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Mustard Biodiesel Blends as an Alternate for Diesel fuel in Futuristic CI Engines: An Experimental Investigation

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Abstract:-- **Depletion of petroleum resources, environmental concerns and growing energy needs associated with the increase of human population triggered various researchers and vehicle manufacturers to search for alternative fuels to replace petroleum based fuels in compression ignition (CI) engines. Transesterified vegetable oil derivatives called biodiesel can be utilized as an alternative fuel in diesel engines has increased significantly in the last two decades. In this experimental research work the performance and emissions of a CI engine was tested with 12% by volume of mustard biodiesel blended with diesel fuel. The performance parameters such as Brake specific fuel consumption (BSFC), Brake thermal efficiency (BTE) and various constituents of exhaust gases such as carbon monoxide (CO), unburnt Hydrocarbons (HC), Nitrogen Oxides (NOx) and smoke of the diesel engine are studied experimentally. The results indicated that the addition of 12% mustard biodiesel blend to diesel fuel improves the performance of the diesel engine and reduces the exhaust emission levels.**

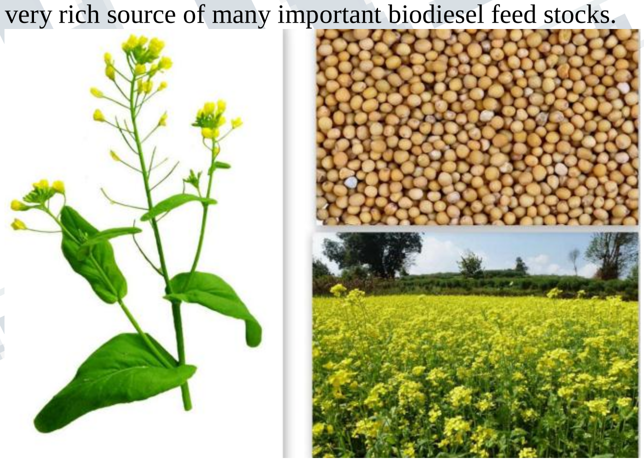
Keywords **— CI engine, Diesel fuel, Emissions, Mustard biodiesel and Performance.**

I. INTRODUCTION

Transesterified vegetable oils can be considered as an attractive alternative fuels for diesel engines as they are renewable, domestically grown, producing low emissions and biodegradable. The high viscosity and low volatility of vegetable fuels lead to poor mixture formation and results in slow combustion. Thus the vegetable oil has been converted to methyl esters which are used in diesel engines. Biodiesel is produced when vegetable oil or animal fat is chemically reacted with alcohol (methanol or ethanol) in the presence of catalyst such as sodium or potassium hydroxide. Glycerine is produced as a co-product. Ozsezen et al, (2011) studied the performance, combustion and injection characteristics of a direct injection diesel engine experimentally when it was fuelled with canola oil methyl ester (COME) and waste (frying) palm oil methyl ester (WPOME). The results indicated that when the test engine was fuelled with WPOME or COME instead of petroleum based diesel fuel (PBDF), the brake power reduced by 4–5%, while the brake specific fuel consumption increased by 9–10%. On the other hand, methyl esters caused reductions in carbon monoxide (CO) by 59–67%, in unburned hydrocarbon (HC) by 17–26%, in carbon dioxide (CO2) by 5–8%, and smoke opacity by 56–63%. However, both methyl esters produced more nitrogen oxides (NOx) emissions by 11–22% compared with those of the PBDF over the speed range. Siva Lakshmi et al, (2011) studied the performance and emission parameters of a diesel engine operating on neem oil and its blends of 5, 10, 15 and 20% volume with ethanol, 1-propanol, 1-butanol and 1-pentanol are evaluated and compared with diesel operation. The results indicate that the brake thermal efficiency is improved with the use of neem oil–alcohol blends with respect to those of neat neem oil. The smoke intensity, CO and HC emissions with neem oil–alcohol blends are observed to be lower with respect to those of neat neem oil at higher loads. The NOx emission is very slightly reduced with the use of neem oil–alcohol blends except for the neem oil–ethanol blend compared with that of neat neem oil. Soo-Young (2011) selected seven vegetable oils i.e., jatropha, karanja, mahua, linseed, rubber seed, cottonseed and neem oils in his review paper. He observed that all biodiesel fuels generally causes an increase in NOx emission and a decrease in HC, CO and PM emissions compared to diesel fuel. It was also reported that a diesel engine without any modification would run successfully on a blend of 20% vegetable oil and 80% diesel fuel without damage to engine parts. Kasiraman et al, (2012) concluded that the performance of neat Cashew nut shell oil (CSNO) can be improved significantly by blending camphor oil and 30% Camphor oil (CMPRO 30) blend can be used as a substitute for diesel. Solaimuthu et al, (2013) concluded from his study that the B0 (Diesel fuel) and B25 (25% Mahua oil with diesel fuel) give optimum performance, whereas B100 (Neat biodiesel fuel) and B75 give the lower emissions of HC and NOx. Finally, it is concluded that B25 could be used as a viable alternative fuel to operate four-stroke tangentially vertical single cylinder direct injection diesel engine with injection pressure of 250 bar and injection timing of 20° bTDC, thereby saving 25% of the precious fossil diesel fuel. Liaquat et al, (2013) investigated experimentally the engine performance and emissions of using diesel fuel as baseline and coconut biodiesel (CB) blends such as CB5 and CB15 respectively. The experimental results revealed that compared to diesel fuel, engine torque and brake power for biodiesel blends were decreased, mainly due to their respective lower heating values. The bsfc values for biodiesel blends were higher when compared to diesel fuel due to lower heating values and higher densities. In case of engine exhaust gas emissions, HC and CO emissions were reduced whereas, CO2 and NOx emissions were increased for CB5 and CB15 when compared to diesel fuel at both engine operating conditions. Tesfa et al, (2013) investigated the effects of biodiesel types, blend fraction values and physical properties on the CI engine's in-cylinder pressure, heat release rate and brake specific fuel consumption for steady state operation conditions. He concluded that the fuels used and engine configurations the biodiesel types do not result in any significant differences in the CI engine's in-cylinder pressure, heat release rate and brake specific fuel consumption. Vallinayagam et al, (2014) tested the use of a new biofuel, pine oil, in a diesel engine without resorting to any engine modifications. Experiments revealed that compared to fossil diesel, experimental investigation of 50D:50B (50% diesel and 50% pine oil) in a diesel engine showed significant decrease in CO (carbon monoxide), HC (hydrocarbon) and smoke emission by 45.9%, 32.4% and 41.5%, respectively, whereas the NOX (nitrogen oxides) emission was noted to be increased. To help reduce the negative impact of pine oil on NOX emission and ignition delay, this work intends to add two ignition promoters, IAN (iso-amyl nitrate) and DTBP (di-tertiary butyl peroxide), with 50D:50B. DTBP is more effective in reducing NOX emission, adding to the other benefits of reduced CO and HC emission by 40% and 34%, respectively, than 50D:50B. In addition, the performance of the engine was also noted to be improved for 50D:50B-DTBP, suggesting that DTBP is a pertinent ignition improver for pine oil–diesel blends. Pradeep Kumar et al, (2014) tested various Adelfa biodiesel blends, keeping brake thermal efficiency as a standard measure. He concluded that there is a reduction in brake thermal efficiency for a very small percentage of 3.33 %. A least increase of smoke opacity 3 HSU among all other biodiesel blends, but slightly higher than diesel fuel and an appreciable reduction of 23.5 % CO emission obtained, which is the highest among all other biodiesel blends.

II. MUSTARD BIODIESEL

Mustard seed plant is an annual herbaceous plant and can grow from two to eight feet tall with small yellow flowers. Wild mustard belongs to the Brassicaceae family and also known as field mustard. The Brassicaceae plant family is a very rich source of many important biodiesel feed stocks.



Mustard Plant and seed

Wild mustard (Brassica juncea L.) have high yield potential for producing biodiesel, especially when cultivated in humid, dry and hot weathers like India, Pakistan and Bangladesh. Mustard oil contains 60 % of monounsaturated fatty acids, 42% of euric acid, 12% of oleic acid, 21% of poly unsaturated fats and 12% of saturated fats. Intensive research is going on currently to improve its productivity.

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III. EXPERIMENTAL SETUP & PROCEDURE

In this experimental research work experiments were carried out in a single cylinder four stroke compression ignition engine having a compression ratio of 17.5. Table 1 & 2 shows the engine specifications and properties of fuel. The engine was running at a speed of 1500 rpm. Exhaust emissions were determined using AVL digas 444 analyzer and the smoke emission was analyzed by AVL smoke meter. Fuel was filled in the measuring burette attached to the fuel tank which provides the measurement of fuel consumption. Engine was allowed for sufficient time to attain steady state. Fig. 1 shows the experimental setup.

Table 1. Engine Specifications

Make and Model	Kirloskar ZS 1110
Bore and stroke	87 × 110 mm
Compression ratio	17.5:1
Cylinder capacity	1322cc
Rated speed	1500 rpm
Rated power	10 HP @ 1500 rpm
Injection Timing	22° BTDC

Table 2. Properties of Fuel

Properties	Diesel	12% Mustard Biodiesel
Oxygen Content (% by weight)	-	0.52
Cetane Index	51	53
Density (kg/m^3)	0.83	0.88
Viscosity (m^2/s)	2.87	4.0
Calorific Value (MJ/kg)	43	42

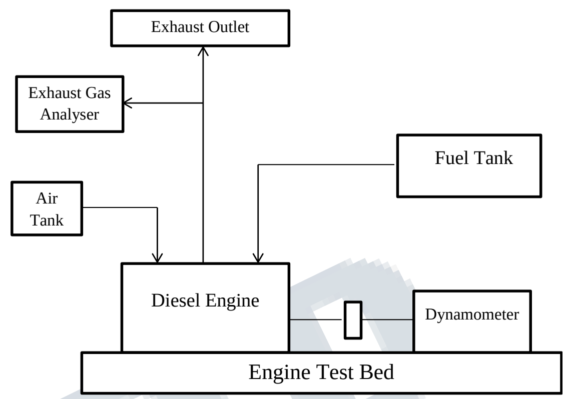

Fig. 1 Experimental Setup

IV. RESULTS AND DISCUSSIONS

(a) Performance Parameters:

Brake specific fuel consumption (BSFC) is the ratio between the mass of fuel consumption and brake effective power and is inversely proportional to thermal efficiency. The variation of BSFC of diesel and 12% mustard biodiesel blend (B12) for different load conditions are shown in figure 2. The results revealed that specific fuel consumption decreases with increase in percentage load. It was observed from the results that the addition of mustard biodiesel blend reduces the fuel consumption compared to diesel fuel at all loads. Mustard biodiesel reduces the specific fuel consumption by 2.3% at 75% load compared to diesel fuel. At lower blending level the biodiesel blend causes better mixture formation and thus reduces the fuel consumption rate.

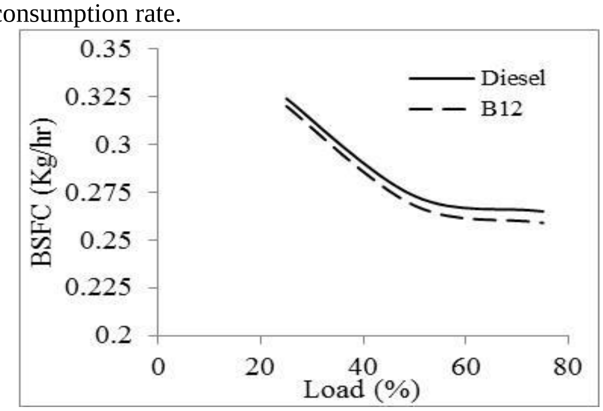

Fig. 2 Variation of BSFC with respect to Load

The variation of brake thermal efficiency (BTE) with respect to load for diesel and 12% blend of mustard biodiesel (B12) at different load conditions are shown in figure 3. It is observed that the addition of mustard biodiesel blend slightly increases the brake thermal efficiency compared to diesel fuel. This is because of oxygen present in the blended fuels improved the combustion compared to diesel fuel. Mustard biodiesel blend increases the thermal efficiency by 2% at 50% load condition compared to diesel fuel.

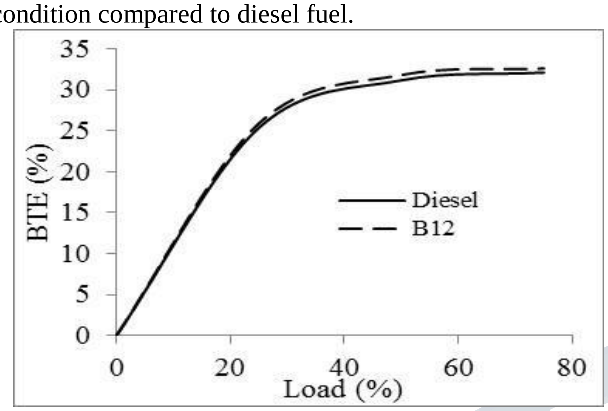

Fig. 3 Variation of BTE with respect to Load

(b) Various Constituents of Exhaust Emissions:

The variation of carbon monoxide emissions (CO) with respect to load for diesel and 12% mustard biodiesel blend is shown in figure 4. It is observed from the results that the emissions of carbon monoxide decreases at all load conditions for the blended fuel. This is due to the oxygen content of blended fuel which makes better combustion resulting in reduced CO emissions. 12% mustard biodiesel blend decreases the CO emission by 48% at 25% load respectively. Maximum CO emissions for diesel and B12 are 0.035% and 0.03%

Fig. 4 Variation of CO emissions with respect to Load

The variation of hydrocarbon emissions with respect to load for diesel fuel and 12% mustard biodiesel blend is shown in figure 5. Unburnt HC emissions consist of fuel that is incompletely burnt. It is observed from the results that the emissions of hydrocarbon are reduced with the addition of mustard biodiesel blended to diesel fuel. The high temperature of the burnt fuel will prevent the condensation of the HC reducing the emission of unburnt hydrocarbon. The emission of HC was lowered by 50% of mustard biodiesel blend at 25% load. The oxygen content present in the blend may be responsible for the reduction in HC emissions.

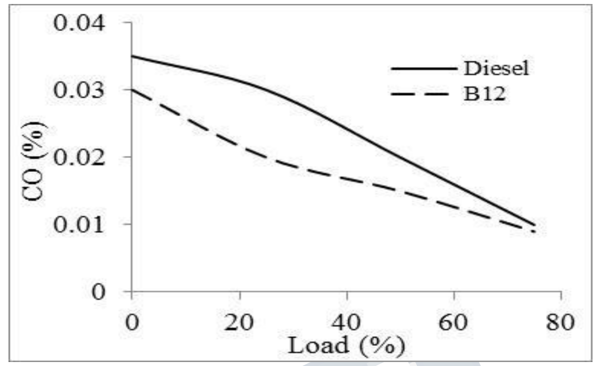

Fig. 5 Variation of HC emissions with respect to Load

The formation of oxides of nitrogen is highly dependent on in cylinder temperatures and the oxygen concentration. The variation of NOx emission with respect to load for diesel and mustard biodiesel blend is shown in figure 6. Addition of 12% mustard biodiesel blend emits lower NOx emissions compared to diesel fuel for all the loads. At 50% load mustard biodiesel blend reduces the NOx emission by 32% compared to diesel fuel. Maximum NOx at 75% load of diesel and B12 are 1330 ppm and 1195 ppm respectively.

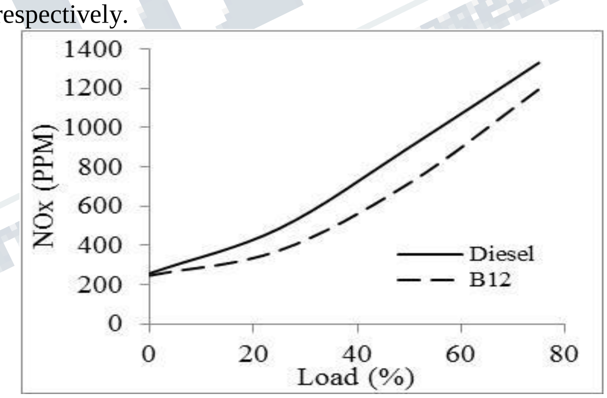

Fig. 6 Variation of NOx emissions with respect to Load

Smoke emission is a result of wastage of fuel by the engine. It is the net result of soot formation and the subsequent oxidation during the combustion process. The variation of smoke intensity with respect to load for diesel and mustard biodiesel blend is shown in figure 7. It is observed from the results that the smoke intensity increases with increase in load. Addition of blended fuel to diesel fuel decreases the smoke intensity compared to diesel fuel at all loads. 12% mustard biodiesel blend reduces the smoke intensity by 26% at 75% load compared to diesel fuel. The reduction found in B12 was due to heterogeneous nature of the blend combustion.

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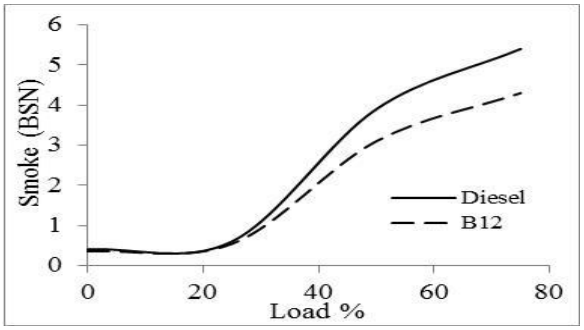

Fig. 7 Variation of Smoke intensity with Load

V. CONCLUSION

The following test results were obtained with the experimental investigation conducted in a diesel engine with mustard biodiesel blend:

1) Addition of 12% Mustard biodiesel blend reduces the specific fuel consumption by 2.3% at 75 percentage load compared to diesel fuel.
2) 12% biodiesel blend slightly increases the Brake thermal efficiency compared to diesel fuel.
3) Mustard biodiesel blend to diesel fuel reduces the emissions of Carbon monoxide and unburnt hydrocarbons compared to diesel fuel due to oxygen content in the blended fuel.

4) NOx emissions were reduced at all loads due to the addition of 12% mustard biodiesel blended with diesel fuel.
5) Smoke intensity of the 12% mustard biodiesel blended with diesel fuel is reduced compared to diesel fuel which is due to its oxygen content.

From the above experimental test results it is concluded that mustard biodiesel blended with diesel fuel could be used as a potential alternative fuel for operating the future CI engines for better engine performance and lower the engine out emissions without any modifications in the existing diesel engine at lower blending ratios.

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