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EFFECT OF METHYL ESTERS OF NEEM AND DIESEL OIL BLENDS ON THE COMBUSTION AND EMISSION CHARACTERISTICS OF A C.I. ENGINE

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ABSTRACT

The depletion of oil resources as well as the stringent environmental regulations has led to the development of alternate energy sources. In this work the combustion, performance and emission characteristics of a single cylinder diesel engine when fuelled with blends of neem and diesel oil are evaluated. Experiments were conducted with different blends of neem oil and diesel at various loads. The results show that the variations in the peak pressures of all the blends at full load are marginal. There is an increase in the ignition delay with biodiesel because of its high viscosity and density. It is found that the brake thermal efficiency of diesel is higher at all loads followed by blends of neem oil and diesel. The maximum brake thermal efficiency and minimum specific fuel consumption were found for blends upto B20. The specific fuel consumption, exhaust gas temperature, smoke opacity and NOx were comparatively higher. However, there is an appreciable decrease in HC and CO_2 emissions while the decrease in CO emission is marginal. It was observed that the combustion characteristics of the blends of esterified neem oil with diesel followed closely with that of the base line diesel.

Keywords: alternate fuel, biofuels, blends, combustion characteristics, emission, engine performance.

INTRODUCTION

Conventional energy sources, such as coal, oil and natural gas, have limited reserves that are expected not to last for an extended period. World primary energy demand is projected to increase by 1.5% per year between 2007 and 2030, from just over 12,000 million tones of oil equivalent to 16,800 million tones - an overall increase of 40%. As world reserves of fossil fuels and raw materials are limited, it has stimulated active research interest in nonpetroleum, renewable, and nonpolluting fuels. With this scenario the need for an alternate fuel arises to maintain the economy of the country. Biodiesel have received significant attention both as a possible renewable alternative fuel and as an additive to the existing petroleum-based fuels. The projected petroleum production in India as given in the eleventh five year plan is shown in Table-1. In India edible oils are much more valuable as a cooking fuel and as such, our concentration is going to be on development of biodiesel from non-edible oils only.

The objective of the present study is to determine the properties of transesterified Neem oil and diesel blends and to study the performance and emission characteristics of these blends when applied in different proportions in a stationary diesel engine. Anand *et al.*, [1] reported an increase in particulate matter emissions for blends of neem methyl esters with diesel. Avinash Kumar Agarwal [2] reported that blending the vegetable oil with diesel and alcohol oxygenates have improved thermal efficiency than neat vegetable oil. Performance and emission characteristics have been investigated by Banapurmath *et al*., [3] on a diesel engine operating with different biofuels. Breda keg [4] investigated the influence of biodiesel on the injection, spray, and engine characteristics to reduce harmful emissions in a bus diesel engine. Carraretto A. *et al*. [5] have reported a significant increase of specific fuel consumption over the entire speed range with biodiesel. Md. Nurun Nabi *et al*., [6] investigated the combustion and exhaust gas emission characteristics when the engine was fuelled with blends of methyl esters of neem oil and diesel. Mustafa Canakcia, Ahmet Erdil B, and Erol Arcakliog [7] used Artificial Neural Network for analyzing and predicting the performance and exhaust emissions from diesel engines. From the engine test results, K. Pramanik [8] reported that up to 50% Neem oil could be substituted for diesel for use in a diesel engine without any major operational difficulties. Ejaz M. Shahid and Younis Jamal [9] in their study reported that chocking of injector nozzles occur after a long run when the engine was fuelled with biodiesel. Though many researchers [10-12] have taken efforts to address the issues of biodiesel, the technology is yet to be fully exploited. This study is to determine the extent to which blending can be done with diesel without scarifying much in the performance and emission characteristics of a diesel engine when fuelled with blends of esterified neem oil and diesel without any engine modifications.

Table-1. Projected production of crude oil of India MMT (2007-2012).

Company	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	Total
ONGC	27.16	28.00	29.00	28.53	27.37	140.06
Oil	3.50	3.55	3.73	3.91	4.30	18.99
Joint vent.	10.57	10.78	9.76	8.75	7.85	47.71
Total	41.23	42.33	42.49	41.19	39.52	206.76

Source: Draft eleventh five year plan document

EXPERIMENTAL METHOD

Transesterified Neem oil was blended with diesel oil in varying proportions to reduce its viscosity close to that of the diesel fuel. It is evident [8] that blending of transesterified vegetable oil with the conventional diesel fuel would bring the viscosity close to diesel. The required physical and chemical properties of the biodiesel thus prepared were found using standard methods. The blends prepared were stable under normal conditions. A blend containing 20% neem oil and 80% diesel by volume is represented by B20. The important properties of the blends are shown in Table-2. When compared with the properties of the mineral diesel oil the results show that the calorific value of all the blends was lower than diesel oil and the kinematic viscosity, specific gravity and the flash point were higher.

Table-2. Properties of neem and diesel oil blends.

S. No.	Blend	Kinematic viscosity at 40°C (mm^2/s)	Flash point (°C)	Specific gravity	Calorific value (kJ/kg)
1.	B10	4.4	95	0.877	43800
2.	B20	4.5	102	0.878	43000
3.	B30	4.6	112	0.880	42100
4.	B40	4.7	120	0.882	41200
5.	B50	4.8	130	0.884	40500
6.	Diesel	4.0	70	0.853	44755

A stationary single cylinder, air-cooled, four-stroke, direct injection diesel engine is used for the present study. The schematic arrangement of the experimental setup is shown in Figure-1. Cooling of the engine is accomplished by the fan attached to the engine itself (Air cooled engine). The engine is loaded by an eddy current dynamometer. The cylinder pressure is measured by a Kistler pressure sensor and the crank angle by a crank angle encoder. A load cell is attached with the dynamometer for the measurement of the torque. The load on the engine is varied with the help of the controller provided with the dynamometer.

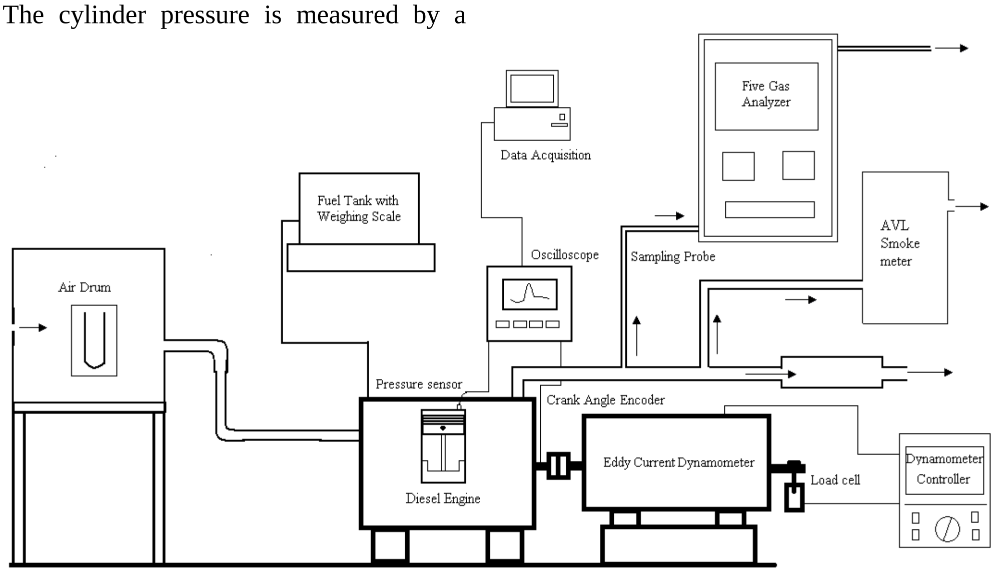

Figure-1. Schematic of the experimental setup.

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Technical details of the engine are given in Table-3. A data acquisition system is used to capture and record the cylinder pressure with time. Fuel flow rates are measured using an electronic weighing scale. Exhaust gas temperature is measured using the thermocouples. An AVL smoke meter and a five gas analyzer are used for the measurement of smoke opacity and NO_X, CO_2, CO and UBHC, respectively.

Table-3. Engine specifications.

Make	**Kirloskar**
Type	Air cooled diesel engine
Number of cylinder	1
Stroke x bore	87.5 mm x 110 mm
Compression ratio	17.5 : 1
Rated speed	1500 rpm
Brake power	4.4 kW
Injection timing	23° bTDC
Injection pressure	200 bar

Experiments were conducted with esterified neem oil and diesel blends having 10%, 20%, 30%, 40% and 50% esterified neem oil on volume basis at different load levels. Tests of engine performance on pure diesel were also conducted as a basis for comparison. The percentage of blend and load, were varied and engine performance measurements such as brake specific fuel consumption, air flow rate, and exhaust gas temperature and emissions (HC, CO_2, CO, NO_X and smoke Opacity) were measured to evaluate and compute the behavior of the diesel engine. Every time the engine was run at the rated speed of 1500 rpm for few minutes to attain steady state before the measurements were taken. The experiments were repeated and the average values were taken for performance and emission measurements.

RESULTS AND DISCUSSIONS

Analysis of the combustion characteristics

The variation of cylinder pressure with respect to crank angle for diesel and different blends of neem and diesel oil at full load is presented in Figure-2. Peak pressures of 67.8 bar and 68.12 bar are found for pure diesel and B30 respectively. From the test results it is observed that the peak pressure variations are less. Since the properties such as calorific value, viscosity and density are brought closer to diesel after transesterification of the vegetable oil, no major variation in the pressures are found.

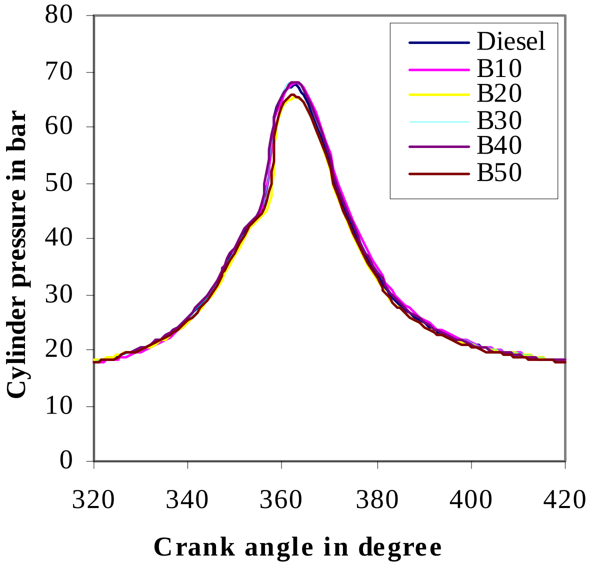

Figure-2. Variation of cylinder pressure with crank angle for different blends of MEON oil.

However there is an increase in the ignition delay for the blends. Though the start of injection is consistent for all blends and pure diesel the start of combustion is delayed when compared to pure diesel. The increase in the ignition delay of about 6 to 8 degree crank angle is due to poor atomization of the biodiesel because of its the higher viscosity and density. Among the blends tested B30 is found to have lesser ignition delay compared with other blends. This increases the premixed combustion phase duration and hence the residence time. Hence peak pressure is higher for B30. As the volume of neem oil in the blend increases beyond 30% the peak pressure decreases.

Effect of brake power on specific fuel consumption

The variation of the brake specific fuel consumption of diesel and various blends of Neem and diesel oil at different loads is shown on Figure-3. It is found that the specific fuel consumption for the blend B20 is close to diesel at full load. However at part load conditions the variations are appreciable for all the blends. Also if the concentration of neem oil in the blend is more than 20 % the variations in the specific fuel consumption are significant. This is because of the combined effects of lower heating value and the higher fuel flow rate due to high density of the blends.

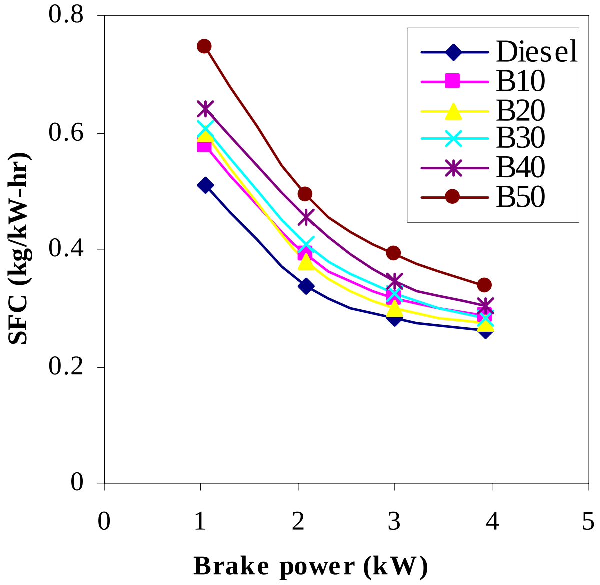

Figure-3. Variation of specific fuel consumption with brake power for different blends of MEON oil.

Higher proportions of neem oil in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

Effect of brake power on brake thermal efficiency

The variation of brake thermal efficiency of the engine with various blends is shown in Figure-4 and compared with the brake thermal efficiency obtained with diesel.

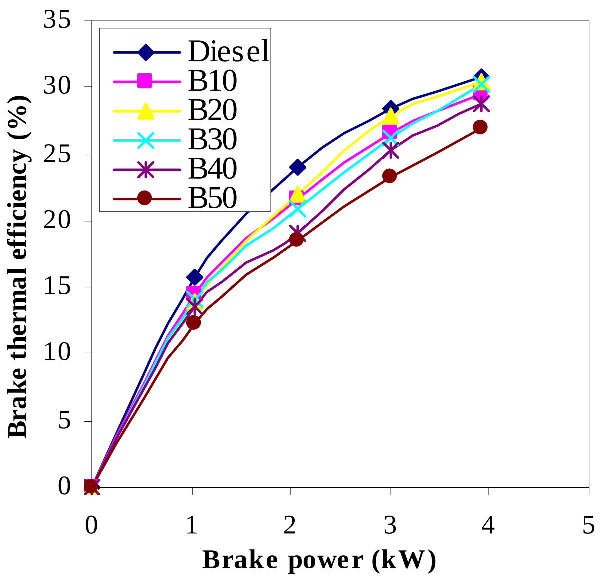

Figure-4. Variation of brake thermal efficiency with brake power for different blends of MEON oil.

It shows that brake thermal efficiencies of all the blends are lower at all load levels. Among the blends B20 is found to have the maximum thermal efficiency of 30.40% at a brake power of 3.9 kW while for diesel it is 30.9% and for B50 it decreased to 26.32%. The decrease in brake thermal efficiency with increase in neem oil concentration is due to the poor atomization of the blends due to their high viscosity.

Effect of smoke opacity on brake power

The variation of smoke opacity with brake power is shown in Figure-5. It is observed that the smoke opacity of the exhaust gas increases with increase in load for all the blends. It also shows that the smoke opacity increases with the concentration of neem oil in the blends. This is caused mainly due to the poor atomization and combustion because of the higher viscosity of the blends. The opacity for diesel showed a similar trend as that of the blends, however the emission levels are comparatively lower at all loads.

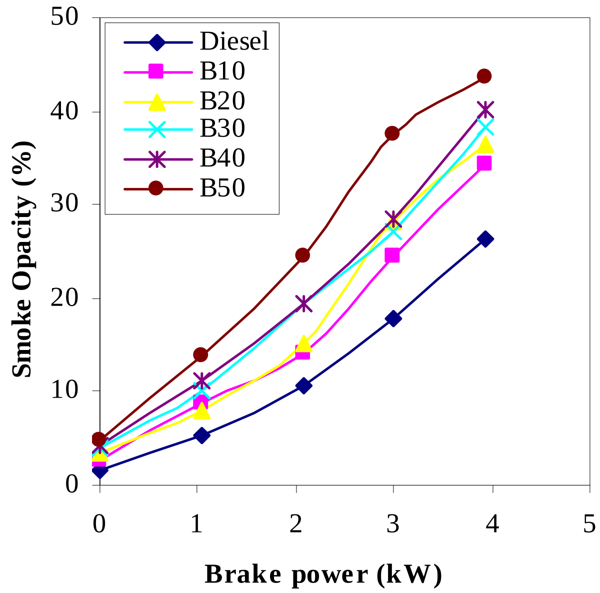

Figure-5. Variation of smoke opacity with brake power for different blends of MEON oil.

CO_2 emission

The emission levels of CO_2 for various blends and diesel is shown in Figure-6. Test measurements reveals that the CO_2 emission for all blends are less as compared to diesel at all loads. The rising trend of CO_2 emission with load is due to the higher fuel entry as the load increases. Biofuels contain lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

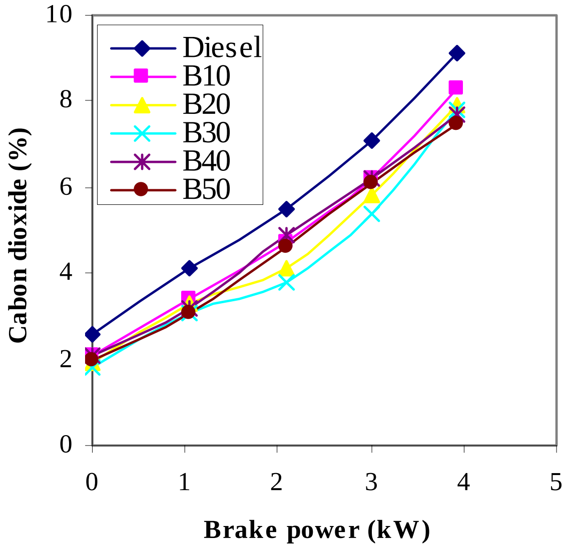

Figure-6. Variation of carbon dioxide with brake power for different blends of MEON oil.

NO_X emission

The variation of NO_X emission for different blends is indicated in Figure-7. The NO_X emission for diesel and all the blends followed an increasing trend with respect to load. For the blends an increase in the emission is found at all loads when compared to diesel. The delay in the ignition timing increases the residence time of the mixture. $NO_{X.}$ is formed generally at high temperatures.

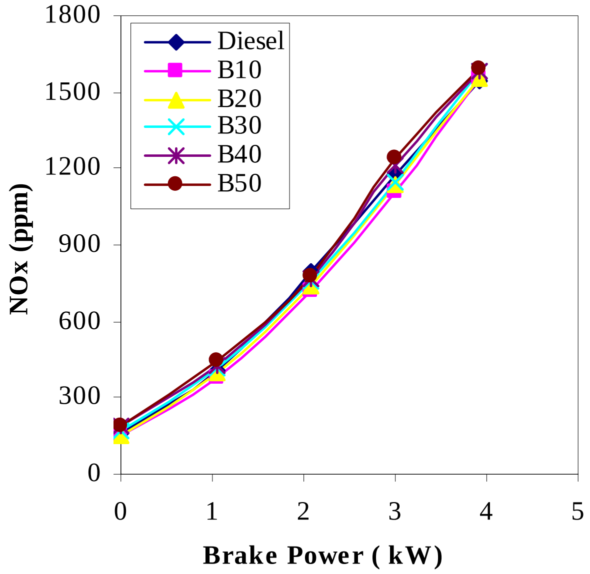

Figure-7. Variation of oxides of nitrogen with brake power for different blends of MEON oil.

Since the exhaust gas temperatures are higher the NO_X emissions are also higher. By and large ignition delay for the blends tested is higher than diesel. This resulted in higher NOx formation.

CO and HC emission

It is observed that the engine emits more CO for diesel at part load conditions when compared to the blends. However the percentage variation of carbon monoxide for all the blends when compared with base line diesel is lesser. The HC emission for the blends followed a similar trend as that of diesel but comparatively the emissions are lower. The presence of oxygen in the neem oil aids combustion and hence the hydrocarbon emission reduced. By and large the CO and HC emissions are less

CONCLUSIONS

Following are the major conclusions that are drawn from the combustion characteristics, engine performance and emission results of the diesel engine when fuelled with blends of transesterified neem oil and diesel.

- The variation in the peak pressures is not significant but an increase in the ignition delay of about 6 to 8 degree in crank angle was observed for the blends when compared to diesel.
- The specific fuel consumption is slightly higher for B20 but closer to diesel among all the blends.
- When the concentration of neem oil in the blend is more than 30% by volume, there is an appreciable increase in the specific fuel consumption.
- The smoke opacity is found to be higher than diesel for all blends.
- Blends up to 20% substantially reduce CO_2 emissions with a marginal decrease in brake thermal efficiency.
- The brake thermal efficiency decreases as the concentration of neem oil in the blend increases
- A maximum brake thermal efficiency of 30.4% was achieved for B20 while for diesel it was 30.9% at full load.

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