable oil or biodiesel can be used as an alternative fuel which has replaced the fossil fuels for internal combustion engine. So this investigation is carried out in order to showcase the performance and emission of thermal barrier coated diesel engine with AME.*

Keywords-*biodiesel; monoalkyl-esters; transesterification; algae methyl ester; brake specific fuel consumption (BSFC); brake thermal efficiency (BTE).*

I. INTRODUCTION

Experimental investigation on performance and emission characteristics of thermal barrier coated diesel engine with ame deals with the alternate fuels like algae methyl ester which is used to run the engine. Normally, alternate fuel is used for reducing the emissions of unburnt hydro carbons, carbon monoxide, NOx, smoke and particulate matter . It improves the engine performance like brake thermal efficiency, specific energy consumption and brake energy along with brake specific fuel consumption. The project has been carried out on the TBC engine is made to run in the proportionality of diesel alone, diesel with twenty percentage of AME, diesel with forty percentage of AME, diesel with eighty percentage of AME and finally raw AME.

II. LITERATURE REVIEW

Ghosh and Dutta, in their paper, "Performance and exhaust emission analysis of direct injection diesel engine using pongamia oil" [1] reported that, "Here, brake thermal efficiency of biodiesel blends nearly lower than the neat diesel and also specific fuel consumption nearer to the neat diesel at full load condition. In same way HC, CO and NOx was reduced". Yuhao Xu et-al, in their paper, "Droplet combustion characteristics of algae-derived renewable diesel, conventional #2 diesel, and their mixtures" [2] reported that "suggest that are hydro treated renewable diesel derived from algae as a good additive or even a drop-in replacement to petroleum-based diesel fuel". Panayiotis Tsaousis et-al, have investigated the "Algae to energy: Engine performance using raw algal oil" [3]. The algal oil is good alternate fuel used in a diesel engine as the performance and emissions are adequate". Ravikumar et-al, have investigated the "Alternative Thermal barrier coatings for CI Engines" [4]. Results show that, the thermal barrier coating increases the thermal efficiency due to high temperature which can withstand in the combustion chamber.

Selman Aydin and Cenk Sayin, have investigated the "Impact of thermal barrier coating application on the combustion, performance and emissions of a diesel engine fueled with waste cooking oil biodiesel–diesel blends" [5]. They report that coated engine has high efficiency and less BSFC also reduced CO and HC emission of diesel with biodiesel blends. Huseyin Aydin, have studied "Combined effects of thermal barrier coating and blending with diesel fuel on usability of vegetable oils in diesel engines" [6]. In this report, the power and torque were increased with simultaneous decrease in fuel consumption (BSFC). Furthermore, CO, HC, and Smoke opacity were decreased.

III. OBJECTIVE AND METHODOLOGY

The main objective of this project is to use biodiesel efficiently as a fuel in the place of diesel engine. It is used to improve the performance characteristics and reduce the emissions by introducing algae biodiesel with diesel blend.

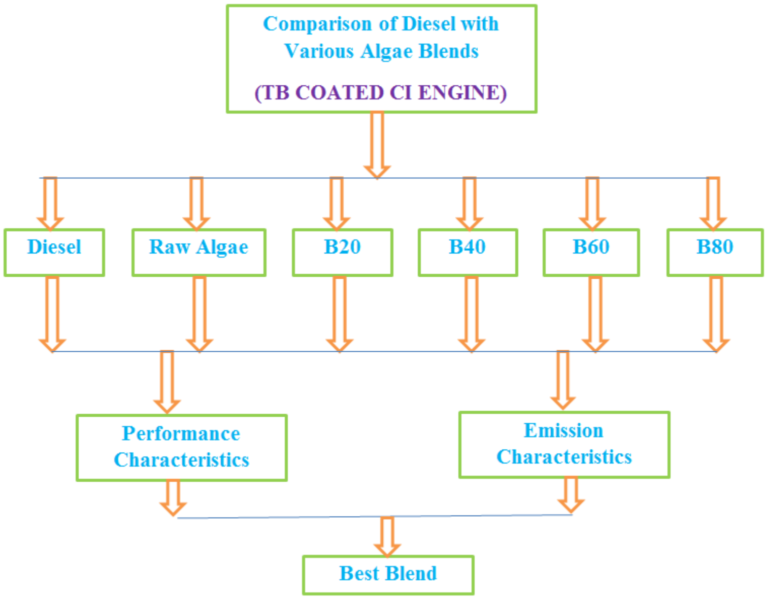


Figure 3.1 Research Methodology for Finding Best Biodiesel Blends

Initially, the diesel and algae methyl ester along with their properties like calorific value, density, specific gravity, kinematic viscosity, flash point, fire point and oxygen content have been compared. The algae and diesel oil based has been divided as B20 (algae 20% + diesel 80%), B40, B60, B80 and B100, to find the fuel properties of various proportional of the blends. Run the thermal barrier coated engine by using various proportions of diesel and biodiesel blends. The results obtained based on performance and emission characteristics will be analyzed. Henceforth the results has been obtained (Performance and emission characteristics) with various proportional blends. The suitable blends which render better performance and emission characteristics at various operating conditions must be selected. Further study can be made on the scope of the future research with selected blends.

IV. THERMAL BARRIER COATING

4.1. Methods to produce tbc

Most of thermal barrier coatings are deposited by Plasma spray coating techniques*:*

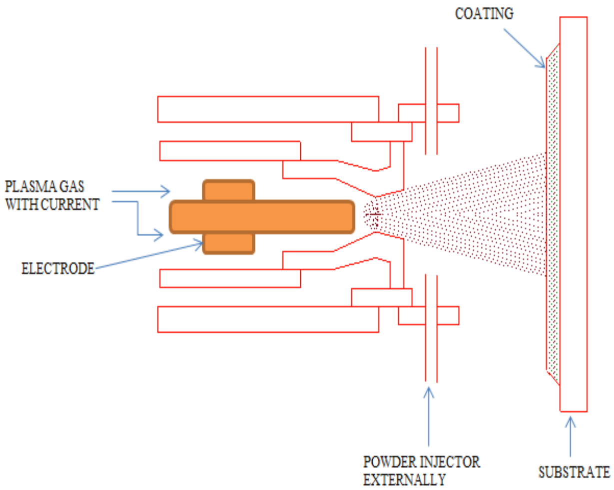


Figure 1. Plasma Spray Coating

The principle behind plasma spraying coating arrangement is illustrated in Figure 1. A high frequency of plasma arc is ignited between an anode and a tungsten cathode. The plasma gas is flowing between the two electrodes. The spray material is injected into the plasma plume through the gun nozzle, where it is melted. An electrical arc is developed which ionizes argon flowing through electrodes and converts them into hot plasma at a temperature of about 8,300°C. By using the plasma jet the ceramic material in powdered form is injected where the ceramic grains melt and move in the stream of the hot gas towards the substrate surface.

4.2. Tbc Coating of Materials

Normally, in internal combustion engines, thermal barrier coatings are applied to the engine parts like Piston crown, cylinder head and cylinder valves. It is mainly used to reduce the heat loss of the engine during combustion from the combustion chamber. The piston is a dynamic component of an internal combustion engine. It reciprocates inside the cylinder bore. But in this project, the piston crown and cylinder head are thermally coated. It is mostly used to analyze engine performance and emissions. Thermal barriers are made up of ceramic layers by partially stabilized zirconia with aluminum oxide (Al_2O_3 ZrO_2) by using plasma spraying method thickness about 200 microns as shown in Figure-2.

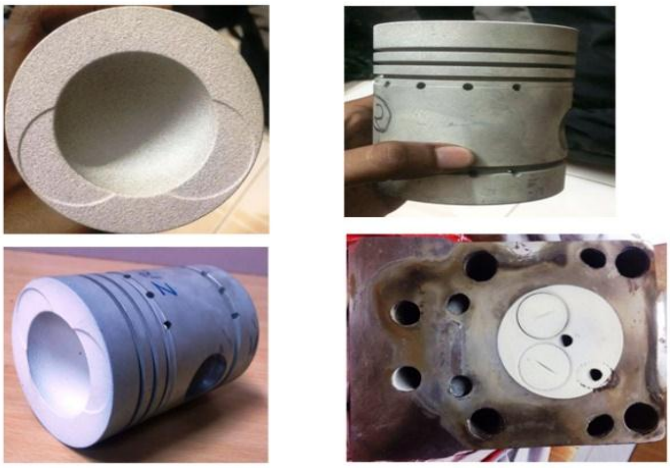


Figure 2 Thermal Barrier Coating on Piston Crown, Cylinder Head and Valves

V. Engine And Experimental Setup

5.1. Engine

The preferred engine to carry out experiments is a single cylinder, four stroke, water-cooled direct injection constant speed Kirloskar diesel engine. The experimental setup is shown in figure 3.

Figure3. Pictorial view of experimental setup

The Kirloskar engine is used widely in agriculture, pump sets, farm machinery and industrial areas.

5.2. Experimental Setup

The engine used for the experiment is four stroke water cooled single cylinder vertical diesel engine running at a rated power of 3.70 kW and at a rated speed of 1500 rpm. The specifications of the engine are shown in Table 1. The diesel engine is fired on no load initially and it is let to run for a period of time until it reaches the steady-state condition denoted by the constant cooling water outlet temperature. A further reading has been taken after the steady state condition was attained.

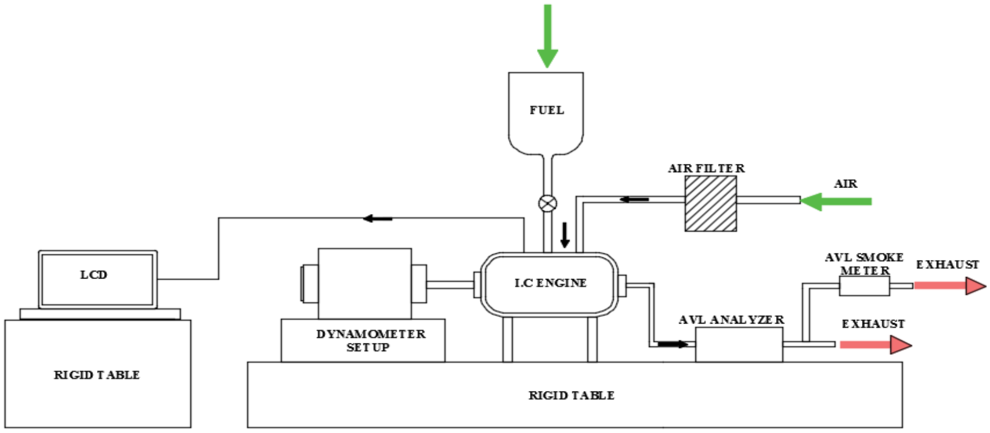


Figure 4 Schematic view of experimental set-up

5.3. Experimental Procedure

The air, lubrication, water, and the fuel level are checked before starting the engine. The engine is rotated by keeping the decompression lever and the fuel cut off lever of the fuel pump in the ON position. When the engine starts, the decompression lever is disengaged and the speed of the engine is increased to 1500 rpm and the speed is maintained. The engine is allowed to run for 15 minutes to reach the steady state conditions. The time taken for 10 cc of fuel consumption for every load charge is recorded; the load 1, 2 & 3 N-m is set for every blends. Further the fuel range such as diesel, biodiesel blends 20%, 40%, 60%, 80% and 100% have been used. Under each load, by using the exhaust gas analyzer, CO, HC, NOx were measured and recorded. Similarly under each load, intensity of smoke and exhaust gas temperature are measured and recorded by using smoke meter. If the testing is completed, stop the engine to cool naturally. Similarly, readings were taken with diesel and algae fuel blends in thermal barrier coated diesel engine.

Table 1 Test Engine Specification

Model	KIRLOSKAR AV1
Type of engine	Vertical ,4-stroke,single cylinder, diesel
Bore	80 mm
Stroke	110 mm
Speed	1500 rpm
Rated Power	5 Hp @ 1500 rpm
Compression ratio	16.5: 1
Cooling Medium	water
Injection pressure	200 bar
Engine Capacity	553 cc
Dynamometer	Eddy Current

VI. Results And Discussion

The tests were conducted on a direct injection thermal barrier coated diesel engine for different blends of Algae methyl ester with diesel. Investigation of performance and emission characteristics such as brake power, brake specific fuel consumption, specific Energy consumption, brake thermal efficiency, hydrocarbon, carbon monoxide, carbon dioxide, oxides of nitrogen are determined.

6.1 Performance characteristics

6.1.1 Brake thermal efficiency

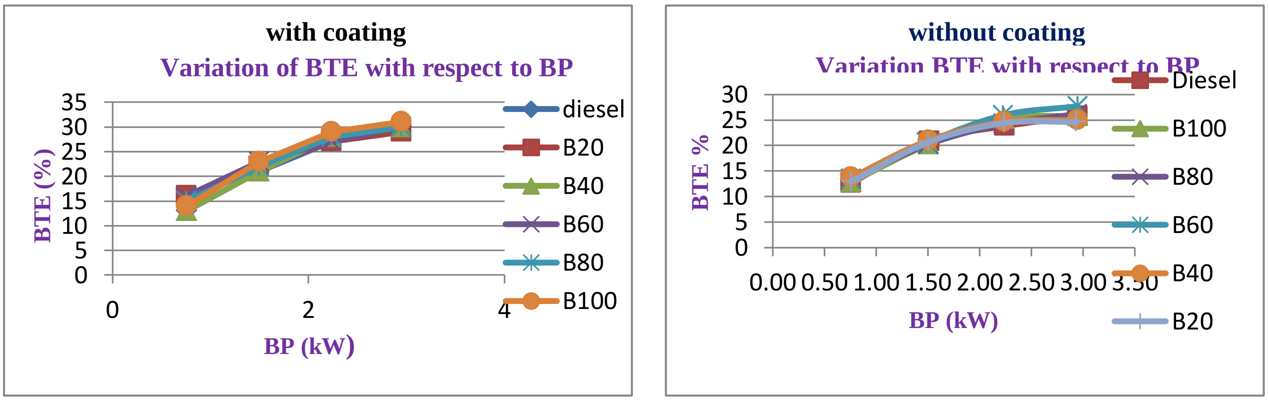


Figure 5 Variation of BTE with respect to BP

Fig 5 shows the brake thermal efficiency which is plotted against brake power of the diesel, algae methyl ester and its blends. Without coating, BTE of B60 has higher efficiency (7.14%) than neat diesel, B20, B40, B80 & B100. If coated, at initial load condition BTE of B40 is similar to that of neat diesel but, at the full load condition, BTE of neat B100 has a higher efficiency (3.22%) than neat diesel and other blends. In both the cases (with coating and without coating) with coating has higher BTE (9.67%) than without coating at end load condition.

6.1.2 Brake specific energy consumption

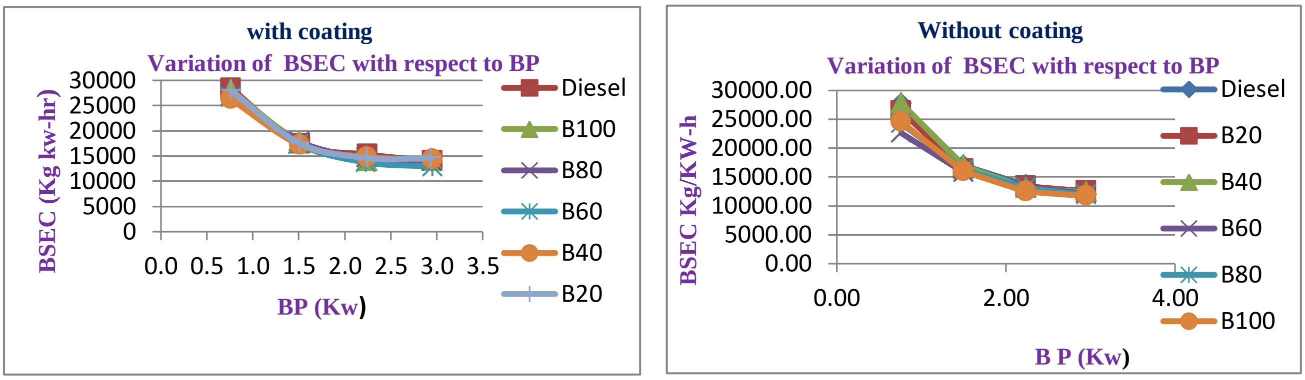


Figure 6. Variation of BSEC with respect to BP

The variation of specific energy consumption with brake power for different blends of biodiesel and neat diesel are shown in fig.6. If uncoated, at initial load condition, the specific energy consumption of B40 is higher (0.36 %) than compared to the diesel. B40 shows higher BSEC among all the blends and diesel. If coated, at initial load condition, the specific energy consumption of B20 is higher (1.64 %) than compared to the diesel. At end load condition, B20 of BSEC is (4.13%) higher than diesel and all other blends. In both cases, with coating and without coating, with coating has higher BSEC (14.28%) than without coating at end load condition for B40 blend.

6.3 Brake specific fuel consumption

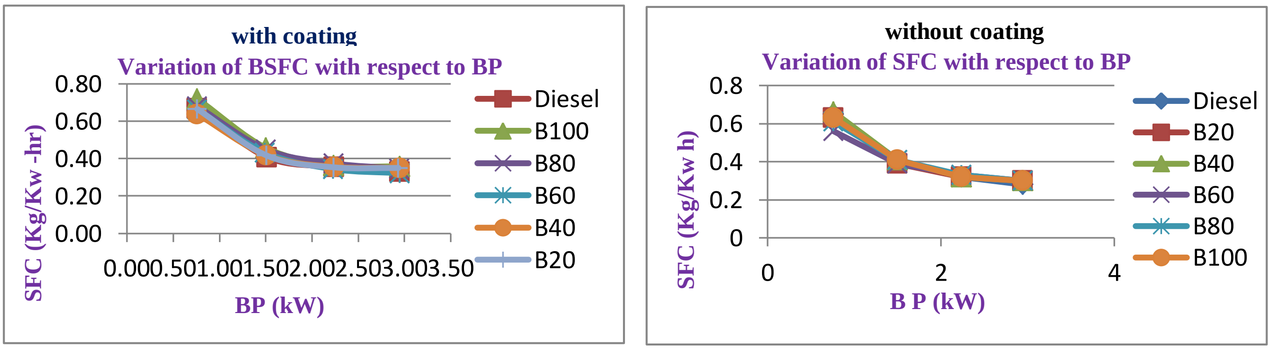


Figure 7. Variation of BSFC with respect to BP

The variation of specific fuel consumption with brake power for different blends of biodiesel and neat diesel are shown in fig.7. Without coating, at initial load condition the specific fuel consumption of B60 is lesser (13.84%) than compared to the diesel. B60 shows lesser BSFC among all the blends. With coating, at initial load condition, the specific fuel consumption of B60 is (1.49%) lower than the diesel. In full load condition, the specific fuel consumption of diesel is lesser (1.49%) than compared to all the blends. In both the cases, with coating and without coating, with coating has higher SFC (6.25%) than without coating at end load condition for B60 blend.

7. EMISSION CHARACTERISTICS

7.1 Carbon Monoxide

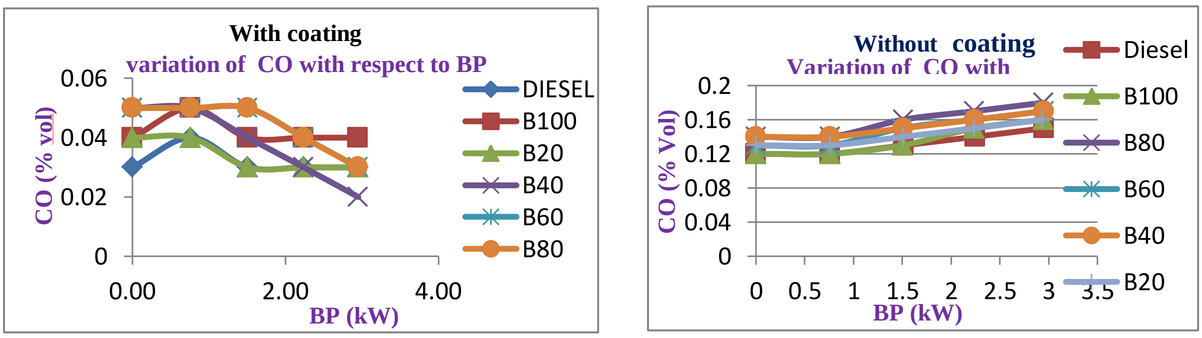


Figure 8. Variation of CO emissions with respect to BP

The variation of carbon monoxide emission with the brake power for different blends of biodiesel and neat diesel are shown in fig.8. In without coating condition, at initial load condition, CO emission is same for diesel and B100 and for all other blends (7.69%) it is higher than diesel. Additionally, at full load condition CO emission of biodiesel of all other blends are (6.25%) higher than diesel. With coating, at initial load condition, CO emission of all the blends are (25%) higher than diesel. At full load condition, CO emission of biodiesel blends B20, B60, B80, B100, and diesel are (33%) higher than B40. CO emission of B40 is (33%) lower than neat diesel fuel at full load condition. In both the cases (with coating and without coating) with coating has lower CO emission (87.5%) than without coating at the end load condition for B40 blend.

7.2 Hydrocarbon

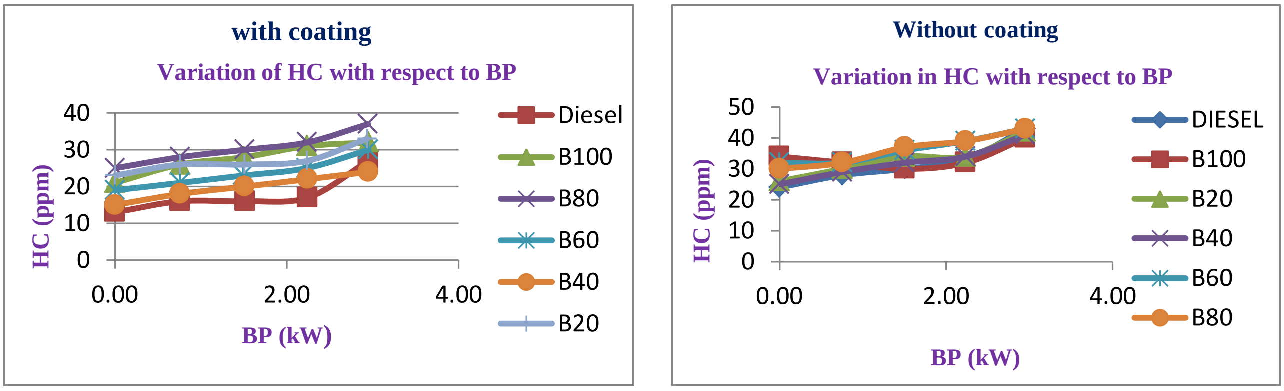


Figure9. Variation of HC emissions with respect to BP

The variation of hydrocarbon emission with brake power for different blends of biodiesel and neat diesel are shown in fig.9. From the above graph, it is evident that, without coating, at initial load condition, the hydrocarbon emission (HC) of biodiesel B40 (4.0%) and B20 (7.69%) are higher than the neat diesel. At full load condition, the hydrocarbon emission of biodiesel B40 (4.65%) and B20 (2.32%) are lesser than diesel. With coating at full load condition, the hydrocarbon emission for B40 is 11.11% which is lesser than the diesel due to clean burning. B100, B20 & B60 have 10% higher than the diesel due to the rich mixture of the blend. The primary reason is the raw algae oil is having more oxygen content, when compared to diesel due to clean burning.

7.3 Oxides of nitrogen

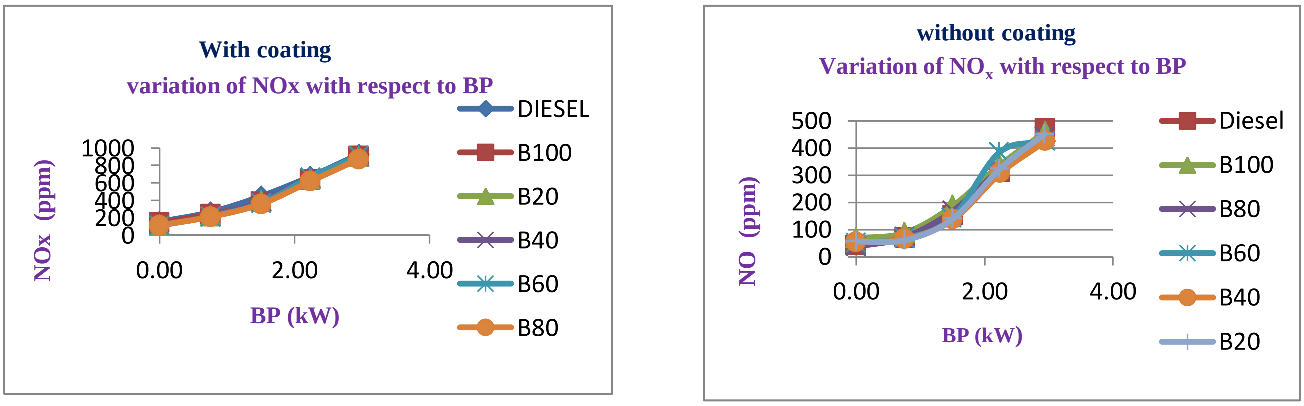
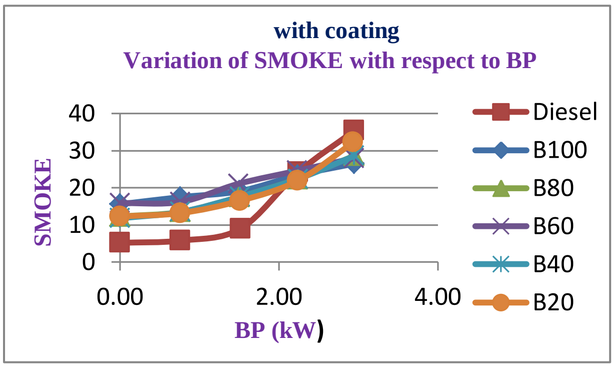


Figure 10 Variation of Nox Emissions With Respect To BP

The variation of oxides of nitrogen (NOx) emission with brake power for different blends of biodiesel and neat diesel are shown in fig.10. From the graph, without coating at end load condition the NOx emission of all the biodiesel blends are lower than the diesel. Also, NOx emission is low (9.57%) in biodiesel blend B80 than neat diesel. When comparing NOx emission of the raw algae oil it is lesser (2.15%) than the neat diesel. Furthermore, the NOx emission of B80 is lesser (6.04%) than the neat diesel. With coating, NOx emission is lower than neat diesel comparatively. It is due to the rich mixture that the oxygen content is low. When comparing, NOx emission of the B80 blend is lower (6.04%) than the neat diesel. In both the cases, (with coating and without coating), with coating has higher NOx emission than the without coating. Normally, nitrogen and oxygen react at relatively high temperatures; therefore high temperatures and availability of oxygen are the two main reasons for the formation of NOx.

7.4 Smoke



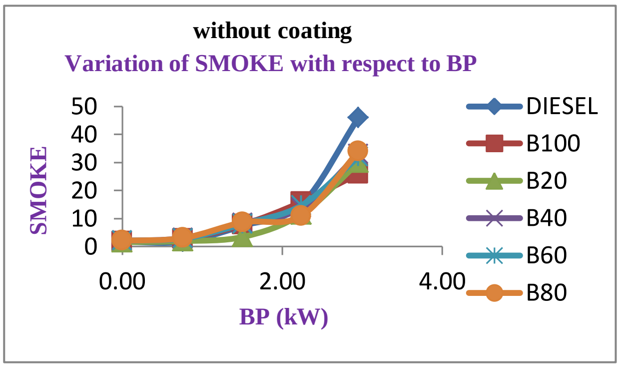


Figure 11. Variation of SMOKE Emissions With Respect To BP

The variation of smoke emission with brake power for different blends of biodiesel and neat diesel are shown in fig.11. From the graph, in the engine without coating at initial load condition, the smoke emission, B80, B60 and B40 of biodiesel blend is (14.28%) higher than diesel. At high load condition, the smoke emission of diesel is higher than all other biodiesel blend. At high load condition B100 of biodiesel blend is lower (43.47%) than the neat diesel. In the coated engine, at initial load condition the smoke emission of various biodiesel blends is higher than the neat diesel. Towards the end load condition the smoke emission of B100 is lower (25.14%) than diesel. Also B40 & B60 is lower (19.2%) & (20.9%) than the diesel. Smoke emission of biodiesel blend is lower when compared to the diesel. Low smoke emission is liberated in exhaust, as the oxygen content is more in the biodiesel.

VII. CONCLUSIONS

7. Conclusions

The following conclusions are drawn based on the experiments, conducted using diesel engine with and without coating conditions.

7.1 Without Thermal Barrier Coating

BTE is higher (7.14%) for B60 on comparing all the blends such as B20, B40, B80, B100 and diesel. Same time BSEC of B40 and B60 is higher when compared to the diesel (3.48%) and all other blends except B40. At the initial load condition BSFC of B60 is lower (13.8%) than diesel and all other blends, but end load condition of BSFC is little higher than diesel. Based on the results, the BTE, BSEC and BSFC; B60 is the best blend. On comparing the emissions such as NOx, HC, CO and smoke; B20 blend gave lower emissions among the other blends. Finally, the engine ran with B60 blend as primary fuel, the BTE was (7.14%) higher than the diesel and BSEC was (1.8%) higher than the diesel. If the engine ran with B20 blend as primary fuel, the CO emission was (6.25%) lower than the diesel. HC emission was (2.3%) lower than the diesel. NOx emission was (3.8%) lower than the diesel. Smoke emission was (34.7%) lower than the diesel. Hence, it could be concluded that B60 blend is the best blend for performance and B20 blend is the best blend for emission.

7.2 With thermal barrier coating

BTE is higher (6.4%) for B100 on comparing the blend such as B20, B40, B60, B80 and diesel. However, BTE is higher (3.33%) for B40, B60 and B80 than diesel; also BSEC is the higher (2.5%) for B40 than diesel and other blends. BSFC of B60 is lower (3.03%) than diesel and all other blends, at the same time B40 is little higher (2.9%) than diesel. It is concluded that B40 is the best blend for BTE, BSEC and BSFC. On comparing the emissions such as CO, HC, NOx and smoke, B40 blend gave lower emissions among the blends. The engine ran with B40 blend as primary fuel, the performance in BTE was (3.33%) higher than the diesel. BSEC was (2.5%) higher than the diesel, and CO emission was (33.3%) lower than the diesel, HC emission was (11.1%) lower than the diesel. NOx emission is (2.48%) lower than the diesel and finally smoke emission is (19.2%) lower than the diesel. So, it is being concluded that B40 blend is the best blend for performance and emission characteristics.

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