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Performance And Emission Characteristics of Single Cylinder Diesel Engine with Safflower Biodiesel Blends

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ABSTRACT

The consumption and demand for the petroleum products are increasing every year due to increase in vehicle population, standard of living and urbanization. This causes fast depletion of petroleum products, which leads to move towards the alternative fuels for researchers. Among so many alternative fuels for diesel engine, non edible vegetable oils are the most widely used under the test. The purpose of present work is to investigate the engine performance and emission characteristics of DI diesel engine with different blends of safflower seed oil. Engine tests have been carried out to obtain comparison of fuel consumption, specific fuel consumption, brake thermal efficiency, volumetric efficiency and smoke opacity and compared with that of diesel fuel. The aim of the proposed project work is to investigate experimentally the performance and emissions characteristics of safflower biodiesel at different loads. A single cylinder, direct injection, compression ignition engine has been selected for investigation.

Keywords: D.I.Diesel Engine, Performance, Transesterification, Emissions.

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I. INTRODUCTION

Fossil fuels are one of the major sources of energy in the world today. Their popularity can be accounted to easy usability, availability and cost effectiveness. But the limited reserves of fossil fuels are a great concern owing to fast depletion of the reserves due to increase in worldwide demand. Fossil fuels are the major source of atmospheric pollution in today's world. So efforts are on to find alternative sources for this depleting energy source. Even though new technologies have come up which have made solar, wind or tidal energy sources easily usable but still they are not so popular due to problems in integration with existing technology and processes. So, efforts are being directed towards finding energy sources which are similar to the present day fuels so that they can be used as direct substitutes. Diesel fuel serves as a major source of energy, mainly in the transport sector.

India is importing crude petroleum and petroleum products from Gulf countries. Indian scientists searched for an alternate to diesel fuel to preserve the global environment and to withstand the economic crisis. As far as India is concerned because of its vast agro forestry base, fuels of bio origin can be considered to be ideal alternative renewable fuels to run the internal combustion engines. Vegetable oils from plants both edible and non-edible and methyl esters (Biodiesel) are used as an alternate source for diesel fuel. Biodiesel was found to be the best alternate fuel, technically, environmentally acceptable, economically competitive and easily available. There are more than 350 oil bearing crops that have been identified, among which only sunflower, soyabean, cottonseed, mango seed, rapeseed and peanut oils are considered as potential alternative fuels for diesel engines. Apart from the renewability, the advantages of biofuel are as follows: High oxygen content, higher flash point and higher lubricity that produce complete combustion in comparison with conventional diesel fuel [1]. Further, the environmental benefit is another investigation factor due to lesser greenhouse effect, less air pollution, less contamination of water, soil and reduced health risk [2]. Traditional oilseed feedstock for biodiesel production predominantly includes soyabean, rapeseed/canola, palm, corn, sunflower, cottonseed, peanut and coconut oil [3]. The long chain hydrocarbon structure, vegetable oils have good ignition characteristics, however they cause serious problems such as carbon deposits buildup, poor durability, high density, high viscosity, lower calorific value, more molecular weight and poor combustion. These problems lead to poor thermal efficiency, while using vegetable oil in the engine. These problems can be rectified by different methods that are used to reduce the viscosity of vegetable oils. The methods are transesterification, dilution and cracking method [4]. The transesterification of vegetable oil gives better performance when compared to straight vegetable oil [5]. Many researches are focused on non-edible oils which are not suitable for human consumption due to the presence of toxic components present in the oil. Moreover, the non-edible oil crops grow in wastelands which are not suitable to use as food [6] and [7]. The increase in brake thermal efficiency and lower in specific fuel consumption were observed in a diesel engine fueled with CalophyllumInophyllum (punnai) biodiesel and additives [8]. The diesel engine performance parameters were higher and lower in emissions while operating with B20 blend biodiesel [9]. Rakopoulos et al. [10] studied the use of four straight vegetable oils such as sunflower, cotton seed, olive and corn oils on mini-bus engine and reported that olive oil has very high content of the unsaturated oleic acid (one double carbon bond) and very low content of the unsaturated linoleic acid (two double carbon bonds), in contrast to the other three vegetable linoleic acids. Further, the cotton seed oil has the highest content of palmitic acid (saturated). These may play some role in the soot formation and oxidation mechanism. Saravanan et al. [11] reported that pure Mahua oil methyl ester (B100) gives the lower emissions as compared with neat diesel (B0) in a DI diesel engine. The performance of diesel engine with rice bran oil methyl ester and its diesel blends resulted in increase of CO, HC and soot emissions and slight increase of NOx with increase in blends compared to diesel. Also the ignition delay and peak heat release rate for RBME were lower for biodiesel and it was increased with increase in RBME blends [12]. Rajan and Kumar [13] have investigated the performance of a diesel engine with internal jet piston using biodiesel and observed increase in brake thermal efficiency and decrease in CO and smoke emissions at full load, whereas NO_x emission is increased at full load compared to diesel fuel. Godiganur et al. [14] investigated the use of Mahua oil methyl ester and its diesel blends as an alternative fuel in a heavy duty diesel engine and observed that B20 blend gives better performance and lower emissions. The methyl ester of Thevetiaperuviana seed oil (METPSO) results in lower emission of CO, HC and higher NO_x as compared to that of diesel [15]. The cylinder peak Pressure of soyabean biodiesel is close to that of diesel and also the peak rate of pressure rise and peak heat release rate during premixed combustion are lower for biodiesel [16].

Implementation of biodiesel in India will lead to many advantages such as green cover to wasteland, support to agriculture, rural economy, reduction in dependence on imported crude oil and reduction in air pollution [17]. Currently, India is spending about Rs. 80,000 million per year for importing 70% of petroleum fuels and produces only 30% of the total fuel requirements. It is estimated that mixing of 5% of biodiesel fuel to the present diesel fuel can save Rs. 40,000 million per year. The objective of the present study is the preparation of biodiesel from safflower seed oil; the performance, emission and combustion characteristics of a diesel engine using biodiesel and its various blends are analyzed and compared with neat diesel.

II. MATERIALS

Safflower (Carthamustinctorius) is a highly branched, herbaceous, thistle-like annual plant. It is commercially cultivated for vegetable oilextracted from the seeds. Plants are 30 to 150 cm (12 to 59 in) tall with globular flower heads having yellow, orange, or red flowers. Each branch will usually have from one to five flower heads containing 15 to 20 seeds per head. Safflower is native to arid environments having seasonal rain. It grows a deep taproot which enables it to thrive in such environments. Safflower seed oil is flavorless and colorless, and nutritionally similar to sunflower oil. It is used mainly in cosmetics and as a cooking oil, in salad dressing, and for the production of margarine.

III. PREPARATION OF BIODIESEL BYTRANSESTERIFICATION

After extraction of oil from safflower seeds, by solvent extractor (soxhlet). The extracted oil was converted tomethyl ester via transestrification reaction (Fig 1) as following conditions: preheating the oil for 0.5 h in 65°C; NaOH as catalyst (1 %wt/wt); alcohol (methanol) to oil molar ratio (6:1); stirring speed (600 rpm); reaction temperature(65°C); reaction time (1.5 hr).

The reaction result was two phases. The upper and lower layers were methyl ester and glycerin respectively. In the next step the produced methyl ester (biodiesel) was heated to 100 °C, and then dried with anhydrous $Na_2SO_4$to get rid of any water.

IV. BIO DIESEL PROPERTIES

Table 1: Properties of safflower oil

Properties	Safflower bio-diesel	Diesel
Kinematic viscosity (cSt) @28°c	28	2-4.5
Flash point(°c)	173	52
Cetane number	48	47
Calorific value(kJ/kg)	36325	43626
Density(Kg/m^3)	876	832
Cloud point(°C)	-2	-18
Pour point(°C)	-8	-25

V. EXPERIMENTAL SET UP

The experimental set up consists of engine with belt brake dynamometer, fuel tank, thermo couples, control panel and manometer.

5.1 Engine

The engine was manufactured by Kirloskar Company. It is single cylinder vertical type four stroke, Water-coo1ed, compression ignition engine with self governed type is used in the present work.

5.2 Engine specifications

Engine	:	Kirloskar make, 4 stroke-stationary.
Type	:	water-cooled
Injection	:	direct injection (DI)
Maximum speed	:	1500
Number of Cylinder	:	One
Bore	:	80 mm
Stroke	:	110 mm
Compression Ratio	:	16.5:1
Maximum HP	:	5 HP
Injection timing	:	250 before TDC
Injection pressure	:	200 bar

5.3 Reasons for Selecting the Engine

The above engine is one of the extensively used engines in industrial sector in India. This engine can with stand the peak pressures encountered because of its original high compression ratio. Further, the necessary modifications on the cylinder head and piston crown can be easily carried out in this type of engine. Hence this engine is selected for the present project work.

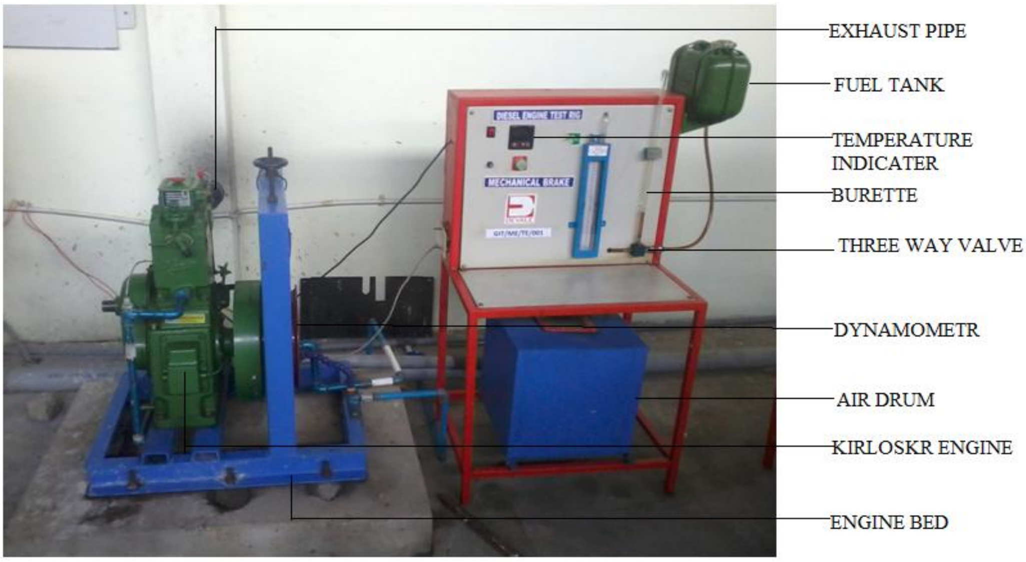

Fig 1: Experimental Setup of the Test Engine

VI. RESULT AND DISCUSSION

Experiments were conducted when the engine was fuelled with normal diesel at different loads with different blends. The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency and volumetric efficiency. The emission characteristics of the engine were studied in terms exhaust gas temperature, concentration of HC, CO, $NO_{X,}$ CO_2 and O_2.

6.1 Brake Specific Fuel Consumption

The result for the variations in the brake specific fuel consumption (BSFC) at different load is shown in fig 2. For all blends the BSFC falls with increasing load. The brake specific fuel consumption (BSFC) at 12 Kg load is 0 .316 Kg/KW hr for diesel and for 0.311Kg/KW hr at blend B-20. This is mainly due to effects of fuel density, viscosity and heating value of blends.

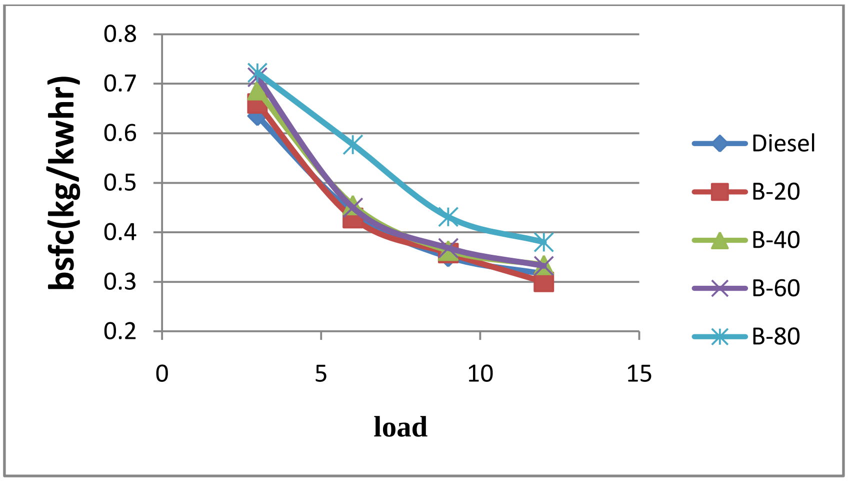

Fig 2: Load Vsbreak specific fuel consumption (bsfc)

6.2 Break Thermal efficiency
The variation of brake thermal efficiency with respect to load is shown in fig.3 Brake thermal efficiency gives an idea of the output generated by the engine with respect to heat supplied in the form of fuel. For all blends the brake thermal efficiency increases with load. The brake thermal efficiency of safflower biodiesel blends B20, B40, B60 and B80 are very near that of the diesel fuel with respect to all loads but for B20 at kg load nearly 4% (from 25% to 28.95%) higher than diesel. The reason may be higher oxygen content and good spray characteristics resulting in higher burning rate.

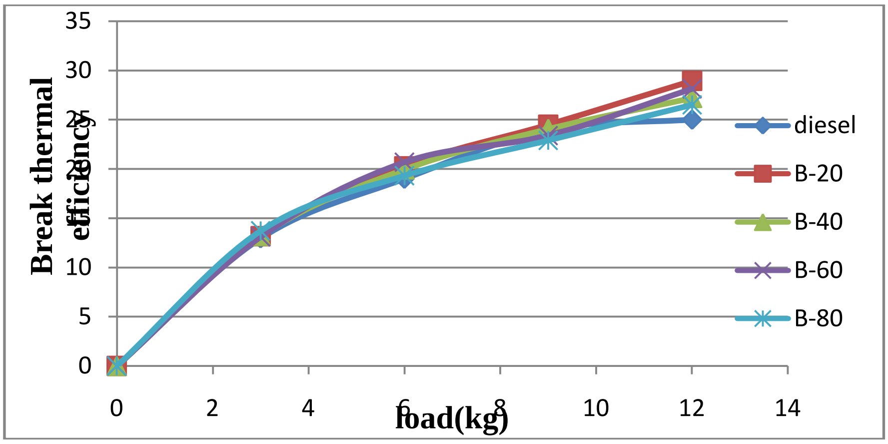

Fig 3: Load VsBrake Thermal efficiency Vs load

6.3 Exhaust Gas Temperature
It is observed that the exhaust gas temperature increases with load because more fuel is burnt at higher loads to meet the power requirement. The exhaust gas temperatures are increases with increasing of load

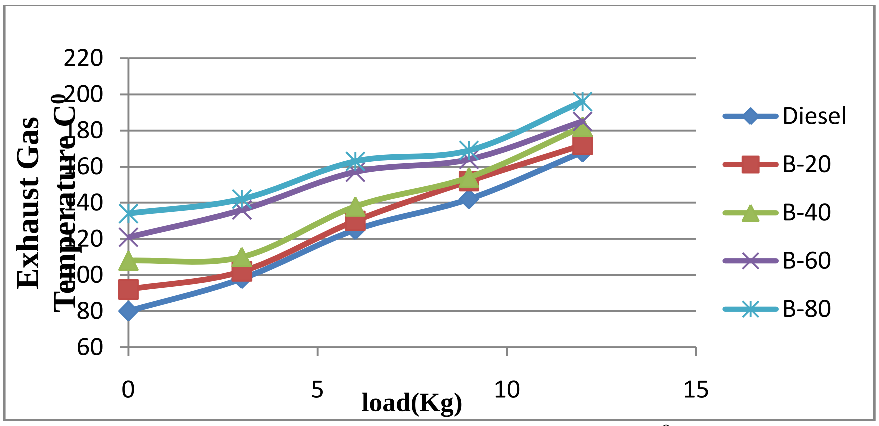

Fig 4 Load Vs Exhaust Gas Temperature(C^o)

6.4 Carbon Monoxide(CO)

CO is predominantly formed due to the lack of oxygen. The fig.5 shows that the CO emissions are increased with increase in load. Formation smoke is high in higher loads as the load increases more fuel is injected and increases in smoke formation

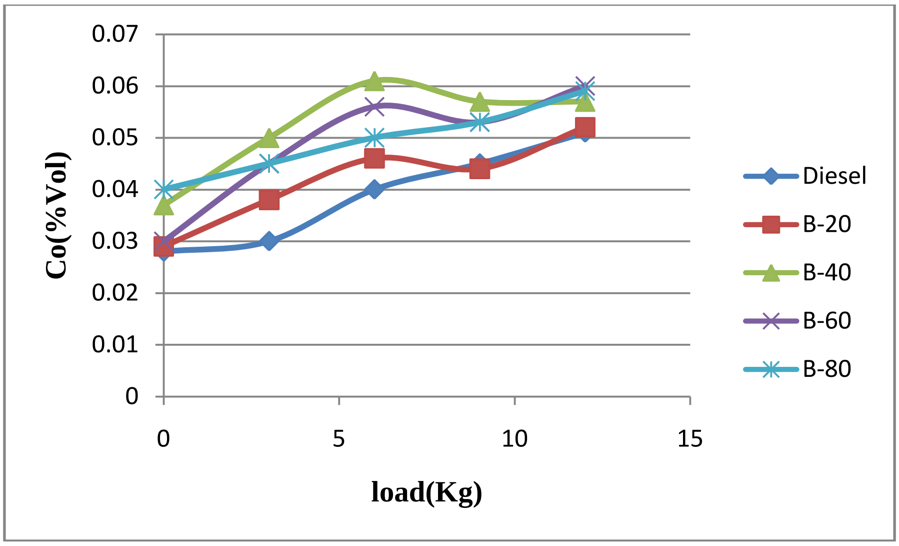

Fig 5 load Vs co

6.5 Hydro Carbons

The variation of hydrocarbon (HC) with load for diesel fuel and different biodiesel blends is shown in Fig 6.HC increased with load with all blends. Safflower oil biodiesel and its different blends B20 showed lower HC than diesel fuel. HC formed due to incomplete combustion or incomplete burning of hydrogen reacts with carbon content.

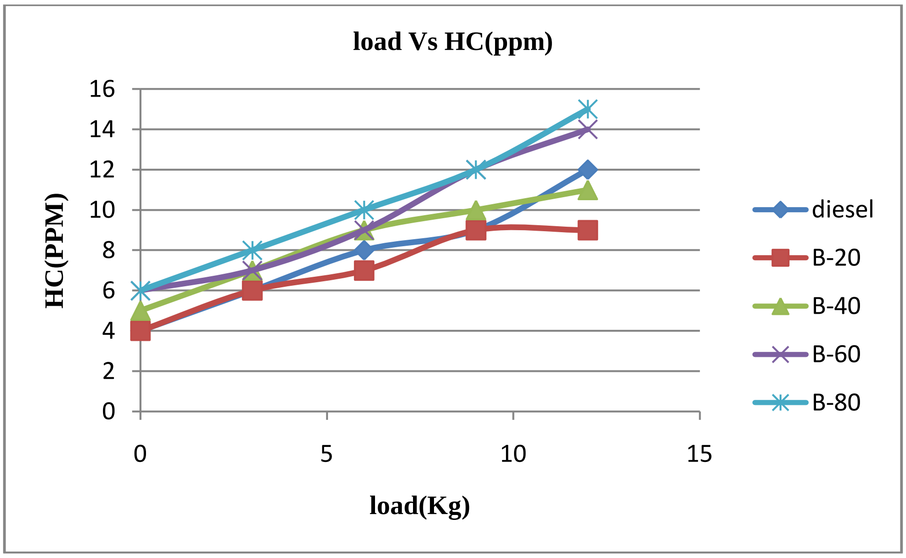

Fig 6 loadVs HC

6.6 Nitrogen oxide

The variation of Oxides of Nitrogen (NOx) with load for diesel fuel and different biodiesel blends shown in fig 7. The NOx emissions of biodiesel blends B20, B40, B60 and B80 were less at low loads and more at medium and high loads than those of diesel fuel. It is due to the higher oxygen content and combustion temperature of the biodiesel at medium and high loads. The percentage reduction of NOx decreased with increased of load. For B20 NOx formation is less than diesel

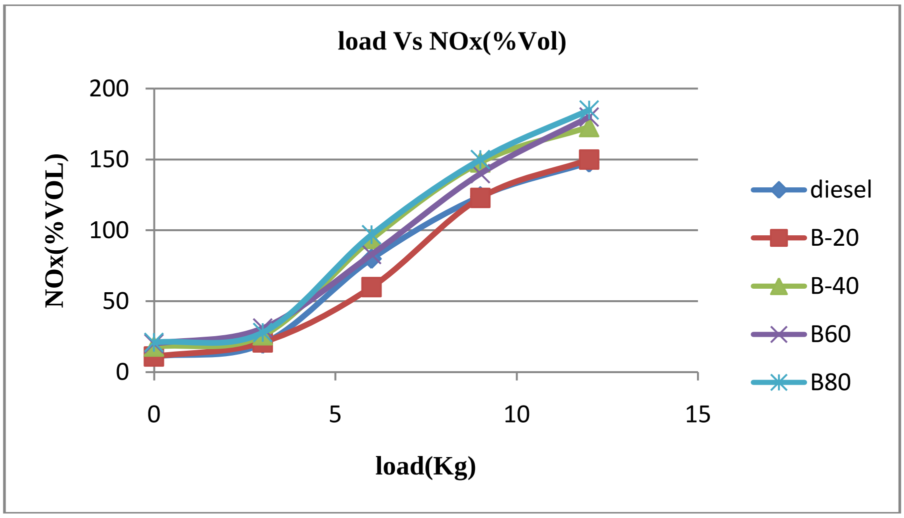

Fig 7load VsNo$_X$

VII. CONCLUSION

The conclusions based on the experimental results obtained while operating single cylinder water cooled diesel engine operated with diesel Blends of safflower oil.

- The engine run successfully during test with safflower oil diesel blends.
- Performance and emission characteristics of safflower oil and its blends were found to be comparable to that of diesel.
- Requires no modification in engine hardware
- The blend B20 is the best fuel with minimum fuel consumption and break specific fuel consumption with 0.316kg/khr to 0.30kg/kwhr.
- The blend B20 is the best fuel with 3.95% (from 25% to 28.95%) higher break thermal efficiency than that of diesel fuel.
- The emissions for B20 are lower than diesel fuel.

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