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PERFORMANCE EVALUATION OF DIESEL ENGINE WITH BIODIESEL ALONG WITH ADDITIVE FOR REPLACING DIESEL FUEL

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ABSTRACT

Experimentation has been carried out with additive Diethyl Ether (DEE) and Mahua biodiesel in diesel engines to replace convectional fuels. This idea is being floated with the objective that low temperature combustion can be maintained and thereby reducing the NO_x emission. Biodiesel application reduces other emissions substantially, but for NO_x. This is because of the reason that Tran esterified vegetable oil contains oxygen in its molecular structure. DEE possesses different properties altogether with higher Cetane number, lesser auto ignition temperature etc., may show the way for smoother start of combustion at lower atmospheric temperatures also. In this study DEE mixed with the Mahua methyl ester (MME) at different proportion such as 3%, 5% 10% and tested at different loads on diesel engine. Emission levels are decreased substantially with 15% DEE blend with MME at full load. The thermal efficiency rise and SFC are better in the case of 15% additive blend.

Key words: Performance, Diethylether, Mahua methylester, Emission, Diesel engine.

INTRODUCTION

Biodiesel as an alternative fuel of diesel is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. It is renewable, biodegradable and oxygenated. Although many researches pointed out that it might help to reduce greenhouse gas emissions, promote sustainable rural development and improve income distribution there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. Rakopoulos[1] studied that bio-fuels made from agricultural products (oxygenated by nature) may not only offer benefits in terms of exhaust emissions but also reduce the dependency of oil. Among these, vegetable oils or their derived bio-diesels (methyl or ethyl esters) and bio-alcohols are considered as very promising fuels the development of alternative fuel sources. Yasin[2] investigated that the

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limitation in using biodiesel as fuel in diesel engine is viscosity. It plays an important impact under low temperature poor atomization, resistance to flow and it will affect the fuel injection quantity and quality. The alcohol additives will improve the viscosity by even small percentage of concentrations like 5% and 10%. Biodiesel fuels have higher lubricity than conventional fuels, but they can contribute to the formation of deposits, the degradation of materials or the plugging of filters, depending mainly on their degradability, their glycerol (and other impurities) content, their cold flow properties, and on other quality specifications[3,4]. Prasada Rao et al.[5] in his study used Diesel, Rice Bran Methyl ester (RBME) and RBME with methanol additive as fuels in DI Diesel engine. The performance and emissions are measured to evaluate the suitable methanol percentage. The Brake Specific Fuel Consumption is increased by 3.57% when using RBME due to higher viscosity. However, with the addition of methanol additive, BSFC is slightly reduced at full load conditions (i.e; 3.88 KW). The Brake Thermal Efficiency of RBME and its blends with methanol additive is higher than that of conventional diesel at all load conditions. Brake Thermal efficiency is increased by 5.83% for RBME + 1% Methanol and by 11.6% for RBME + 5% Methanol at full load conditions. The Exhaust gas temperature is decreased by 9.6% for RBME + 1% Methanol at full load conditions. Nagaraja[6] studied the effect of compression ratio on preheated palm oil biodiesel blends. Results showed that the brake power of palm oil biodiesel- diesel blend is higher than that of standard diesel at higher compression ratio and full load condition. There was an increase in mechanical efficiency and thermal efficiency and indicated mean effective pressure. Also, there was a reduction in CO and unburned hydrocarbon with increase in CO_2 emissions. Muralidharan and Vasudevan[7] investigated the effect of biodiesel from waste cooking oil-diesel blends in a variable compression ratio engine.

The EGT tends to reduce with increase in compression ratio. HC and NO_x emissions were increased while CO and CO_2 remains the same. Hansen[8] suggested that ethanol, among the alcohols, can be used in a diesel engine as ablend with diesel to reduce or replace the dominance of diesel. Many researchers studied about ethanol-diesel blends in a diesel engine. Ethanol addition to diesel has some limitations such as lower calorific value, cetane number, and flash point. Also, ethanol-diesel blends phase separation issue, above 15% of ethanol content. To reduce these limitations, researchers used ethanol addition to diesel-biodiesel blends. Various researchers studied about these blends. Rakopoulos[9] evaluated the effect of using blends of ethanol and diesel. It was observed bythe author that there was an increase of the BSFC, decrease in smoke density and NOx emissions similar to diesel. Labeckas[10] examined the influence of ethanol and biodiesel addition to diesel fuel and reported about the effects on start of injection, ignition delay, combustion and maximum heat release rate, engine performance efficiency and emissions and the results were increase in heat release rate, decrease in CO, NO_x and smoke compared to diesel. Prasada Rao et al.[11,12] in his study used Mahua methyl ester blended with methanol as fuel. Methanol was chosen because it provides oxygen at time of combustion as it has 50% of oxygen content and conducted several experiments on MME and methanol additive as an alternative fuel to replace diesel and observed that MME blending with methanol replaces diesel fuel. Also the emissions are affecting the health of people and plants significantly. In this study, an attempt is made to improve the performance and to reduce exhaust emissions by using Mahua Methyl Ester as base fuel and additive Diethyl Ether in DI diesel engine.

EXPERIMENTAL

Experimental set up and experimentation

The experimental setup consists of single cylinder DI-diesel engine loaded with eddy current dynamometer, exhaust gas analyzer and smoke analyzer. The experimentation is conducted on the single cylinder direct injection diesel engine operated at normal room temperatures of 28^{o}C to 33^{o}C in the author's laboratory. The fuels used are diesel fuel in neat condition and as well as methyl ester of Mahua oil (MME) with 3%, 5%, 10%, and 15% additive Diethyl ether (DEE) and at five discrete part load conditions, namely No Load, One Fourth Full Load, Half Full Load, Three Fourth Full Load and Full Loads. The data collection is done independently for the above said oils. The engine is initially made to run at 1500 rpm continuously for one hour in order to achieve the thermal equilibrium under operating conditions. Engine performance data is acquired to study the performance and engine pollution parameters. The smoke values in HSU, the exhaust gas temperatures and exhaust gas analysis of different components of exhaustare measured and compared. Fuel characterization and Engine specifications are mentioned in Table 1 and 2.

Table 1: Fuel characterization

S. No.	Property	Diesel	Mahua methyl ester	DEE
1	Density at 33^{o}C Kg/m^3	830	899	713
2	Gross Calorific Value, KJ/Kg	43000	36700	33900
3	Viscosity at 33^{o}C, cSt	2.75	4.25	0.23
4	Cetane Number	45	50	> 125

Table 2: Specifications of the test engine

Model	AV1, Kirloskar make
Rated horse power:	5 hp (3.73 kW)
Rated speed:	1500 rpm
No of strokes:	4
Mode of Injection and injection pressure	Direct Injection, 200 kg/cm^2
No of cylinders:	1
Stroke	110 mm
Bore	80 mm
Compression ratio	16.5

RESULTS AND DISCUSSION

Engine performance analysis

The brake specific fuel consumption increases from 0.3 kg/kW/hr to 0.375 kg/kW/hr when additive is being added with the defined blend percentages to the bio diesel. In the case of Neat biodiesel application, the SFC stays at approximately 0.35 and with the additive percentages, it increases slightly, synchronously increasing the equivalence ratio. Fig. 1 also depicts same thing which is drawn between BSFC and Brake power. There is a steep rise of thermal efficiency for the additive percentages '3' and '15' at part loads of the engine which can be observed from Fig. 2. For the additive blend 15%, the thermal efficiency stays at approximately 27% at full load. Even though the thermal efficiency suffers a little at full load, it is giving better at part load performance of the engine. This steep rise may be due to better Cetane number and lower boiling point temperature of the additive. Better dilution with higher percentages of additive yielded better results but as the dope percentage is increasing, the emission of unburned hydrocarbons (HC) keep on increasing and this additive increase tells on the overall heat value of the blend. Figure 3 envisages higher exhaust gas temperature difference values in comparison to the absolute diesel. With 15% additive than at 3% indicating better diffused combustion. Fig. 4 gives the smoke emission plot in HSU at various loads and at various additive percentages with plus or minus quantities with respect to diesel fuel absolute properties. 15% of the DEE additive gives better smoke reduction indicating better combustion. There is a substantial 12% decrease in HSU in the case of 15% DEE blend and with a consistent relative lower levels of smoke at all other part loads.

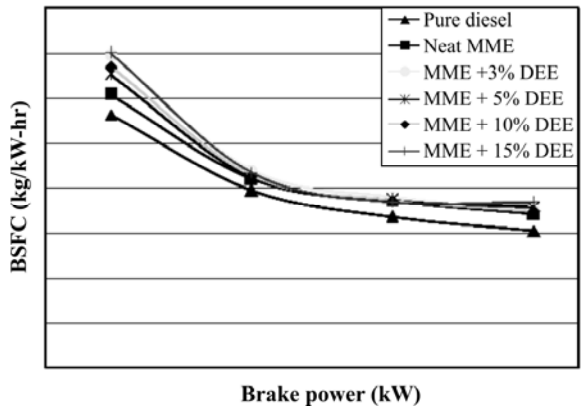

Fig. 1: Brake specific fuel consumption vs brake power with different percentages of additive

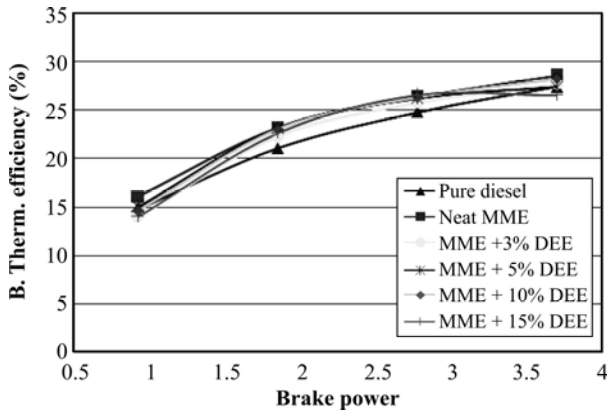

Fig. 2: Brake thermal efficiency vs brake power with different percentages of additive

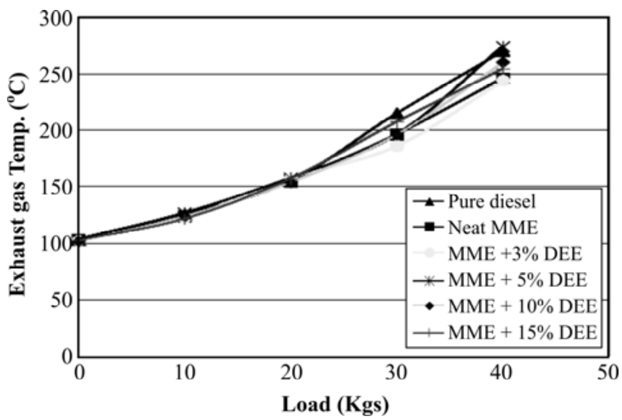

Fig. 3: Exhaust gas temperature vs load with different percentages of additive

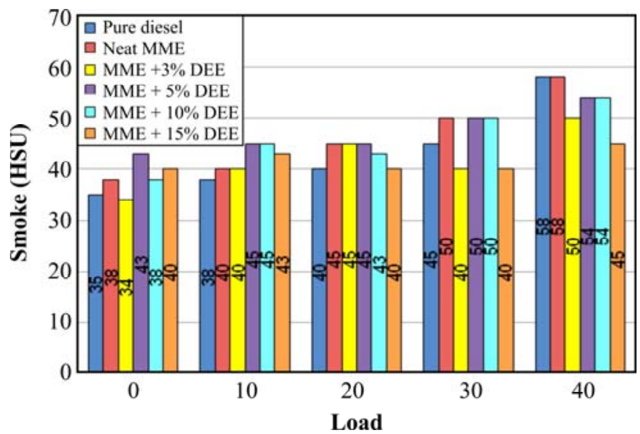

Fig. 4: Smoke vs load with different percentages of additive

Engine emissions

The Figs. from 5 to **7** represent pillar graphs from no load to full load running condition of the engine with different fuel blends. These plots indicate comparison of various tail pipe emissions viz. Carbon monoxide (CO), Nitric Oxide (NO_x), Hydrocarbons (HC), and CO_2, respectively. As explained earlier, our concentration lies with 3% and 15% of DEE blend with biodiesel fuel and its emission spectrums to evaluate the successful blend out of the two. There is 0.08% of CO emission difference at full load; the minimum happens to 15% DEE and Biodiesel blend and maximum for neat diesel. At part loads also the emission difference is also reasonable as can be observed from the Fig. 5. 3% DEE blend in question is not standing superior to 15% blend as the emission quantities are lower. Even though, there is more oxygenated additive at 15%, contribution to NO formation is less and there is contribution to the formation of CO_2 as can be observed from the Fig. 6. The unburned hydrocarbon (in ppm) emission is more in the case of additive blends and it is maximum with 15% blend. There is nearly 50 ppm of HC emission difference in between the fuels diesel and 15% DEE blend (Fig. 7).

DEE is highly volatile liquid and hence its evaporation suffers and that is the reason there is higher HC emission. With 5% additive blend the HC emission is the lowest of all at all loads but there is slight increase in CO correspondingly. Smoke emission (Fig. 4) showed minimum at all loads with 15% blend which made to rethink the suitability of 15% blend for practical use where the load variance of the engine lies at part loads to keep up the thermal efficiency. It can be observed that there is nearly 50% reduction in CO emission with the application of blends and this makes beautiful advantage of the blends with DEE. There is a reason to accept that the NO emission reduction is insignificant with the blends because of higher molecular oxygen both in biodiesel and DEE.

There is rise in NO emission at full load with additive and at part loads the emissions are lower by margins of 62, 85, and 85 ppm at 1/4th, 1/2, and 3/4th full loads, respectively. Lower loads mean lower combustion temperatures and hence lesser formation of NO. Only one danger that can be anticipated is raise in the HC emission with respect to its percentage in the blend. 15% is the maximum limit of the blend proportion that has been preset here keeping in view the maximum emission of harmful HC. CO_2 emission (Fig. 8) is lesser than when the engine is running with petro diesel but the variance with the percentage of additive is insignificant with higher quantities of HC in the exhaust and because of lower boiling point of DEE. The absolute value of emission is obtained by adding or removing from the absolute diesel value.

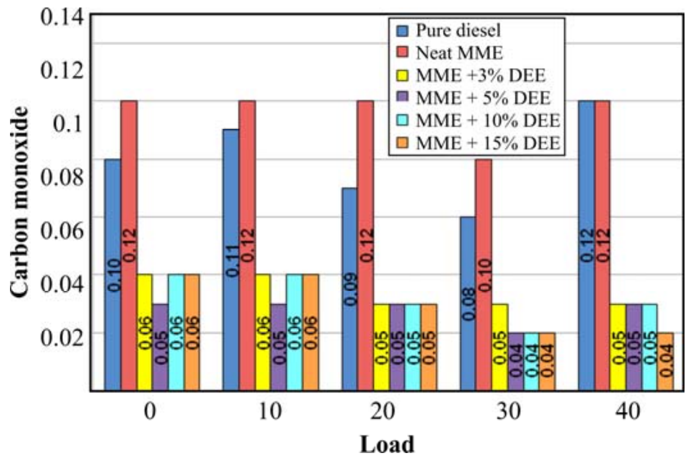

Fig. 5: Carbon monoxide vs load with different percentages of additive

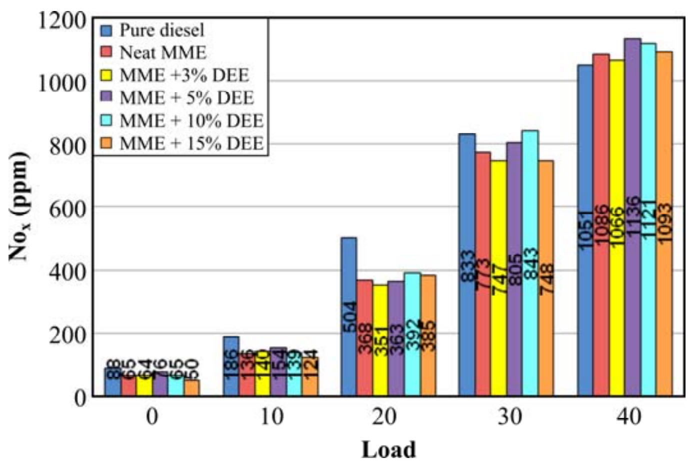

Fig. 6: Nitric oxide vs load graph with different percentages of additive

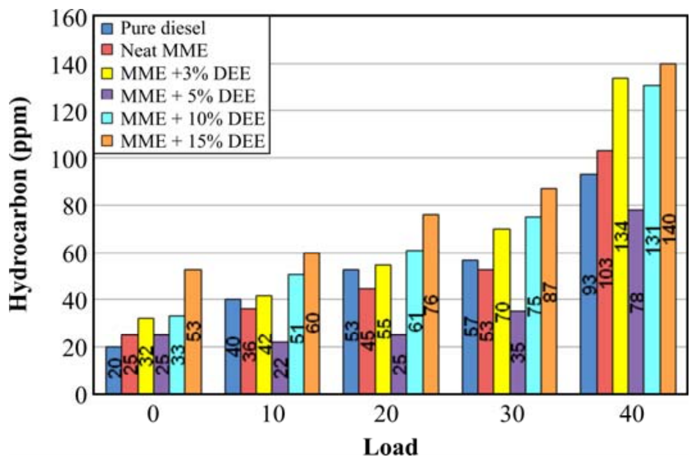

Fig. 7: Hydrocarbons vs load graph with different percentages of additive

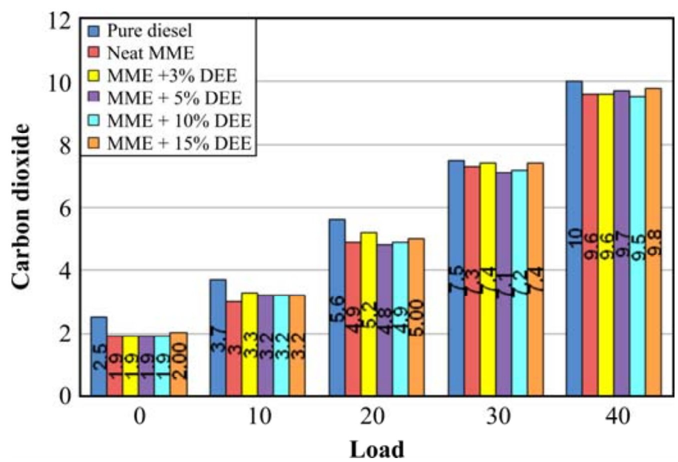

Fig. 8: Carbon dioxide vs load graph with different percentages of additive

CONCLUSION

(i) 15% DEE blend with biodiesel is adjudged as the best combination, which yielded better results than other fuel blends, especially 3% blend which is the nearest competitor.

(ii) The thermal efficiency rise and SFC are better in the case of 15% additive blend and since diesel engines give better efficiency at part loads this percentage of blend can be recommended.

(iii) The smoke levels have decreased substantially with 15% DEE blend with biodiesel at full load and at immediate part load except very low loads at which the diesel engine may not be put to operation normally because of high bsfc. CO and smoke levels have decreased in tandem indicating better combustion.

(iv) There is NO_x reduction at part loads in the case of additives. But at full load the NO emission has increased due to excessive molecular oxygen in both additive and biodiesel.

(v) There is approximately 67% reduction in the CO emission with 15% DEE - biodiesel blend at full load running of the engine.

Finally 15% DEE blend is proved to be more compatible blend when compared to other blends tested in view of the all-round performance exhibited by the additive.

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