Experimental analysis of combustion and emission characteristics of a CI engine using linseed oil with methanol additives

Rishav Dey1,*, Madhav Sreekumar2, Panneerselvam S3, Mathanraj V4

1,2UG Students, Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
3,4Assistant Professor, Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India

*Corresponding author email: rs8213@srmist.edu.in

Abstract: The use of Biodiesel is increasing all around the world which makes it an alternate substitute for Diesel. In the current study Linseed oil is used as the alternative for Biodiesel with methanol additives. The blending ratios used were B20, B40, B60, B80, B100, B20+5%, B40+5%, B60+5%, B80+5%, B100+5%, B20+10%, B40+10%, B60+10%, B80+10%, B100+10%. The experiment was carried out on a 4 stroke diesel engine which runs at a maximum speed of 1500 rpm with maximum rated power of 5.2 kW. The experiments results indicate that B20+5% shows better performance characteristics and B40+5% shows good performance characteristics. The emission tests showed that CO2 emissions of the B20+5% were lower than that of diesel. Though lower than diesel, the performance characteristics of B40+5% were better than the other blends.

Keywords: Biodiesel, emissions, thermal efficiency, combustion, fuel.

1. Introduction

Biodiesel is an alternate fuel similar to that of regular diesel which is used on daily basis. It is safe, biodegradable and produces less emission rates than the conventional diesel. In today's world the usage of automobiles is increasing day by day. The requirement of petroleum for the modern society is huge, but the availability of petroleum is scarce. As a result, an alternative fuel must be used in place of petrochemicals to provide enhanced fuel combustion characteristics. Various literature studies were conducted to know more about the use of Biodiesel.

Ashutosh Kumar Rai et al [1] conducted studies using linseed oil as a CI engine fuel to investigate if the results are marginally inferior to fuel oil. The engine's thermal efficiency was observed to be decreased, though as a result, the engine's BSFC was higher than diesel oil. The nitrogen dioxide from the whole experiment were also found to be lower than diesel, but the unburned HC's and CO emissions were found to be higher. Chiranjeeva Rao Seela et al [2] demonstrated evaluation on a supercharged DI diesel using Linseed Methyl Ester as a biofuel. The experiment shows a slight improvement in turbocharger efficiency and lesser emissions from LME and also an increase in the overall performance. Kinematic
viscosity of biodiesel fuel compounds as well as related compounds, as well as its consequence on compound structure as well as comparison to petroleum diesel fuel components, were studied by Gerhard Knothe et al [3].

Study shows that compound structure significantly influences kinematic viscosity of fatty compounds. The chain length, position, number, and structure with double bonds both are essential components, as is the existence of oxygenation molecules. Madhuri Srinivas et al [4] carried out a linseed oil-based diesel output research Biodiesel blends on a single-cylinder diesel engine with two different mixed biodiesel fuels. Analysis of emission and performance tests were conducted for two blends of B20 and B40 and compared to diesel fuel, it showed that as the load and concentration of biodiesel increased the brake power also increased. It also shows that diesel has higher fuel efficiencies compared to blends but at max load the efficiencies are similar. Narendra Kumar Yadav et al [5] Variations in emission levels were shown for a four-stroke single-cylinder engine. It also shows that the mixture of turpentine oil and linseed oil taken as a fuel has a capacity to replace conventional diesel fuel in terms of the indicated power when tested over a variety of ratios. But in terms of pollution the whole study has less NO emissions than diesel with higher emissions. Saggarla Murali [6]

A Ceramic Coated Head LHR engine operating on linseed oil has also been shown to economic growth is expected and exhaust emissions. It showed that a conventional Kirsolkar AVI engine with a ceramic-coated cylinder head at 31oC bTDC shows a reduction in performance compared to pure LHR engine diesel operation. Srinivasa Rao P et al [7] displays the performance and exhaust of diesel engines powered by linseed oil-based biodiesel. Tests with linseed formulations on a water cooled, single cylinder, four-stroke engine led to these conclusions. For L10, L20, and L30 pure diesel at 1500rpm, the BSFC, BTE, and CO emissions of L30 drop by 4.56 percent, improve by 7.21 percent, and decrease by 40 percent, respectively, while the smoke opacity for mixes decreases. Whereas emission as NO also raise for all blends

In the study by Sukumar Puhan et al [8], the injection pressure, efficiency, emissions, and combustion process of every four-stroke DI diesel would be characterized by increased linoleum linseed oil methyl ester. The results revealed that high-viscosity, low-volatility linseed oil is unsuitable for use in diesel engines, but that trans-esterification and injection pressures of 240 bar could enhance performance and emissions. Mr. Kanji D. Dodiya [9] Experiment with performance and exhaust emissions Four-stroke diesel with direct injection that runs on a linseed oil and diesel fuel blend. From the experiment it is observed that maximum L30D70 brake thermal performance is compared to other blends. The fuel consumption also rose with an increase in the proportion of the blend. Furthermore, increasing the concentration of mixtures reduced CO emissions while increasing the fraction of mixtures increased HC and NOX emissions. Saggarla Murali[10]. An experiment was carried out to assess the efficiency of Linseed Oil (L) on ceramic coated cylinder heads with Low Heat Rejection (LHR) engines at various injection pressures. When compared to diesel fuel, brake specific energy consumption (BSEC), exhaust gas temperature (EGT), and smoke levels (SL) improved, although brake thermal efficiency (BTE), volumetric efficiency (VE), and the air-fuel ratio (A/F) decreased. At 190 bar, 240 bar, and 270 bar injection pressures, BSEC increased by 15.26 percent, 15.26 percent, and 10.66 percent, respectively. At 190 bar, 240 bar, and 270 bar, A/F increased by 33.5 %, 25.82 %, and 20.18 %, correspondingly. At 190 bar, 240 bar, and 270 bar injection pressures, BTE dropped by 11.58 %, 4.91 %, and 1.75 %, respectively. The environmental benefits of biodiesel have made it more appealing. Linseed oil with methanol additions is utilized as a Biodiesel equivalent in this research. The results were compared to that of Diesel after that the performance and emission testing were completed. The experiment was conducted out using a 4-stroke diesel engine with a maximum rated output of 5.2kW and a maximum speed of 1500
rpm. The load varies from 0 kg to 16 kg with a maximum load of 16 kg, the engine's compression ratio is 17.5:1. The engine's stroke length is 110 mm with a 87.5 mm bore diameter.

2. Preparation of bio-diesel

Linseed oil is employed as a biodiesel substitute with methanol additions in the current investigation. The data was compared to that of diesel after the performance and emission tests were completed. The Biodiesel was obtained by directing mixing of Linseed oil with Diesel. The Blending ratios (B20,B40,B60,B80,B100,B20+5%,B40+5%,B60+5%,B80+5%,B100+5%,B20+10%, B40+10%,B60+10,B80+10%, B100+10%). was prepared by direct mixing of diesel and linseed oil with methanol. Pure Linseed oil and its blends were evaluated for their characteristics. Linseed oil and its blends are contrasted to diesel for their qualities.

Table 1. Comparison of properties of linseed oil and its blends with diesel.

| PROPERTIES                         | LINSEED OIL | DIESEL | B80+ D20 | B60+ D40 | B40+ D20 | B20+ D80 |
|------------------------------------|-------------|--------|----------|----------|----------|----------|
| DENSITY (g/cm³)                    | 0.860432    | 0.860432 | 0.7877   | 0.7790   | 0.8081   | 0.7991   |
| FLASH POINT                        | 289°C       | 50°C    | 33°C     | 39°C     | 38°C     | 39°C     |
| FIRE POINT                         | 294°C       | 58°C    | 36°C     | 43°C     | 41°C     | 41°C     |
| KINEMATIC VISCOSITY (Centistokes) at 40°C | 50.506     | 7.298   | 32.112   | 20.486   | 14.852   | 10.407   |
| DYNAMIC VISCOSITY (Centipoises) at 40°C | 41.680     | 6.028   | 26.525   | 16.921   | 12.268   | 8.596    |
| CALORIFIC VALUE (KJ/KG)            | 35569.06    | 42000   | 36855.524 | 39427.627 | 39427.627 | 37072.368 |

3. Experimental set-up

A single-cylinder, four-stroke diesel engine with 5.2 KW of power and 1500rpm linked to eddy current and dynamometer style water-cooled for loading has been used. When the calorific value as well as density value are correspondingly placed into the engine programme. The engine speed was kept constant at 1500 rpm under various load circumstances to measure the performance indicators. (i.e. 0 kg, 4 kg, 8 kg, 12 kg and 16 kg) Engine exhaust is connected to AVL DiGas 444 analyzer having Electro Chemical style oxygen gas sensor used to test the parameters of engine emissions such as CO, HC, CO2, O2 and NOx.
4. Results and Discussion

4.1 Engine Performance

4.1.1 Load Vs Brake Thermal Efficiency

The variation in Brake Thermal Efficiency (BTE) of all mixes of diesel is shown in Figure 2. It can be shown that the blends' Brake Thermal Efficiencies increase as the load increases. However, throughout most of the curve, these BTEs are smaller than those of diesel. Linseed oil has a higher viscosity and a lower calorific value than diesel, owing to its higher viscosity and lower calorific value. Out of all the blends, B60+5% and B40+5% show better BTEs. The BTEs of the other blends are not comparable to that of diesel.
4.1.2 Load Vs Brake Specific Fuel Consumption

The relationship among Brake Specific Fuel Consumption (BSFC) and load is seen in Figure 3. The density and volume flow rate have been used to calculate the brake specific fuel consumption. The engine's power is contingent on the mass flow rate because it runs at such a consistent speed due to the variable load values. The BSFCs of the blends can be seen decreasing with increases in loads throughout the entire range and are lower than that of diesel. This is due to the combined effects of linseed oil's relative fuel density, viscosity, and heating value. B40 + 5% seems to have the lowest BSFC when compared to other blends.

4.2 Emission Characteristics

4.2.1 Load Vs Nitrogen Oxide

Figure 4 depicts the range in NOx emissions throughout all mixes and diesels. Because of the elevated temperatures of fuel burning, nitrogen oxides are released. When the temperature is high enough, the
nitrogen in the air is degraded into free radicals, which are extremely toxic and generate NOx when combined with oxygen in the air. Here, NOx emissions increase gradually with increase in loads for different blends. Diesel emits the lowest amount of NOx while B100+10% emits the highest amount of NOx at high load.

4.2.2 Load Vs Carbon Monoxide

Figure 5. Load Vs Carbon Monoxide

Figure 5 shows the CO emissions values as a function of load and rpm. Incomplete fuel combustion, caused by low peak temperatures at lower loads and lower air-fuel ratios at greater loads, is the primary cause of CO production. At lower loads, the combination is very lean, enabling incomplete combustion and greater CO levels, whereas at higher loads, the mixture has much more air due to the lower A/F ratio. This results in the formation of larger carbon spheres on which the gasoline condenses and escapes unburned. B20 + 5% produce the least amount of CO, with the exception of peak load, where the volume of CO is slightly higher than diesel. Smaller the viscosity, and the atomization will be lower.

4.2.3 Load Vs Carbon Dioxide

The graph above in figure 6 shows the variation of the blends and diesel CO2 emissions. Because the A/F ratio is greater and there is less fuel to burn in air at lower loads, the curve has a low CO2 value. Some other major cause would be that combustion doesn't really take place properly at low loads. At lower loads, the carbon in the fuel converts to CO rather than CO2 due to the reduced temperatures of the tubes, which results in poor atomization. At lower loads, the CO2 content is higher because the A/F levels are superior, and the fuel entering is lower than expected of lower CO2 emissions. Because of the amount of oxygen in the blends, this really is the case. The carbon level of the blends is lower than that of gasoline. B20 + 5% emit the least amount of CO2 and is hence preferable to other mixes.
4.2.4 Load Vs Hydrocarbon

Figure 7 above displays the plot for HC against the load in terms of ppm. The trends in these graphs are natural and do not reflect a clear pattern about methanol inclusion. Many of the blends have higher HC concentrations than gasoline, as can be seen in the graph illustrated. The major cause of elevated HC levels in the effluent is the high viscosity of the blends, which slows down the mixing of air and fuel and causes flame quenching, which results in poor atomization because they are left unburned. B20+5 %, on the other hand, emit less HC than diesel and would be the lowest of all the blends, making it a viable fuel.
4.2.5 Load Vs Smoke Graph

Figure 8 shows the smoke variations for the respective loads for all the fuel blends prepared. The blends without additives are higher than the other blends for loaded engine operation. There are 2 types of smoke namely Black Smoke and White Smoke. Black Smoke emission is due to incomplete combustion of fuel inside the engine, white smoke is due to the fuel being completely intact or unburnt. It can be noted from the graph that B20+5% has the lowest smoke emission than the other blends.

5. Conclusion

The framework consisted of a single cylinder, four stroke, 5.2 KW diesel engine running at 1500rpm linked to eddy current and a water-cooled dynamometer for loading. The engine starts first with diesel for 10-15 minutes and then with the blends (B20, B40, B60, B80, B100! B20+5%, B40+5%, B60+5%, B80+5%, B100+5%, B20+10%, B40+10%, B60+10%, B80+10%, B100+10%). When the calorific value and density value are simultaneously entered through into engine software. To test the efficiency metrics, the engine speed was kept constant at 1500 rpm under various load conditions (i.e. 0 kg, 4 kg, 8 kg, 12 kg, and 16 kg). The results demonstrate that the engine's capability on linseed oil is comparable to that of a diesel engine. B20+5% has superior emission characteristics than the other blends, whereas B40+5% has improved performance characteristics. The BTEs and BSFCs of the blends were marginally lower than those of diesel in the performance testing. The performance requirements of B40+5% were superior than the other blends, although being lower than diesel. The CO2 emissions of the B20+5% were found to be lower than those of diesel in emission tests. According to the results of the experiment, B20+5% and B40+5% could be a good alternative fuel for diesel engines.

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