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Experimental Investigation on Performance Characteristics of Diesel Engine Using Neem Oil Methyl Ester and its Diesel Blends

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ABSTRACT

Ever increasing energy consumption, declining reserves of petroleum fuel and concern over environmental pollution have encouraged researchers further in search of alternative energy sources. The past research results revealed that wind, solar and geo-thermal energies can be considered as alternative renewable energy sources. In case of automotives and agricultural equipment, diesel fuel is most widely used fuel and bio-fuel is the preeminent alternative fuel to replace diesel partially/completely. The vegetable oil based biodiesels, which are derived from transesterification of plant based oil seeds, have comparable heat energy value of diesel on volume basis and almost nearer cetane number. The use of edible oil as fuel or biodiesel feedstock has raised concerns of a food crisis. Hence, the present paper aims to investigate the performance characteristics of direct injection compression ignition engine using neem oil methyl ester (NOME) and their diesel blends as fuel. The experiment analysis was carried-out using single cylinder, water cooled, direct injection diesel engine and observed lower brake thermal efficiency (BTE), higher brake specific fuel consumption (BSFC) and brake specific energy consumption (BSEC) when compared with petro-diesel fuel. The test results confirmed that B10N methyl ester of neem oil diesel blend has comparable performance characteristics as diesel fuel among all tested blends of biodiesel and can be used as fuel in unmodified diesel engine.

Keywords: Biodiesel, Transesterification, Neem Oil, Methyl Ester, Engine Performance.

I. INTRODUCTION

The diesel engines are most widely used in automotives, construction equipment, marines and agriculture pumps. The diesel engine has higher thermal efficiency and durability when compared with other internal combustion (IC) engines. In agricultural based countries like India, China, and other south-east Asian countries, petroleum based diesel is not only widely used in the agriculture sector but also in transportation sector, accounting for more than 95% of the fossil fuel use [1]. At present, fossil fuels are playing a biggest role in the energy sector, but the deteriorating fossil fuel reserves, ever increasing the prices of crude oil that causing colossal influence on nations' economies [2,3]. The usage of fossil fuels has also perilous effect on environment and global warming effect [4]. Alternative fuels derived from biological sources such as plant based oils, waste oil and animal fat oil; provide a source for sustainable growth, energy conservation, efficiency and environmental protection. Some of the alternative fuels explored are ethanol, biogas, vegetable oils, animal fat based oils and waste oil [5].

In the last few decades, vegetable oils such as soybean oil, rice bran oil, canola oil, palm oil and sunflower oil can be directly used in diesel engine as bio-fuel [6]. The usage of edible oils such as sunflower oil, palm oil in the diesel engine as fuel or as a feedstock of biodiesel has raised concerned over food items' prices. To avoid this problem, the researchers have started to look towards non-edible oils such as jatropha curcas, pongamia, linseed, karanja and mahua etc. and their methyl esters as fuel in diesel engines [7,8]. Because non-edible oils are not used in any food products and most of the oils have poisonous and toxic chemical compounds [9-11]. Furthermore, they could grow in the uncultivable, unfertile waste lands. Due to this, interestingly the focus of researchers have been moved forward towards non-edible oils and endorsing that it would be promising feed stocks for the production of alternative biodiesel, especially in the developing nations like India where the demand for edible oils is more and hard to find excess amount of oil in huge quantities.

The diesel engines was invented by German Scholar, Rudolf Diesel and first demonstrated his engine at the 1900 World Exhibition in Paris by using peanut oil. Murayama et al. were conducted experiments and evaluated the engine performance and emission characteristics of a waste vegetable oil as biodiesel using direct injection (DI) and indirect injection (IDI) diesel engines. The research results revealed that, for engine performance, the esterified fuel was at par with light oil. For the emission of particulates, with the IDI diesel engine there was no significant difference between the light oil; however, the DI engine proved to emit a much larger quantity of particulates in the low to middle range[12]. Murthy et al. were used vegetable oil in a conventional diesel engine, which showed the deterioration in the performance, while LHR (Low Heat Rejection) engines showed improved performance, when compared to diesel fuel operation on conventional engine [13]. Dorado et al. evaluated a blend of 10% waste vegetable oil-90% diesel fuel in a 3-cylinder direct injection (DI) diesel engine, without any modifications. The results revealed 12% drop in thermal efficiency, slight increase in fuel consumption, and drop in combustion efficiency during the testing period [14]. Sirivella et al., were conducted experiments using jatropha curcas oil methyl ester (JCOME) in a single cylinder DI diesel engine and their research results revealed that B20J biodiesel blend of JCOME has comparable brake thermal efficiency as diesel fuel and the lowest BSFC, BSEC and EGT in all tested biodiesel blends. Their results confirmed that B20J biodiesel blend can be used as alternative to diesel fuel in unmodified diesel engine [15].

II. METHODS AND MATERIAL

In this study, neem oil that was produced from dried neem seeds, collected from local vendor at Hyderabad, Telangana state, India and filtered to remove solid impurities in order to use it to prepare the biodiesel using transesterification process. The methyl ester of neem oil was used to conduct the experimental analysis on performance characteristics of direct injection diesel engine. The principal active component of neem oil is Azadirachta indica and its chemical structure is depicted in Figure 1 [16].

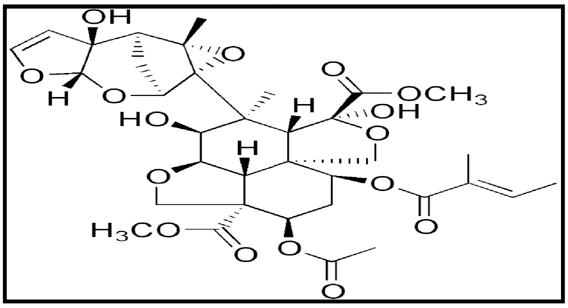


Figure 1. Chemical structure of azadirachtin

A. Fuel Characteristics

For this research study, neem oil methyl ester-diesel fuel blends were prepared by mixing 20% (B20N), 40% (B40N), 60% (B60N) and 100% (B100N) respective methyl ester with diesel fuel on volume basis. The chemical properties of diesel fuel and neem oil methyl ester were evaluated and presented in Table 1.

Table 1. Fuel Properties of Diesel and Biodiesel Blends

Property	Diesel	NOME
Kinematic Viscosity at 40^0 C (Cst)	3.52	4.5
Density at 15^0 C (Kg/m^3)	830	870
Flash Point (^{0}C)	51	175
Cetane Number	50	53
Calorific Value (KJ/kg)	42000	41500
Total Sulphur (% by mass)	0.01	Nil

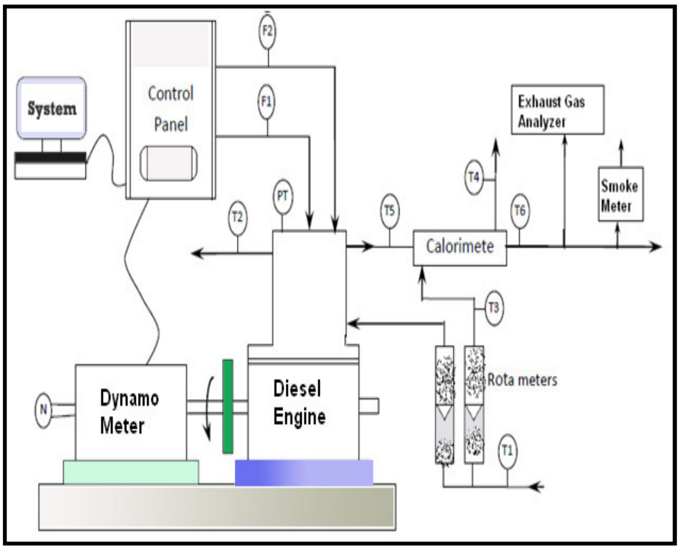
B. Experimental Setup

The experimental analysis was carried-out with a single cylinder, water cooled, 4-stroke direct injection diesel engine and the specifications of the test engine are given in Table 2.

Table 2. Specification of Test Diesel Engine

Engine Make	Kirloskar AV1, India
No. of Cylinders	One
Engine Details	Four stroke, Water cooled
Injection Type	Direct Injection
Bore & Stroke	80 × 110 mm
Rated Power	3.7 KW (5 HP) at 1500 rpm
Speed	1500 rpm
Injection Pressure	200 bar
Compression Ratio	16.5:1
Dynamometer	Eddy Current

The schematic diagram of test engine's setup is shown in figure 2. The neem oil methyl ester and its diesel blends in the ratio of 20:80, 40:60, 60:40, and 100:0 with diesel fuel were used as fuel in the test engine. The test engine was initially started with diesel and then continued with methyl ester of neem oil and its blends. After engine has reached the stabilized working condition at constant speed of 1500 rpm, time for 10ml of fuel consumption was recorded for each applied load for diesel and each biodiesel blend in order to calculate the performance characteristics of DI diesel engine.



T1	Inlet water temparature	PT	Pressure transducer
T2	Outlet engine jacket water temp	F1	Air intake differential pressure unit
T3	Inlet water temparatue	F2	Fuel Flow differential pressure unit
T4	Outlet cal. water temparature	T6	Exhaust gas temparatue after Cal
T5	Exhaust gas temparatue before Cal		

Figure 2. Schematic diagram of experimental setup

III. RESULTS AND DISCUSSION

The engine performance characteristics in terms of brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and brake specific energy consumption (BSEC) were estimated through a series of experimental tests. The test results and analysis is presented below.

A. Brake Thermal Efficiency (BTE)

The variation of brake thermal efficiency (BTE) with engine load for diesel fuel and neem oil methyl ester (NOME) blends is presented in figure 3. The graph reveals that diesel has highest and neat neem oil methyl ester (NOME) has the lowest brake thermal efficiency among all tested fuels. It is observed that BTE decreasing with the increase of percentage of neem oil methyl ester in the blend. The BTE of diesel fuel, methyl ester of neem oil and its blends increased as load increases at part load condition. The BTE has decreased at full load condition for all tested fuel except diesel. All blends of neem oil methyl ester (NOME) are performing well at 80% of engine load and producing highest BTE when compared with other load conditions. In among all the blends of methyl ester of neem oil, B20N blend has closest BTE with diesel fuel when compared to all other blends. It is also noted that the rate of increase in brake thermal efficiency is higher at lower loads and low at higher loads.

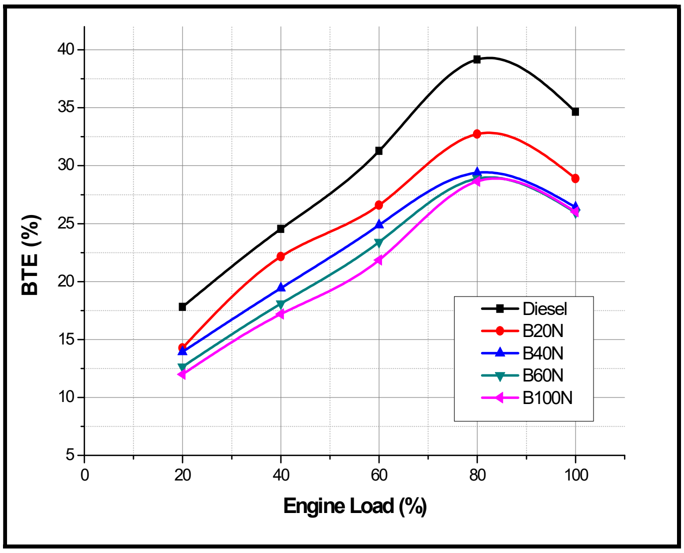


Figure 3. Variation of BTE with Engine Load for Diesel and Blends of NOME

B. Brake Specific Fuel Consumption (BSFC)

The brake specific fuel consumption measure of the efficiency of the engine to generate unit power by the unit amount of fuel supplied to the engine. Figure 4 shows the variations of Brake Specific Fuel Consumption (BSFC) for all tested fuels with engine load at rated speed of 1500 rpm. The diesel fuel has lowest BSFC in all tested fuels and B20N blend of neem oil methyl ester has exhibited lowest BSFC in among blends of NOME biodiesel. As shown in figure, BSFC increased with increase of percentage in neem oil methyl ester (NOME) in blend. It is also observed that brake specific fuel consumption has decreased with increase of load the for all tested fuels. At part loads the increase in specific fuel consumption is higher but as the load increases this value decreases and reached to lower at full load condition.

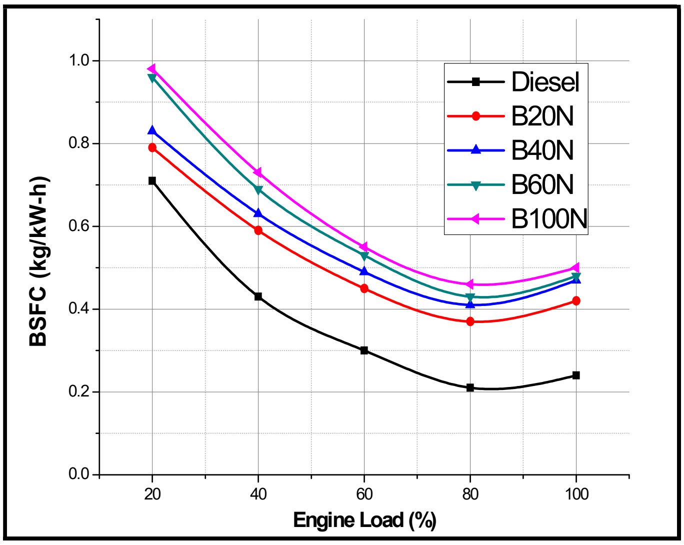


Figure 4. Variation of BSFC with Engine Load for Diesel and Blends of NOME

C. Brake Specific Energy Consumption (BSEC)

The variations of BSEC for all tested fuels with engine load are shown in Figure 5. The brake specific energy consumption of the engine with neat neem oil methyl ester (NOME) as fuel is higher when compared to petro-diesel fuel at all loads. This is due to higher density and lower heating value, higher density of neem oil methyl ester than diesel fuel.

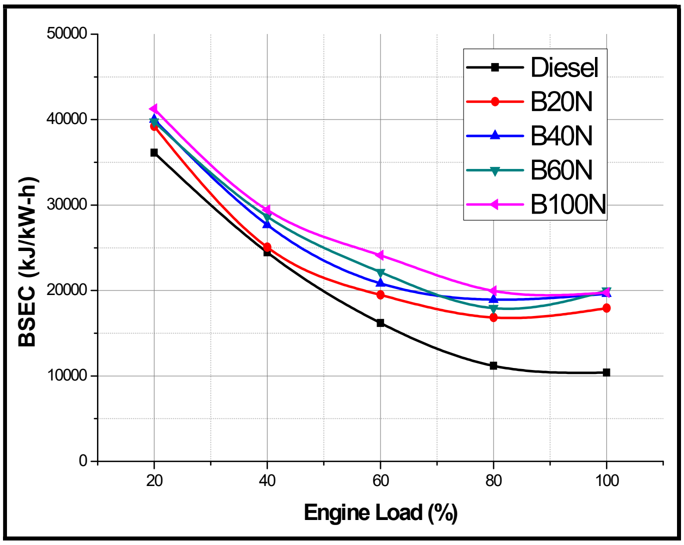


Figure 5. Variation of BSEC with Engine Load for Diesel and Blends of NOME

It is observed that the BSEC has increased with increase of NOME percentage in blend and diesel has shown lowest BSEC among all the tested fuels.

Evidently, B100N blend has highest BSEC throughout the engine load range and B20N blend has lowest BSEC compared to all others blends other than diesel fuel. At lower load conditions the BSEC is higher and gradually decreasing when the engine load increasing. At higher loads, it is noticed that the BSEC is lowest for all tested fuels.

IV. CONCLUSION

Based on the experimental results using neem oil methyl ester (NOME) and its diesel blends as fuel in a single cylinder, 4-stroke, and water cooled DI diesel engine, the following conclusions were drawn:

- ✓ The neem oil methyl ester (NOME) can be used as a bio-fuel in compression ignition engine without any engine modification
- ✓ The brake thermal efficiency (BTE) of the test engine with methyl ester of neem oil and its blends has lower performance than diesel at all load conditions
- ✓ The brake specific fuel consumption (BSFC) and brake specific energy consumption (BSEC) of the engine is more with NOME biodiesel and its blends for same power developed due to its lower calorific value and higher density
- ✓ B20N blend of neem oil methyl ester has comparable performance characteristics as petro-diesel fuel among all tested blends of NOME biodiesel.

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