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Performance and Emission Characteristics of Cardanol Hybrid Biofuel Blend with Diesel

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Abstract— *As a renewable, sustainable and alternative fuel for common rail direct injection engines, biodiesel instead of diesel has been increasingly fuelled to study its effects on engine performance and emission in the recent years. In this present study karanja oil biodiesel, cotton seed oil biodiesel and cardanol oil are blended with diesel which are used as biofuels. The blends with diesel were in the ratio of 25% and 40%.Experimental study was made for performance and emission characteristics on single cylinder,4 stroke CRDI engine. The engine test as carried at constant speed of 1500rpm, at a compression ratio of 17:5:1 at an injection pressure of 350bar for different loads. It was found that performance and emission characteristics of the engine with respect to load factor for 25% blend and 40% blend. They show that BP closer to diesel, higher BTHE, lower BSFC, lower CO and HC emission at peak load. Hence above cited Biofuel are acceptable to use them as alternative fuel in CRDI engine but for 40% blend certain modification factors has to be considered for the engine.*

Keywords— *Biodiesel, cardanol, performance, emission.*

I. INTRODUCTION

Biodiesel is alkyl esters of fatty acids and can be obtained by employing the transesterification treatment of vegetable oils, animal fats, waste cooking oil and waste restaurant greases [1]. Vegetable oil can be obtained from both edible (palm oil, rapeseed oil, sunflower oil, coconut oil, peanut oil etc) and non-edible (jatropha, pinnata, cotton, jojoba, rubber, Mahua and castor etc) oil sources[2].

The major components of vegetable oils and animal fats are triacylglycerols (often also called triglycerides). Chemically, triglycerides are esters of fatty acids with glycerol (1, 2, 3-propanetriol; glycerol is often also called glycerin).The triglycerides of vegetable oils and animal fats typically contain several different fatty acids. Thus, different fatty acids can be attached to one glycerol backbone. The different fatty acids that are contained in the triacylglycerols comprise the fatty acids profile (or fatty acids composition) of the vegetable oil or animal fat. Because different fatty acids have different physical and chemical properties, the fatty acids profile is probably the most important parameter influencing the corresponding properties of a vegetable oil or animal fat. To obtain biodiesel, the vegetable oil or animal fat is subjected to a chemical reaction termed TRANSESTERIFICATION. In that reaction, the vegetable oil or animal fat is reacted in the presence of a catalyst (usually a base) with an alcohol (usually methanol) to give the corresponding alkyl esters (or for methanol, the methyl esters) of the FATTY ACIDS mixture that is found in the parent vegetable oil or animal fat. Biodiesel is miscible with petrodiesel in all ratios. In many countries, this has led to the use of blends of biodiesel with petroleum diesel instead of neat biodiesel. It is important to note that these blends with petroleum diesel are not biodiesel. Often blends with petrodiesel are denoted by acronyms such as B20, which indicates a blend of 20% biodiesel with petrodiesel. Methanol is used as the alcohol for producing biodiesel because it is the least expensive alcohol, although other alcohols such as ethanol or i s o-propanol may yield a biodiesel fuel with better fuel properties.

The shell of cashew is about 3 mm thick, having a soft feathery outer skin and a thin hard inner skin. Between these skins is the honeycomb structure containing the phenolic material known as cashew nut shell liquid (CNSL) [3]. Inside the shell is the kernel wrapped in a thin skin known as the testa. Cardanol is one of the derivatives of CNSL which can be used for blending in preparation of biodiesel.

II. METHODOLOGY

A. Free Fatty Acid Test

The free fatty acid in oil is estimated by titrating it against KOH in the presence of phenolphthalein indicator. The acid number is defined as the mg KOH required to neutralize the free fatty acids present in 1g of sample. However, the free fatty acid content is expressed as oleic acid equivalents.

For preparation of free fatty acid test (FFA) first Dissolve 1-10g of oil or melted fat in 50mL of the standard solvent in a 250mL conical flask. Add a few drops of phenolphthalein. Titrate the contents against 0.1N potassium hydroxide. Shake constantly until a pink color which persists for fifteen seconds is obtained.

$$\text{FFA} = \frac{28.2 \text{ X Normality of NaOH X Burette reading}}{\text{Weight of the oil}}$$

B. Method to Obtain Biodiesel

For Cardanol oil dilution process is carried out where a blend of 20% Cardanol oil and 80% diesel fuel is mixed and diluted in this process. . For other oils which are karanja oil and cotton seed oil transesterification is done which is also known as alcoholysis and is the reaction of fat or vegetable oil with an alcohol to form esters and glycerol. Mostly a catalyst is also used to improve the rate and yield of the reaction. Since the reaction is reversible in nature, excess alcohol is used to shift the equilibrium towards the product. Hence, for this purpose primary and secondary monohydric aliphatic alcohols having 1-8 carbon atoms are used [4].

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Transesterification process parameters

1. Methanol to oil molar ratio: 9:1
2. Reaction Temperature:70^{o}C
3. Reaction time:3 hours

Fig. 1. Transesterified bio-diesel with 2 layers.

C. *Properties of Diesel and Blend*

The biodiesel blend of cotton seed, karanja methyl ester, and cardanol oil with diesel on 25% and 40% volume based was prepared and fuel properties are measured following standard procedure. The properties of blend 1 that is B25 = (5%cardanol+10%karanja+10%cotton seed+75%diesel)
B40 = (10%cardanol+15%karanja+15%cotton seed+60% diesel

TABLE I. Properties of diesel & Cardanol, Karanja, cotton seed oils and their blends.

S.No	Property	Diesel	Cotton seed oil	Karanja oil	Cardanol oil	Blend 1 B25	Blend 2 B40
1	Specific gravity	0.88	0.929	0.9	0.925	0.825	0.835
2	Viscosity (cSt) at 40^{0}C	3.9	41.5	40.2	31.9	17.83	19.2
3	Density (kg/m^{3})	832	929	900	925	825	835
4	Calorific value(kJ kg^{-1})	44800	38900	36100	40660	41471	41388
5	Flash point (^{0}C)	58	224	225	208	69	78
6	Fire point (^{0}C)	64	229	230	220	72	83

D. *Engine Test*

For the test of fuel blends Computerized Common rail direct Ignition engine was used unlike normal CI engines these engines are attached with a Control panel and a Computer. This type of Engines are user friendly, easy to operate and less time consuming since they are attached with control panel which can be used to start and stop engine, can be used to control flow rate of water, Engine speed, Load etc. Computerized engines are also attached with Exhaust gas analyzers and Dynamometers. All these accessories are connected to computer hence easily without doing much calculation results can be obtained. This reduces time for calculations of data.

Fig. 2. Computerized common rail direct injection engine.

III. Result and Analysis

This paper compares Brake power, BSFC, Bthe, HC. Nitrous oxide and carbon monoxide emission against load with diesel and blends

Performance Characteristics

Engine performance characteristics are the major criterion that governs the suitability of a fuel. This study concerned with evaluation of brake power, mechanical efficiency of the blend with diesel by varying the load factor.

Brake Power (BP)

The brake power increased as the load increases significantly, least for biodiesel blend compared to petroleum diesel. This is due low atomization efficiency of biodiesel blends mixture compared with diesel. There is 5.44% increase in brake power for petroleum diesel than the biodiesel blend B25 and B40.

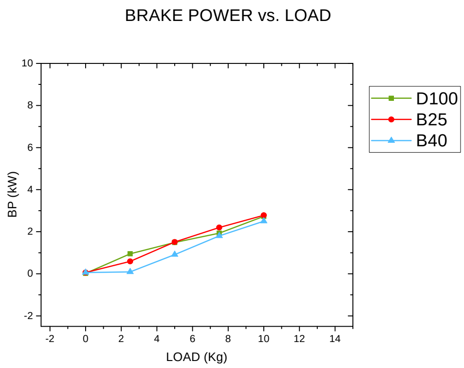

Fig. 3. Brake power vs Load.

Brake Specific fuel Consumption

The Brake Specific fuel Consumption decreased as the load increases, least for biodiesel blend compared to petroleum diesel. This is due to improved combustion, low viscosity and high volatility. This shows that the blend showed close results to diesel.

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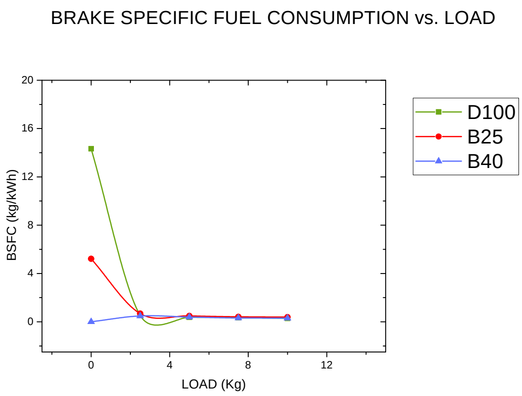

Fig. 4. BSFC vs load.

For B40 certain modification has to be done.

Brake thermal efficiency

The brake thermal efficiency increased as the load increases significantly, least for biodiesel blend compared to petroleum diesel. This is due high heat content high atomization efficiency of biodiesel blends mixture compared with diesel. There is 21.522% increase in brake thermal efficiency for petroleum diesel than the biodiesel blend B25 and B40.

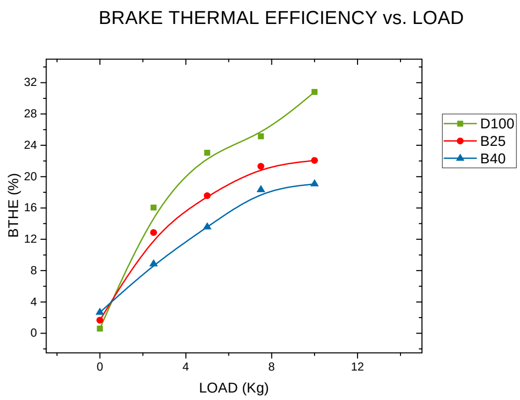

Fig. 5. BTHE vs load.

Emission Characteristics

With global warming being a major issue which leads to ozone depletion and many other problems such as photochemical smog in addition to widespread air pollution. This led automotive emission under a microscope which made us to ensure every possible method in attempt to reduce emission.

Hence the study compares the emission of pollutants of hydrocarbons, carbon monoxide of blends under loading factor.

Hydrocarbon Emission

The variation of Hydrocarbon emission at various loads on the engine for the biodiesel blend is shown in the fig.6. It is noted that the Hydrocarbon emission increases as the load increases [5]. This is due to poor combustion of the biodiesel blend due to high viscosity. At the peak load the Hydrocarbon emission percentage tend to increase because for a given engine speed, F/A equivalence ratio increases with increase in load in a diesel engine which may lead to increase in Hydrocarbon emission.

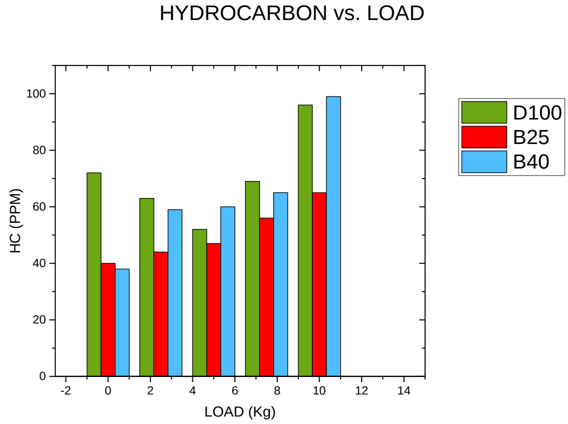

Fig. 6. Hydrocarbon emission vs Load.

Carbon monoxide Emission:

The variation of carbon monoxide emission at various loads on the engine for the biodiesel blend is shown in the fig.7. It is noted that the carbon monoxide emission reduces as the load increases. This is due to good and proper combustion of the biodiesel blend. At the peak load the carbon monoxide percentage tend to increase because for a given engine speed, F/A equivalence ratio increases with increase in load in a diesel engine which may lead to some percentage increase in carbon monoxide [6].

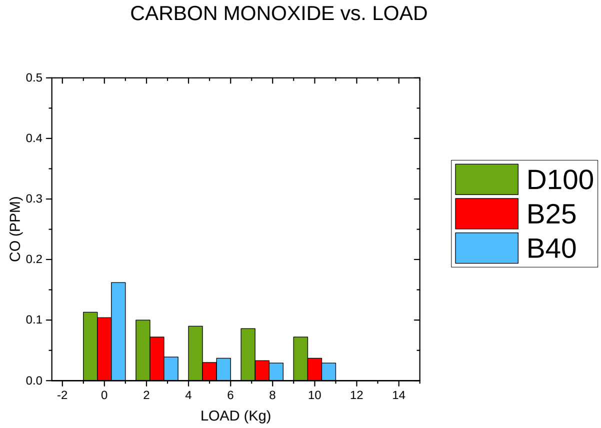

Fig. 7. Carbon monoxide vs Load.

i. Nitrous oxide Emission

The variation of Nitrous oxide emission at various loads on the engine for the biodiesel blend is shown in fig.8. It is noted that the Nitrous oxide emission increases significantly as the load increases. At the peak load the Nitrous oxide percentage tend to increase because faster burning of the blends increases heat release rate and combustion temperature and hence NO emission increases. Faster burning of the blend is due to presence of alcohol content in it.

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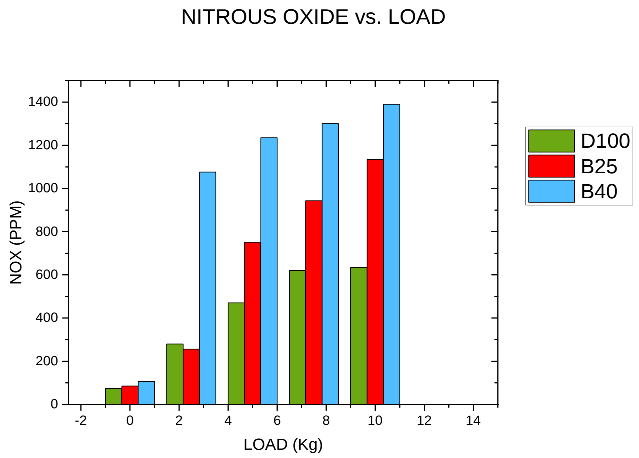

Fig. 8. Nitrous oxide vs Load.

IV. Conclusion

Performance and Emission characteristics of diesel engine fueled with diesel and blends of cardanol, honge, cotton seed oil with diesel were compared by plotting graphs with respect to load variation. In this project the result were compared directly with diesel fuel.

1. Properties of the biodiesel blends depends on free fatty acid (FFA) content in the oils (cardanol, honge, cotton seed).If the oils are kept for longer period the FFA value increases which in turn affects the properties such as its and density.
2. Honge (karanja) oil requires stage 2 Transesterification for getting its yield. But sometimes if the Honge is extracted recently and purified their FFA value decreases and maybe does not have to go Transesterification.
3. Brake power of the blend (B25) is near to brake power of petroleum diesel. There is 5.44% increase in brake power for petroleum diesel than the biodiesel blend B25 but for B40 certain modification has to be done.
4. The brake thermal efficiency of the blend (B25) shows similar variation for the load factor without much variation in values. There is 21.522% increase in brake thermal efficiency for petroleum diesel than the biodiesel blend B25 and B40.
5. After comparing all the performance parameters we come to a conclusion that the blend B25 5%cardanol+10%karanja+10%cotton seed+75%diesel of biodiesel shows a overall good performance without any modification.
6. CO emission for the blend is less than that of diesel fuel emission and reduced as this is due to good and proper combustion of the biodiesel blend. At the peak load the carbon monoxide percentage tend to increase because for a given engine speed, F/A equivalence ratio increases with increase in load in a diesel engine which may lead to some percentage increase in carbon monoxide.
7. Nitrous oxide emission for the blend found to be more than that of diesel. . At the peak load the Nitrous oxide percentage tend to increase because faster burning of the blends increases heat release rate and combustion temperature and hence NO emission increases.
8. Finally it can be concluded that it is possible to run the diesel engine with biodiesel blend for B25 blend without any modification.

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