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Performance Analysis of a Neat Jatropha Biodiesel Fuelled Turbocharged Crdi Diesel Engine

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Abstract— As civilization is growing, transport becomes essential part of life. The biggest problem is the growing population & depletion of fossil fuel. About 100 years ago, the major source of energy shifted from recent solar to fossil fuels. This necessitates the search for alternative oil as energy source. The present research is aimed at exploring technical feasibility of jatropha oil in CRDI diesel engine without any substantial hardware modifications. In this work the methyl ester of jatropha oil was investigated for its performance as a diesel engine fuel. Fuel properties like kinematic viscosity, flash point, density, calorific value and copper corrosion value of mineral diesel, jatropha biodiesel with different blends and jatropha oil were evaluated. Based on engine performance tests, it can be found that biodiesel blends can be used satisfactorily in the diesel engine without any major modifications in the hardware of the system. Brake thermal efficiency of an engine was found a little bit lower for biodiesel blends when compared with brake thermal efficiency for diesel.
Keywords: *Biodiesel, Jatropha, Transesterification, Free fatty acids*.

1 Introduction

As civilization is growing, transport becomes essential part of life. The biggest problem is the growing population & depletion of fossil fuel. About 100 years ago, the major source of energy shifted from recent solar to fossil fuels. This necessitates the search for alternative of oil as energy source. Biodiesel is an alternative fuel for diesel engine. The esters of vegetable oils and animal fats are known collectively as biodiesel. It is a domestic, renewable fuel for diesel engine derived from natural oil like jatropha oil. Biodiesel has an energy content of about 12% less than petroleum-based diesel fuel on a mass basis. It has a higher molecular weight, viscosity, density, and flash point than the diesel fuel. Jatropha curcas is unusual among tree crops is a renewable non-edible plant. From jatropha seeds jatropha oil can be extracted which have similar properties as diesel but some properties such as kinematic viscosity, solidifying point, flash point and ignition point is very high in jatropha oil. By some chemical reactions, jatropha oil can be converted into biodiesel. Jatropha oil can also be used directly by blending with diesel. Biodiesel is less damaging to the environment because it is made from renewable resources and has lower emission compared to fossil fuels. The toxic effects are even less than from table salt and it biodegrades as fast as sugar when spilled. Since it is made from renewable resources such as rapeseed or similar oil plants, its use decreases dependence on imported oil, contributing to the local rural economy. The trans-esterification process in an industrial unit can be summarized as following: the oil, after acid correction is transferred to the first reactor. In a second reactor, the catalyst (KOH or NaOH) and the alcohol (NaOH or KOH) are organized and transferred to the first reactor [1, 2]. Biodiesel has similar combustion characteristics as diesel and biodiesel blend can reduce hydrocarbons, smoke opacity, particulate matters, carbon dioxide and but NOx emissions have slightly increased [3]. Vegetable oils have the potential to substitute a fraction of petroleum distillates and petroleum-based petrochemicals in the near future. Fundamentally, high viscosity appears to be a property at the root of many problems associated with direct use of vegetable oils as engine fuel. Vegetable oils can be converted into to avoid these viscosity related problems. Different ways have been considered to reduce the high viscosity of vegetable oil [6]. The biodiesel from Jatropha oil has higher density but lower calorific value than that of diesel, however, the difference is not significantly higher. The kinematic viscosity of biodiesel derived from Jatropha oil is higher than that of diesel [7].

2 Experimental procedure

2.1 Biodiesel Production

Jatropha biodiesel is produced by the trans-esterification of jatropha curcusa oil. Trans-esterification consists of a sequence of three consecutive reversible reactions. The first step is the conversion of triglycerides to di-glycerides, followed by the conversion of di-glycerides to mono-glycerides, and finally mono-glycerides to glycerol, yielding one ester molecule for each glyceride at each step. The criteria for selection process are based on the presence of the free fatty acid (FFA) content in the oil. If the Free Fatty acid content of the raw oil is less than the 4%, single stage (Alkali base) process has to be under taken. If the Free Fatty acid (FFA) of the raw oil is more than 4%, Double Stage method (Acid base + Alkali Based Catalyst) Processes has to be undertaken. Hence the determination of the free fatty acid content of the raw oil becomes the most critical aspect of the biodiesel manufacturing.

Biodiesel production unit is developed from MS materials with 5mm thickness. The trans-esterification tank has a capacity of 20 liters. The methanol recovery unit has 12 liters capacity. Industrial coil is provided to trans-esterification tank to heat the mixture inside. Professional thermocouples, safety valves are provided to reactor. Reactor welded by using gas welding to prevent the leakage of vapours. The safe and efficient compact biodiesel production unit is shown in the figure below.

Fig. 1. Biodiesel Production Unit

3 EXPERIMENTAL SETUP

The engine tests were conducted on a four-stroke, four-cylinder CRDI Diesel engine whose specifications are given in Table below. The engine operated by varying speed and load.

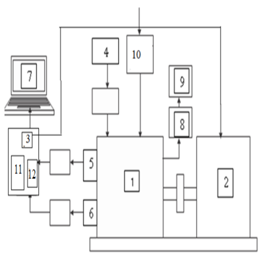


Fig. 2 Schematic Diagram of the Experimental setup of CRDI Diesel Engine.

1.Diesel engine, 2. Eddy Current dynamometer, 3. Dynamometer controls, 4. Fuel tank, 5. Pressure pickup, 6. TDC Position sensor, 7. Computer, 8. Exhaust gas analyzer, 9. Smoke meter, 10. Air box, 11. Fuel consumption manometer, 12. Air flow measurement.

4 EXPERIMENTAL PROCEDURE:

Before the actual tests were carried out the engine was checked for lubrication and fuel supply. Experiments were initially carried out on the engine using diesel as the fuel in order to provide base line data. The engine was stabilized before taking all measurements. Subsequently experiments were repeated with methyl ester of Jatropha oil for comparison. In all cases the pressure and crank angle diagram was recorded

TABLE 1
CRDI DIESEL ENGINE SPECIFICATION

Make	Maruthi Suzuki
Engine type	CRDI Diesel Engine
Capacity	1248cc
Bore	74mm
Stroke	75.5 mm
Power	75bhp@4000rpm
Torque	190Nm@2000rpm
Compression Ratio	17.6:1

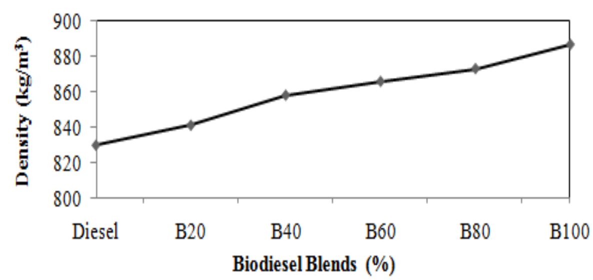
and processed to get combustion parameters. The following parameters measured are load, fuel consumption

5 RESULTS AND DISCUSSIONS

5.1 Properties of jatropha biodiesel:

The determined properties of jatropha biodiesel shown in the table 2 are within the limits of ASTM standards. Hence this jatropha biodiesel is used for performance and emission analysis in the CRDI diesel engine.

5.1.1 Density of biodiesel blends



PROPERTIES OF JATROPHA BIODIESEL

Properties	Jatropha biodiesel	ASTM standards
Flash Point (^{0}C)	158	≥ 130
Kinematic Viscosity at 40^{0}C (m^2/s)	$5.54x10^{-6}$	$1.9x10^{-6}$-$6x10^{-6}$
Density (kg/m^3)	887	870-900
Calorific Value (MJ/kg)	38.35	-

The above fig.3 indicates the variation of density with biodiesel blends. Density of the biodiesel is very high when compared with diesel. The density of biodiesel decreases as the ratio of diesel increases in the biodiesel blends.

5.1.1 Kinematic Viscosity of biodiesel blends

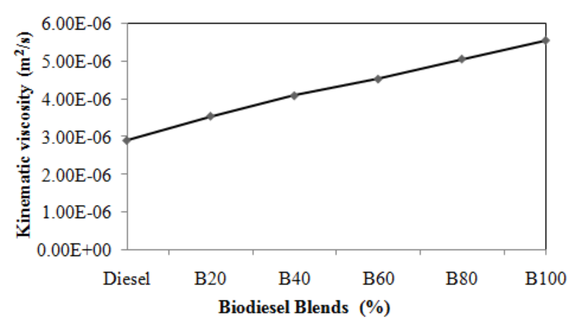


Fig. 4 Variation of Kinematic viscosity for different blends of Biodiesel

The above fig.4 indicates the variation of kinematic viscosity with biodiesel blends. Kinematic viscosity of the 100% biodiesel is 5.54×10^{-6} m^2/s which is higher than the diesel having a value of 2.91×10^{-6} m^2/s. The viscosity of the biodiesel blends decreases as the diesel ratio increases in the biodiesel blends.

5.1.2 Calorific Value of biodiesel blends

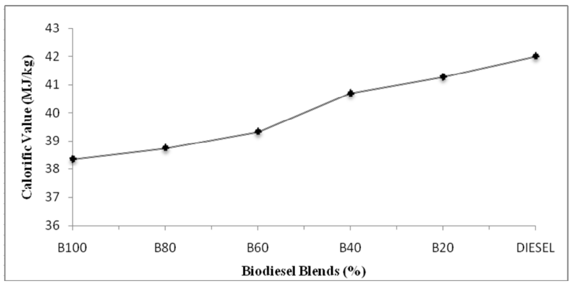


Fig. 5 Variation of calorific values for different biodiesel blends

The above fig.5 indicates the variation of calorific values for different biodiesel blends. The calorific value of 100% biodiesel is 38.35 MJ/kg, which is lower than the diesel having a value of 42.023MJ/kg. The calorific value of the biodiesel blends increases as the diesel ratio increases in the biodiesel blends.

5.1.2 lash and fire point of a jatropha biodiesel

Pensky-Marten closed cup tester is used to measure the lower temperature at which the application of the test flame causes the vapour above the bio-diesel sample to ignite. It is used to assess the overall flammability hazard of the biodiesel. Measured biodiesel is poured up to the mark indicated in the flash point Apparatus. Then the oil is heated and stirred at regular interval. The external fire is introduced at the regular period till flash is observed. Once the flash is observed the temperature is noted. Noted temperature at the time of the flash is the Flash point of the biodiesel.

6 Performance of Analysis

6.1 ENGINE OPERATING AT 1000 rpm

6.1.1 Brake specific fuel consumption

TABLE 3
FLASH AND FIRE POINT OF A JATROPHA BIODIESEL

Sl. No.	Temperature in °C	Observation
1	100	No Flash
2	110	No Flash
3	120	No Flash
4	130	No Flash
5	140	No Flash
6	150	No Flash
7	158	Flash observed
8	168	Fire Observed

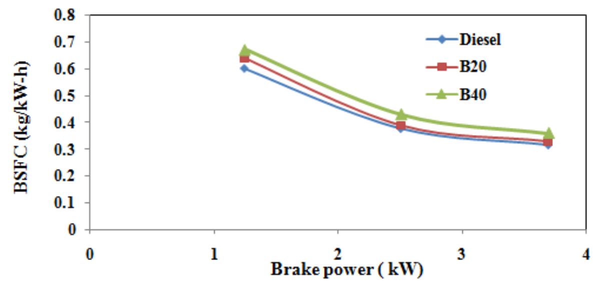


Fig.6 Variation of BSFC with Brake Power at 1000 rpm

The above fig.6 indicates the variation of BSFC with Brake Power at 1000 rpm. Specific Fuel Consumption was calculated by fuel consumption divided by the rated power output of the engine. B40 biodiesel is having higher BSFC than B20 and B20 is having higher BSFC than diesel. It shows that as blended percentage increases the BSFC increases

6.1. 2 Brake thermal efficiency

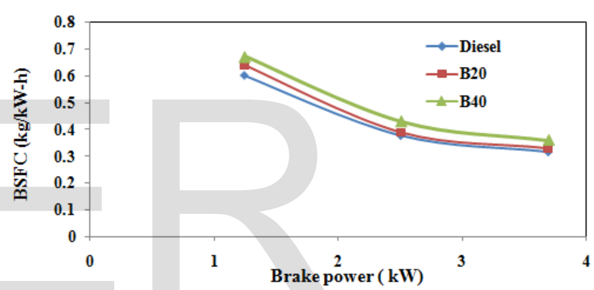


Fig.7 Variation of Brake Thermal Efficiency with Brake Power at 1000 rpm

The above fig.7 indicates the variation of brake thermal efficiency (%) with brake power at 1000 rpm. It can be seen that brake thermal efficiency is lower for jatropha biodiesel blends than diesel. This is due to poor mixture formation of jatropha biodiesel due to high viscosity, density and low volatility.

7 Conclusion

Biodiesel is a viable substitute for petroleum-based diesel fuel. Its advantages are improved lubricity, higher cetane number, cleaner emissions, reduced global warming. Jatropha oil has potential as an alternative energy source. However, this oil alone will not solve our dependence on foreign oil within any practical time frame. Use of this and other alternative energy sources could contribute to a more stable supply of energy.

Based on the biodiesel blends property tests and engine performance tests it can be concluded that.

- All the biodiesel properties i.e. Flash point, Kinematic viscosity, Density and Calorific values are lies within the ASTM standards.

- Diesel is having lesser density as compared with blended biodiesel. It also shows that as the percentage of biodiesel blends increases, the density is also gets increases. The maximum density that found is 887 kg/m^3 at B100.
- Diesel is having lesser kinematic viscosity as compared with blended biodiesel. It also clears that as the percentage of biodiesel blends increases, the kinematic viscosity is also gets increases. The maximum kinematic viscosity that found at B100 is $5.54*10^{-6}$ m^2/s. B20 biodiesel is having kinematic viscosity approximately equal to diesel.
- Diesel is having higher calorific value as compared with blended biodiesel. It also clears that as the percentage of biodiesel blends increases, the calorific value will get decreases. The maximum calorific value that found at B20 is 41.27 MJ/kg and minimum calorific value that found at B100 is 38.25 MJ/kg.
- The fuel consumption of the engine is somewhat higher at low loads on fuel blends, due to lower gross heat of combustion.
- Brake thermal efficiency of an engine was found a little bit lower for biodiesel blends when compared with diesel.
- Knocking is not observed for biodiesel blends at all operating conditions.

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