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Experimental Investigation on the Performance Characteristics of Compression Ignition Engine Fuelled with Various Blends of Nerium Biodiesel

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***Abstract**: In the present study, an experimental work had been carried out to analyze the Performance characteristics of compression ignition engine fuelled with various blends of Nerium biodiesel. The engine tests are conducted on kirloskar, 5.2 kW, 4-stroke, single cylinder, 1500 rpm, water cooled, direct injection diesel engine with eddy current dynamometer with injection timing 23° bTDC and injection pressure 210 bar were maintained constant throughout the experiment. Different blends of Nerium biodiesel such as B0, B20, B40, B60, B80 and B100 are prepared to analyze the Performance characteristics. From the test results, it could be observed that among different blends B20 blend showed very close performance with the neat diesel.*

***Keywords** – Nerium biodiesel, Blends, Performance, Engine.*

1. INTRODUCTION

Biodiesel has been under research for past many years, for blending with petroleum diesel as it has better heating value than vegetable oil and doesn't require any major modification in the engine. In few countries, it has been used in compression ignition engines, with a smaller rate of blending. The various biodiesel fuels under research are Jatropha, Karanja, Cotton seed, Pongamia, etc. Pradeep Kumar A. R. et al. [1] found that, for all load conditions and for all injection timings the BTE was found to be maximum at three fourth of load condition. The maximum efficiency was obtained with diesel fuel to a value 25.608%. The decrease in the efficiency were found to be 11.71%, 3.71% and 3.87% when the injection timings were 24° bTDC, 27° bTDC and 33° bTDC. The HC emission increased when the injection timing was retarded and decreased when the injection timing was advanced, for both diesel and A20 biodiesel. The HC emission was found to be 73 ppm at maximum load, with petroleum diesel with standard injection timing. The increase in HC emission was found to be 2.74%, when the injection timing was retarded to 24° bTDC. The decrease in hydrocarbon emission was found to be 11.87% and 8.21%, when the injection timing was advanced to 30° bTDC and 33° bTDC. The CO emission increased with the decreased of injection timing and decreased when the injection timing was advanced. The CO emission was higher at initial load condition and decreased gradually with the increase of load, for both diesel and A20 biodiesel. The decreased CO emission was found to be 5.88%, 9.44%, 22.35% and 16.47% when the injection timings are 24° bTDC, 27° bTDC, 30° bTDC and 33° bTDC. The Smoke Opacity increased when injection timing was retarded and decreased when injection timing was advanced. The increase in smoke opacity was found to be 32.1%, when the injection timing was retarded to 24° bTDC. The decrease in Smoke Opacity was found to be 3.84% when the injection timing was advanced to 30° bTDC. NOx emission increased with the increase of injection timing with A20 biodiesel fuel than diesel. The decrease in NOx emission was found to be 18.04% when the injection timing was retarded. The increase in NOx emission was 24.01% with A20 biodiesel at standard injection timing (27° bTDC). The increase in NOx emissions were found to be 42.02% and 35.43% more than diesel, when the injection timings were 30° bTDC and 33° bTDC. S. Prabhakar et al. [2] found that, the BTE was highest with diesel in all loads. The maximum efficiency was obtained for Methyl Esters of Nerium oil (MEON) blends compared with Ethyl Esters of Nerium oil (EEON) blends. The UBHC increased with increase in load for all fuels. The UBHC emission was less in case of MEON blends when compared to EEON blends. The amount of NOx emission was increased with increase in load for all fuels. The NOx emission was higher in case of EEON blends when compared to MEON blends. Pradeep Kumar A. R. et al. [3] found that, the Brake Power was maximum at three fourth of load condition. There was a marginal decrease of 4.72% in BTE was found when methyl esters of Adelfa oil blend was used. At three fourth of load, the HC emission was the least for both reference and test fuel. The HC emission of A20, was found to be 8.125% lower than petroleum diesel at three fourth of load condition. The CO emission significantly better with A20 biodiesel compared to diesel. At three fourth of load the CO emission of A20 was found to be 16.36% lower than diesel. The NOx emission was more with methyl esters of Adelfa oil, at all load conditions, when compared to diesel. The increase in NOx emission was about 129 ppm, A20 was used. K. Suresh Kumar et al. [4] found that, the blends of Nerium oil showed lowest Specific Fuel Consumption than the diesel at part loads. Mechanical Efficiency for NO30 was higher compared to diesel fuel. Brake Mean Effective Pressure was also increased as the percentage of the Nerium oil increased with the diesel. The Volumetric Efficiency was raised as the blend of the Nerium oil increased in the diesel. CO emission decreased with increased in percentage of Nerium oil in the fuel up to 3000W. CO_2 emissions of Nerium oil and its diesel blends were slightly lower than that of diesel. HC emissions of Nerium oil and its diesel blends were lower than that of diesel. Suresh Kumar S. et al. [5] found that, for an applied load, the Brake Power was similar for both diesel and biodiesel. There was an increase of 0.12% of Brake Power when biodiesel was used. The TFC value was decreased by 0.1622 kg/hr when biodiesel was used at no load condition. The SFC value was decreased by 0.4187 kg/kW-hr when biodiesel was used at no load. Isaac Joshua Ramesh Lalvani J. et al. [6] found that, diesel showed the superior BTE on all loads. BTE of the engine was reduced by increased blend ratio of Adelfa biodiesel with diesel. Specific Energy Consumption for the Adelfa biodiesel and their blends was higher than diesel. UBHC emission for Adelfa biodiesel blends were less as compared to diesel due to complete combustion. CO emission of Adelfa biodiesel blends were less as compared to diesel due to complete combustion. The NO_X emissions were higher for the Adelfa biodiesel and their blends as compared to diesel. Adelfa biodiesel and their blends showed complete combustion so they had lower Smoke emissions. Cijil. B. John et al. [7] found that, the Peak Cylinder Pressure was higher for eucalyptus biodiesel (E30 blend) at all tested loads. For an engine power output of 0.9 kW, the Peak Pressures were found to be 70 bar, 72.6 bar and 74 bar, respectively, for diesel, N30 and E30. For an engine power output of 3.6 kW, the Peak Cylinder Pressures were found to be 86 bar, 87.4 bar and 90 bar respectively for pure diesel, N30 and E30 fuel blends respectively. At lower power outputs (0.9 kW), the SFC of pure diesel and the lower blends was found to be much lower than that of N30 and E30. The maximum BTE of the engine using diesel was found to be around 28.6%. There was a marginal decreased in the BTE of nearly 6.9% while using E30 blend as the fuel. The BTE of the engine for N30 fuel blend was found to be further lower than that of both diesel and E30 blends. The HC emission for Eucalyptus biodiesel (E30) was found to be nearly 27% lower than diesel fuel at higher power outputs (3.6 kW). Similarly, the use of Nerium blend (N30) also recorded a reduced HC emission of nearly 16% lower than that of diesel. CO emissions of biodiesel blends were found to be significantly lower than that of diesel fuel. At all engine loads, the NO_X emissions of biodiesel blends (N30 and E30) were higher than that of diesel. For all the tested fuels, the maximum NO_X emissions were found at a power output of 3.60 kW. E30 fuel blend resulted in an increase in Smoke Intensity when compared to diesel while the use of N30 fuel blend resulted in a slight decrease in the Smoke especially at high engine loads. Senthil Kumar R. et al. [8] found that, the BTE for neat diesel at full load was 28.75%, and it was 24.08%, 23.56%, 22.45%, 21.923%, 21.07% for N20, N40, N60, N80 and N100. The best BTE was obtained for N20 blend and was 4.67% less than that of diesel at full load condition. The Specific Energy Consumption was highest for N100 and least for N20 fuel. The Specific Energy Consumption for N20 was 7.5% higher than diesel fuel. The UBHC emissions were approximately 16.86% less in case of biodiesel and its blends when compared to diesel. The UBHC emissions for N20 were approximately 5% less than diesel fuel. The CO emissions of N20 were 0.013% lower than the diesel fuel. The CO emissions were decreased with increase in load for all fuels. The amount of NO_X emissions were increased with increase in load for all fuels. The NO_X emissions of N20 were 17.9% higher than diesel fuel. The noise increased with increase in load for all fuels. The noise was 9.06% higher in case of biodiesels and its blends when compared to diesel. The noise of N20 was 3.9% higher than the diesel fuel. The CO_2 emissions were 34.2% higher in case of biodiesel blends when compared to diesel. The CO_2 emissions of biodiesels were 14.3% higher than diesel fuel. The amount of CO_2 emissions were increased with increase in load for all fuels. Peak Pressure for pure diesel at 27° bTDC was 77 bar. Peak Pressure for N20 was 66 bar, N40 was 63 bar, N60 was 61 bar, N80 was 59 bar and N100 was 58 bar. Instantaneous Heat Release Rate for diesel was 76.50 J/deg CA. Instantaneous Heat Release Rate for N20 was 80.23 J/deg CA, N40 was 83.73 J/deg CA, N60 was 86.17 J/deg CA, N80 was 88.1 J/deg CA and N100 was 91.9 J/deg CA. Cumulative Heat

Release Rate for N20 was 346.04 J/deg CA, N40 was 351.93 J/deg CA, N60 was 367.05 J/deg CA, N80 was 420 J/deg CA, N10 was 433.9 J/deg CA. Cumulative Heat Release Rate for pure diesel was 329.04 J/deg CA. S. Prabhakar et al. [9] found that, at normal injection timing of 27º bTDC the BTE for neat diesel at full load was 26.48% and it was 24.08%, 23.56%, 22.45%, 21.923%, 21.07% for N20, N40, N60, N80 and N100. The best BTE was obtained for N20 blend and was 2.4% less than that of diesel for full load. BTE at different injection timings for best efficiency blend (N20) at 24º bTDC was 22.60%, at 30º bTDC was 26.12% and at 33º bTDC was 24.61%. For N20 at 30º bTDC it was found to be 2.04% higher than N20 at 27º bTDC. The Specific Energy Consumption was highest at 33° bTDC and was least at 30º bTDC. The UBHC and CO emissions were highest at 24º bTDC and were least at 30º bTDC. The NOx and CO_2 emissions were highest at 30º bTDC and were least at 24º bTDC. The sound characteristics was highest at 33º bTDC and was least at of 30º bTDC. Peak Pressure for pure diesel at 27º bTDC was 72 bar. Peak Pressure of N20 for 30º bTDC was 70 bar, 33º bTDC was 67 bar, 27º bTDC was 66 bar and 24º bTDC was 63 bar. Instantaneous Heat Release Rate for pure diesel was 76.50 J/deg CA at 27° bTDC. Heat Release Rate of N20 at 30º bTDC was 78.6 J/deg CA, at 33º bTDC was 79.7 J/deg CA, at 27º bTDC was 80.23 J/deg CA and at 24º bTDC was 86.12 J/deg CA. Cumulative Heat Release Rate for pure diesel was 329.04 J/deg CA at 27° bTDC. Cumulative Heat Release Rate of N20 at 30º bTDC was 335.01 J/deg CA, at 33º bTDC was 340.23 J/deg CA, at 27º bTDC was 349.04 J/deg CA, and at 24º bTDC was 366.60 J/deg CA. A. R. P. Kumar et al. [10] found that, the maximum BTE obtained was 25.61% with diesel as fuel and it was decreased by 13.6% with A20 biodiesel fuel at three fourth of load. The decrease in BTE was found to be 10.8%, 8.2% and 2.77% for A20 + 5% DEE, A20 + 10% DEE and A20 + 15% DEE blends respectively. The BTE was found to be 24.9% with A20 + 15% DEE at three fourth of load. Specific Energy Consumption was more than diesel when A20 biodiesel was used as fuel and it gradually decreased with increase DEE blending up to 15%. The increase in Specific Energy Consumption was 16% more than when A20 biodiesel was used. The increase in Specific Energy Consumption was found to be 16.41% and 15.04% when the fuels used were A20 and A20 + 5% DEE. Specific Energy Consumption was almost close to diesel when A20 + 10% DEE was used as fuel with variation of 1.05%. The pressure developed was highest when diesel was used and the pressure obtained was almost equal to diesel with A20 + 15% DEE with a marginal decrease of 0.72%. The lowest Heat Release next to diesel, was obtained when the A20 + 15% DEE blend was used. The percentage decrease of Heat Release Rate with diesel was found to be 0.36% for A20 + 15% DEE, which was lesser than A20 and other blends of A20 + DEE. Heat Release Rate was 6.12% more than diesel with A20 biodiesel. A maximum increase of HC emission about 5 ppm was found when A20 + 15% DEE was used as the test fuel, which was highest among all other blends. A maximum decrease of HC emission about 4 ppm was found when A20 biodiesel was used. The CO emission increased with DEE blend was increased with biodiesel. CO emission of biodiesel (A20) was lesser than diesel. Smoke Opacity increased when the load was increased. When DEE percentage was increased the Smoke Opacity emission decreased. NO_X emission decreased with the increased content of DEE with biodiesel. When compared to diesel, maximum reduction of 31 ppm of NO_X was found, when A20 + 15% DEE was used as the test fuel.

Fig-1: Nerium seeds with outer shell

Fig-2: Nerium seeds without outer shell

2. TRANSESTERIFICATION REACTION

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification.

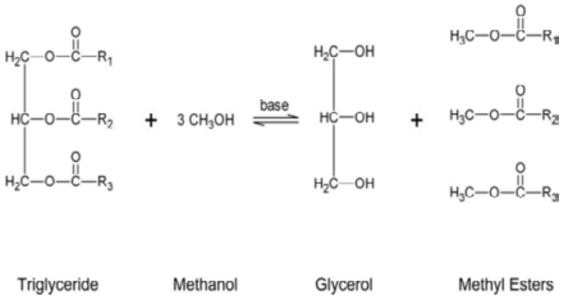

Fig-3: Transesterification reaction

The first step for biodiesel preparation is the transesterification of vegetable oils. By this process the molecular size of the component (triglycerides) reduces. Such that the resultant esterified oil could be used in diesel engine for a prolonged period without any serious issues like carbon buildups, scum formation, etc. The transesterification process is as follows: one liter of raw oil was taken in a round bottom flask and was heated up to 110°C in order to remove the moisture content present in it. Base catalyst NaOH (7.5 g approx.) was dissolved in methyl alcohol (300 ml) and maintained at the reaction temperature of around 65°C for a period of 60 minutes. The reaction products were allowed to settle under gravity in separating funnel for 24 hours to separate methyl esters and glycerol. Due to the higher density of glycerol it settled at the bottom of the funnel and obviously methyl esters occupied the top surface. The methyl ester was then washed with warm water to remove un-reacted methanol, catalyst and impurities. The washed methyl ester was again heated to 110°C to remove the moisture content. Various biodiesel-diesel blends (B20, B40, B60, B80 and B100) were prepared for the experimental work.

3. PROPERTIES OF FUELS

Table-1: Properties of Nerium biodiesel blends compared with diesel

Properties	B0	B20	B40	B60	B80	B100
Density (kg/m^3)	827	835	849	862	876	890
Kinematic Viscosity at 40°C (cSt)	3.517	4.403	4.714	5.025	5.336	5.648
Flash Point (°C)	52	74	103	131	155	182
Fire Point (°C)	59	89	116	143	168	194
Calorific Value (MJ/kg)	42.21	40.14	39.94	39.75	39.56	39.87

4. EXPERIMENTAL SETUP

Fig-4: Engine setup

A single cylinder, direct injection, four-stroke, water-cooled, Compression Ignition (CI) engine is used in the experimental study. The technical specification of the engine is given in Table-2. The engine was loaded by eddy current dynamo meter. The fuel flow rate was measured by noting down the time taken for the consumption of a known quantity of fuel (10cc) from a burette. The viscosity of raw as well as esterified oil was measured by red wood Viscometer, density by hydrometer, calorific value by bomb calorimeter, flash and fire point by open cup method. Initially, before starting experimental tests, the engine was made to run under ideal condition as warm up phase and then the tests were conducted. The engine was started and allowed to warm-up for about 10 minutes. The engine was tested under five discrete part load conditions i.e. 20%, 40%, 60%, 80% and 100%.

Table-2: Engine specifications

Engine Parameter	Specifications
Engine Type	Kirloskar
No. of Strokes	4
No. of Cylinders	1
Type of Cooling	Water Cooling
Type of Injection	Direct Injection
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Rated Power	5.2 kW
Rated Speed	1500 rpm
Injection Pressure	210 bar
Injection Timing	23° bTDC

5. RESULTS AND DISCUSSION

5.1. Performance Characteristics

5.1.1. Brake Thermal Efficiency (BTE)

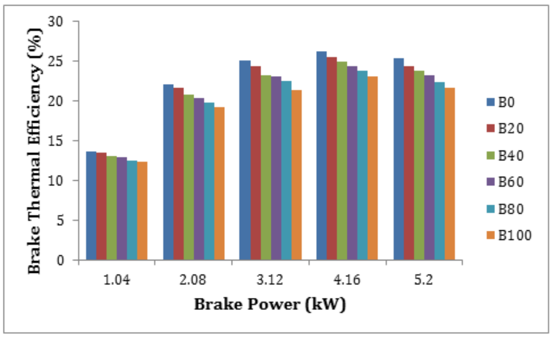

Fig-5: Variation of Brake Thermal Efficiency with Brake Power

The variation of Brake Thermal Efficiency with Brake Power for different blends of Nerium biodiesel as shown in Fig-5. For all the fuels tested the Brake Thermal Efficiency increases with increase in load. This is due to, reduction in heat loss and increase in power with increase in load. The Brake Thermal Efficiency of Nerium biodiesel blends was found to be lower compared to diesel at all power output. This is due to, the lower calorific value, higher viscosity, higher density which leads to poor atomization of biodiesel than diesel which results into increase of Brake Thermal Efficiency for diesel than Nerium biodiesel blends. At 80% load condition all tested fuels give higher Brake Thermal Efficiency than at 100% load condition. This is due to the fact that, the power produced from the engine is less than the amount of fuel consumed to develop that power at 100% load condition so that Brake Thermal Efficiency decreases at 100% load condition as compared to 80% load condition.

5.1.2. Total Fuel Consumption (TFC)

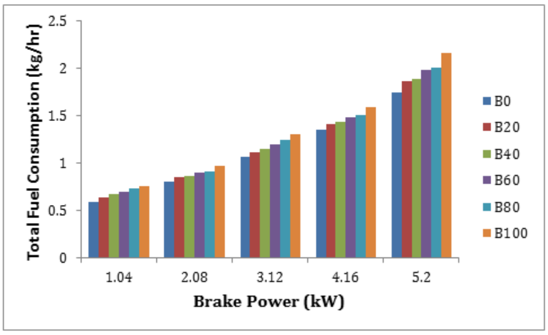

Fig-6: Variation of Total Fuel Consumption with Brake Power

The variation of Total Fuel Consumption with Brake Power for different blends of Nerium biodiesel as shown in Fig-6. As the load increases Total Fuel Consumption increases for all fuels tested. Total Fuel Consumption for diesel is less as compared to Nerium biodiesel blends. This is due to higher viscosity, higher density which leads to higher fuel consumption of biodiesel than diesel.

5.1.3. Brake Specific Fuel Consumption (BSFC)

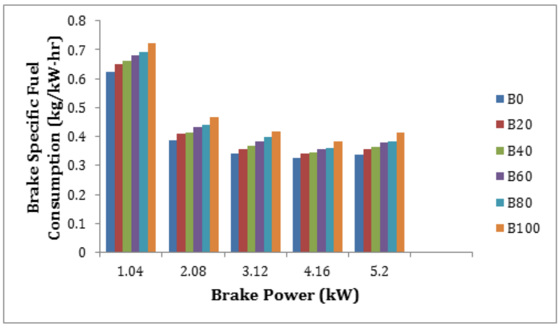

Fig-7: Variation of Brake Specific Fuel Consumption with Brake Power

The variation of Brake Specific Fuel Consumption with Brake Power for different blends of Nerium biodiesel as shown in Fig-7. As the load increases Brake Specific Fuel Consumption decreases. It is observed that Brake Specific Fuel Consumption for blends of Nerium biodiesel blends is higher when compared with diesel. For effective burning of the fuel the calorific value of the fuel should be higher so that the evaporation of the fuel is also high. The calorific values of blends of Nerium biodiesel are lower when compared with diesel; hence the fuel evaporation is slower. Slower evaporation rates leads to higher brake specific fuel consumption.

6. CONCLUSION

The Brake Thermal Efficiency of Nerium biodiesel blends was found to be lower compared to diesel at all power output. Total Fuel Consumption for diesel is less as compared to Nerium biodiesel blends. Brake Specific Fuel Consumption for blends of Nerium biodiesel blends is higher when compared with diesel. Among the Nerium biodiesel blends tested, B20 gave the best performance with reduced emissions. The BTE of the engine with the B20 blend at 80% power output which is closer to diesel operation. Hence B20 blend is recommended for existing diesel engine.

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