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Formulation and Utilization of Higher Blends of Castor Biodiesel-Diesel in C.I. Engine

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ABSTRACT

This paper deals with the formulation of castor biodiesel (CB) at optimum condition by single step base catalysed transesterification reaction. The produced ester were utilised in a compression ignition (C.I.) engine. The optimum conditions of oil to methanol molar ratio were kept at 1:9. Amount of alkali catalyst is 0.9% weight of oil at 65^{0}C temperature with constant speed of 500 rpm for 2.5 hours. The physico-chemical properties of the produced methyl ester (biodiesel) were evaluated as per ASTM norms. Exhaustive emission and performance test were carried out with a vertical, single cylinder four stroke diesel engine with rated power of 4.4 kW at a constant speed of 1500 rpm. The test was conducted with CB30, CB40 and CB50 by volume of biodiesel added to petrodiesel under various operating conditions. The results of the test clearly indicates that all existing diesel engines can be adopted to use blends of diesel and biodiesel in various proportions to produce comparable performance and emission characteristics with neat diesel-operated engine.

Keywords- *Castor oil, transesterification, methyl ester, diesel engine, emission.*

I. INTRODUCTION

The world energy demand is growing at a faster rate due to growing modernization and industrialization. Most less developed nations import crude oil to deal with increasing energy demand. Thus, a major portion of their hard earned earnings is spent on pur chase of petroleum products. Besides the energy crisis, the other major problem associated with fossil fuel combustion is the degradation of global climate and environment. Thus it is essential that eco-friendly low emission alternate renewable fuels must be developed and promoted for use in diesel engines. [1-3].

Vegetable oils including edible and non-edible are one of the important sources from which alternate renewable fuel can be generated for use in the diesel engines. Use of vegetable oil in CI engines is not a new concept; as the inventor of diesel engine ‘‘Rudolf Diesel’’ experimentally demonstrated his first diesel engine at the World Exhibition at Paris in 1900 by using peanut oil as fuel. Considerable research is already being done globally to develop sustainable suitable alternative of the conventional liquid fuels. Among the other possible options of the conventional liquid fuels, non–edible vegetable oils have been considered as an appropriate alternate due to its prevalent fuel properties. In India, non-edible based biodiesel is gaining more importance due to the non-availability of edible oil for the production of bio-based fuels [3-5].

Apart from being a substitute fuel, mono-alkyl esters of various vegetable oils markedly enhance the lubricity of ultra-low-sulfur diesel. Previous studies shows that ethyl and methyl esters of castor oil have more lubricating behavior even at low volume (0.5−1.0%) over other esters, such as soy, sterling, dwarf essex, coconut, etc.[6-8].

II. EXPERIMENTAL

Materials and methods

Castor oil used for the study was procured from Delhi and reagents were used of analytical grade for the preparation of castor oil methyl ester in biodiesel reactor with one litre batch capacity.

Preparation of castor biodiesel

Castor oil methyl ester was prepared in laboratory scale using one litre capacity per batch reactor by single step base catalyze transesterification reaction at optimum experimental conditions.

Fuel properties of castor biodiesel –diesel blends

The fuel properties of castor oil methyl ester – diesel blends of CB30, CB40 and CB50 were tested as per the ASTM standard methods and the results obtained are in accordance with ASTM.

Engine study

The performance and emissions characteristics of the prepared blends were tested in Vertical, Single Cylinder 4-Stroke diesel engine with rated power of 4.4 kW with constant speed of1500 rpm.

III. RESULTS & DISCUSSION

Preparation of castor biodiesel

Transesterification is an equilibrium reaction in which excess of alcohol is required to drive the reaction close to completion. The optimum ratio was found to be 1:9 molar ratio of methanol to oil (triglyceride) which is sufficient to give approximately 92% yield of methyl ester. It might be anticipated that, in such an equilibrium system, the observed phase separation of the by-product, glycerol, would play a major role in achieving a conversion of methyl ester. The reaction conditions for the preparation of methyl ester of castor oil is summarized in Table1.

Table 1: Optimum reaction conditions for castor oil methyl ester

Parameter	Methanol oil molar ratio	Catalyst concentration (%)	Rate of mixing (RPM)	Reaction temperature (^{0}C)	Reaction duration (hours)
conditions	9:1	0.9	500	65	2.5

Fuel properties of castor biodiesel –diesel blends

The fuel properties or the test blends CB30, CB40 and CB50 were evaluated; and are shown in Table 2. It was observed that the fuel properties of test blends were found to be close to the permissible limit.

Table 2. Fuel properties of castor biodiesel blends at optimum conditions

Properties	Limits	Diesel	CB30	CB40	CB50	Test Method
Flash Point, ºC	130.0	77	115	123	129	ASTM D 93
Kin. Viscosity @ 40º C, cSt	1.9 – 6.0	2.85	3.87	4.11	4.53	ASTM D 445
Density @15ºC, g/cm3	0.86-0.90	0.83	0.86	0.87	0.89	EN 14214
Cloud point ºC	-	-4	-7.4	-8.1	-8.8	ASTM D2500
Pour point ºC	-	-9	-11.8	-12.5	-13.4	ASTM D97
Calorific value (MJ/Kg)	42.5-45.0	45.0	43.490	42.86	42.33	ASTM D420

Engine performance and Emissions study

The performance and exhaust emissions characteristics with diesel engine were carried out under various operating conditions to ascertain the suitability of these fuels for engine application. The suitability of higher test blends CB30, CB40 and CB50 were tested from zero to full load conditions. The performance parameters such as brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were evaluated. From Fig. 1-2, it was observed that initially with increasing load the brake thermal efficiencies of base diesel and methyl ester blends increases. However, there was a decrease in efficiencies with methyl ester test blends at higher load. The brake thermal efficiency was observed marginally higher for CB30 at lower load and could be due to higher calorific value compared to CB40 and CB50.

It was observed that at lower loads the BSFC was higher for CB30, CB40 and CB50 blends than the base diesel. In overall picture, brake specific fuel consumption was found to decrease with increase in load. The brake specific fuel consumption of the CB50 was higher than that of diesel; it is because of the lower calorific value [9].

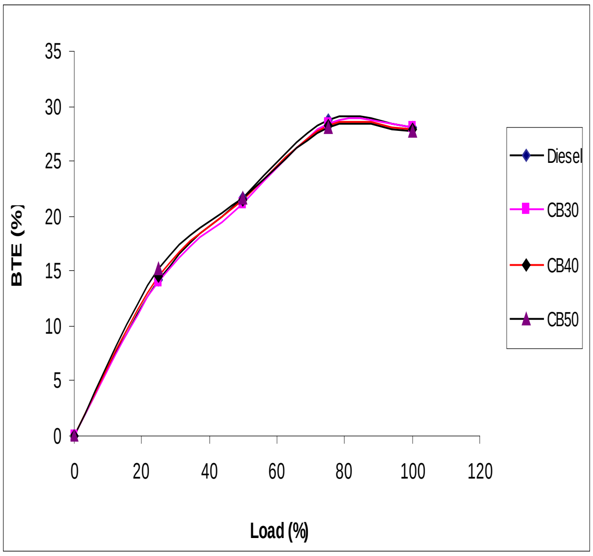

Figure 1. Brake thermal efficiency (BTE) vs Load %

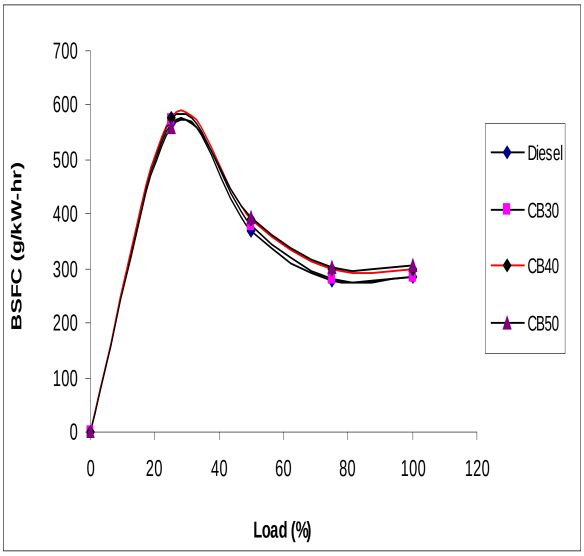

Figure 2. Brake specific fuel consumption vs Load %

The engine exhaust emissions such as carbon monoxide, oxides of nitrogen, unburned hydrocarbon and smoke were measured with a five gas analyzer (AVL DiGas – 4000 model) and a smoke-meter (AVL 437 model). The sensor of the analyzer was exposed to the exhaust gas and the observations were recorded. The measured emissions were analyzed and interpreted graphically as shown in Fig.3-6.

At lower loads, CB30 gives relatively higher hydrocarbon emissions as compared to other test blends however it was less than base diesel. In Fig. 3, at lower loads due to incomplete combustions, the emissions of hydrocarbon increases for CB30. As the load increases hydrocarbon emissions gradually decreases for all castor biodiesel blends.

Oxides of nitrogen increase with increase in load. This was probably due to the formation of higher combustion chamber temperature and presence of oxygen in biodiesel blends. From the Fig. 4 it can be observed that with increase of castor biodiesel blends the emissions of Oxides of nitrogen emissions increases [10].

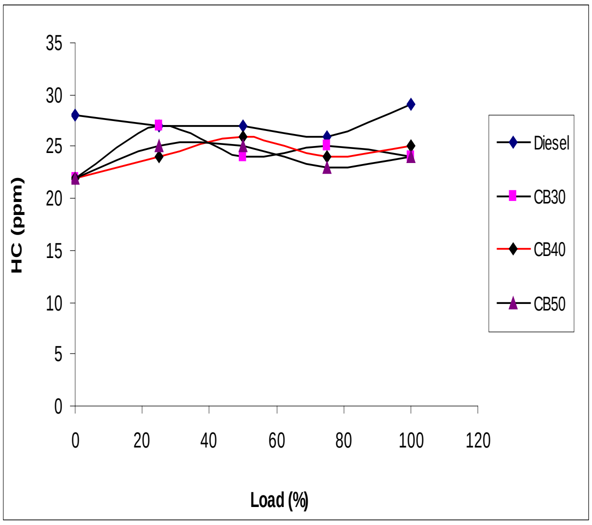

Figure 3. Hydrocarbon vs Load %

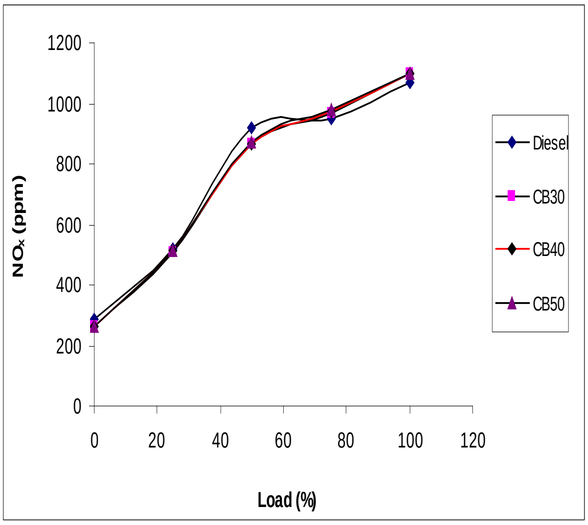

Figure 4. Oxides of Nitrogen (NO_x) vs Load %

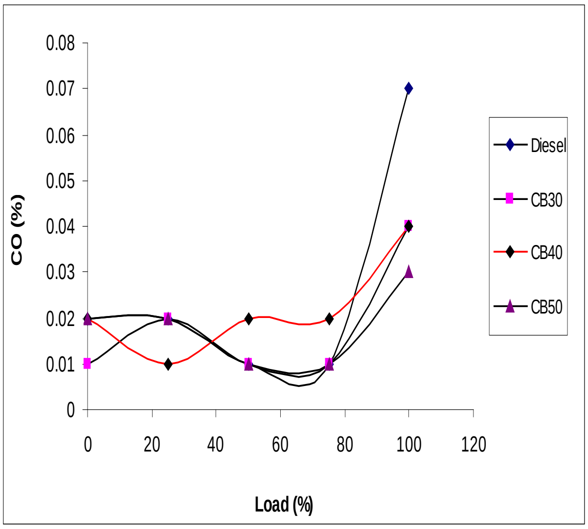

Figure 5. Carbon monoxide (CO) vs Load %

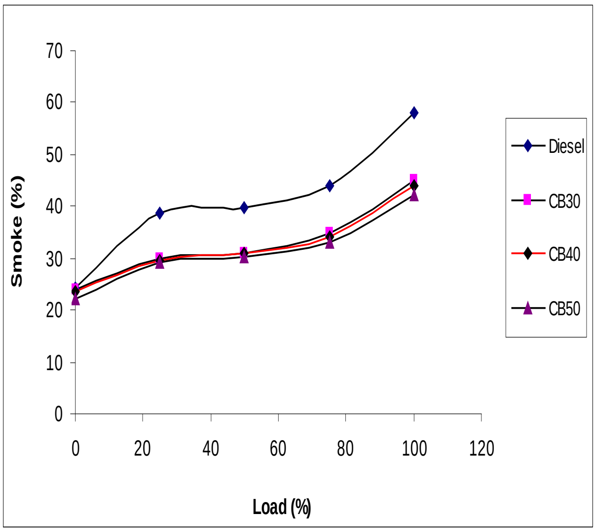

Figure 6. Smoke vs Load %

At lower loads the carbon monoxide emissions were nearly the same for all test blends except CB40 as shown in Fig. 5. However at higher load, the CO emissions for diesel were highest (0.07%) and lowest in case of CB 50 (0.02%).

From Fig. 6 as the loads increase the smoke opacity increases gradually. The smoke opacity for CB blends was found to be lower than base diesel. This may be due to the fact that biodiesel blends have higher oxygen content which improves the combustion. Due to negligible sulphur content soluble organic fraction (SOF) reduces significantly; hence low smoke opacity [11 and 12].

IV. Conclusion

Production of castor oil methyl ester is a d ifficult process with respect to separation and purification. The maximum conversion of oil to methyl ester was found to be 92% at methanol/oil molar ration 9:1, catalyst concentration 0.9 %, rate of mixing 500rpm and reaction temperature of 65 ^{0}C for 2.5 hours of reaction duration.

The different fuel properties of castor biodiesel blends were found to be close to conventional diesel fuel. After engine studies, it was found that marginal decline in brake thermal efficiency can be attributed to lower calorific value of the blends than of the base diesel. The lower hydrocarbon emissions for biodiesel blends could be due to their relatively better combustion compared to base diesel. As the load increases, NO_x emissions shows marginally rising trends which was due to the higher cylinder temperature pressures; and can be reduced by controlled injection timing and using exhaust gas recirculation (EGR), catalytic converter and water cooling etc, therefore most of the pollutant (HC, CO and smoke) shows a decreasing trend. Thus the castor based methyl ester can be used as a supplementary fuel for diesel engine.

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