PERFORMANCE EVALUATION OF DIESEL ENGINE WITH SAFFLOWER OIL

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Abstract: The vegetable oils and their blends have come across the world as alternative fuel in place of fossil fuels. This paper presents the results of experimentation carried out on a diesel engine with different blends of safflower oil with diesel fuel. 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. From the experimental investigation, the safflower diesel blends show better performance and lower smoke when compared to diesel. With blend B20 the thermal efficiency is increased by 5.2%.

Keywords: Alternative fuels, diesel engine, safflower oil, engine performance, smoke opacity

1. INTRODUCTION

Due to the diminishing reserves of petroleum fuels and environmental degradation, the search for alternate fuels for diesel engines has been intensified from the last two decades. Diesel engines are the major source of transportation, industrial power generation and agriculture sector [1]. Using straight vegetable oils in diesel engines is not an invention; Rudolf Diesel first used peanut oil as a fuel in his newly developed CI engine. During the World War II vegetable oils were used as fuel in emergency conditions when diesel was scarce. Due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there has been focus on vegetable oils and animal fats as an alternative to petroleum fuels. Vegetable oils are renewable and environment friendly. Disadvantage of vegetable oil is its high viscosity, which leads to poor fuel atomization, which may lead to poor combustion, injector deposits, injector cocking, ring sticking, injector pump failure [2, 3]. Heating, blending with diesel and trans-esterification are some of the methods used to reduce viscosity of vegetable oils. Several investigators [4-7] conducted experiments with different vegetable oils and diesel blends and very few of them conducted experiments with 100% straight vegetable oils. Literature suggests that vegetable oils can be substituted for diesel fuel if viscosity is reduced by blending it with diesel.

In view of the future energy crises and environmental protection, the author has chosen safflower oil, the oil, which is having calorific value slightly less than diesel. The suitability of safflower oil as alternative fuel is identified through the evaluation based on the performance and emission parameters.

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2. SAFFLOWER OIL AND ITS PROPERTIES:

Safflower oil is native to the Middle East and is widely cultivated throughout Europe and the United States. This plant grows approximately one metre height with a single, smooth, upright stem produces profuse yellow to deep red flowers. Seeds are produced in August. Safflower oil is a drying oil that is used in white and light-coloured oil-based paints instead of linseed oil, because it does not yellow with age like similar oils rich in linoleic or oleic acid (depending on cultivar). Safflower pigment was used as a substitute for an adulterant of saffron, e.g., as a colouring agent in cheeses. Safflower was particularly important as an oil and pigment in southern Asia (Iran, Afghanistan, and India), and early carpets from these regions used safflower dye. Fuel properties of different blends of safflower and diesel are given in Table 1.

Table 1. Fuel properties of different blends and diesel.

Property	Diesel	B20	B40	B60	B80	B100 (Pre heated raw oil)
Density (kg/m^3) @ 28^o C	832	841	852	863	874	876
Calorific Value(kJ/kg)	43626	41345	39641	38448	37419	36325
Kinematic Viscosity (cSt) @28^o C	2-4.5	3.28	4.14	5.18	6.24	28.34

3. ENGINE SPECIFICATIONS & EXPERIMENTAL METHODOLOGY

The experimental setup consists of a single-cylinder, four-stroke, vertical, water cooled, direct injection, natural aspirated Kirloskar diesel engine connected to water brake dynamometer for loading the engine. The specifications of the engine are given in Table 2. In the present work the fuel considered for investigation is Safflower oil. The fuel blends were prepared using an emulsifier and the investigation was mainly focused on the performance and emission of the engine at fuel injector opening pressure of 240kg/cm^2.

Table 2. Specifications of the engine setup.

Make	Kirloskar oil engines Ltd. India
Type	Single cylinder DI, NA CI engine
Rated output	3.68 kW
Engine speed	1500 rpm
Injection timing	23^{0}BTDC
Loading device	Water Brake dynamometer
Stroke	110 mm
Compression ratio	16.5:1
Bore	80 mm

The following blends of safflower oil and diesel are prepared on volume basis. The instrument used for measuring volumes of each oil is measuring flask of capacity 500ml. Oils are measured according to the blend ratios and taken into the emulsifier.B20: 20% safflower oil and 80% diesel, B40: 40% safflower oil and 60% diesel, B60: 60% safflower oil and 40% diesel, B80: 80% safflower oil and 20% diesel, B100: 100% safflower oil and 0% diesel. Oils are measured according to the blend ratios and taken into the emulsifier (Figure 1). The time for complete mixing of oils varies with the blend and the least time among them is for blend B20. The blend B80 took more time for mixing. The engine was started with diesel fuel and warmed for 15 minutes and the experimental tests were conducted three times at no load, 20, 40, 60, 80 and 100% of rated load with all the fuels at 1500 rpm (rated speed). The time taken for the consumption of 10 CC of fuel is taken thrice and average value has been taken for plotting. Smoke emissions were measured using NETEL smoke meter in HSU (Model No.NPM-SM-111B).The emphasis is on the comparison of the engine performance, smoke opacity with diesel fuel.

Fig. 1. Emulsifier for the blend preparation.

4. RESULTS AND DISCUSSION

The results concerning performance and smoke opacity of the safflower diesel blends in comparison to the diesel fuel are presented and discussed here.

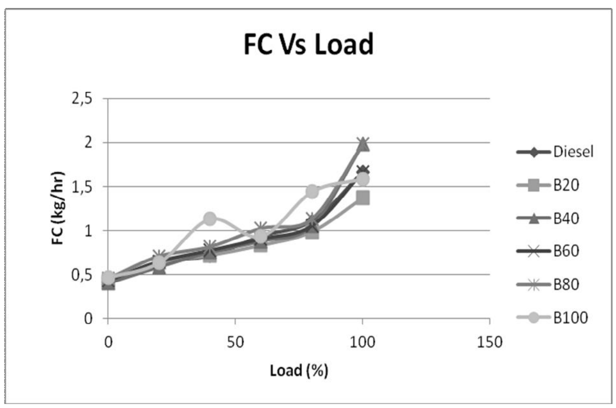


Fig. 2. Variation of fuel consumption with respect to load.

Figure 2 shows the variation of fuel consumption with load for Safflower oil and its blends with diesel. It is seen that the blend with minimum fuel consumed by the engine is B20. It is also seen that up to 80% loading B40 shows less fuel consumption than diesel because of better combustion. With the other blends B80 and B100 the fuel consumption is more due to poor combustion.

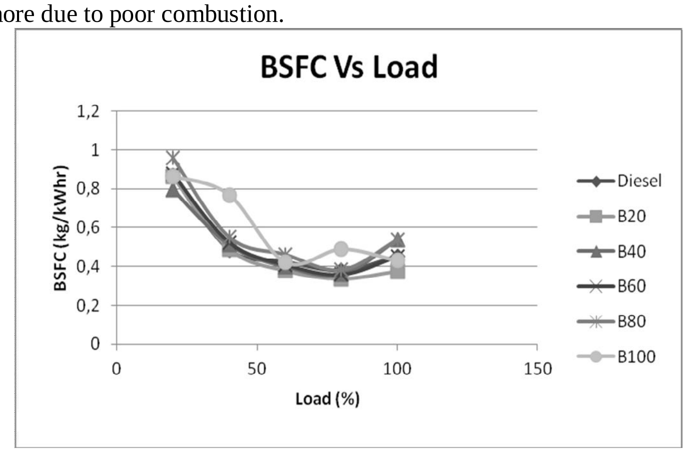
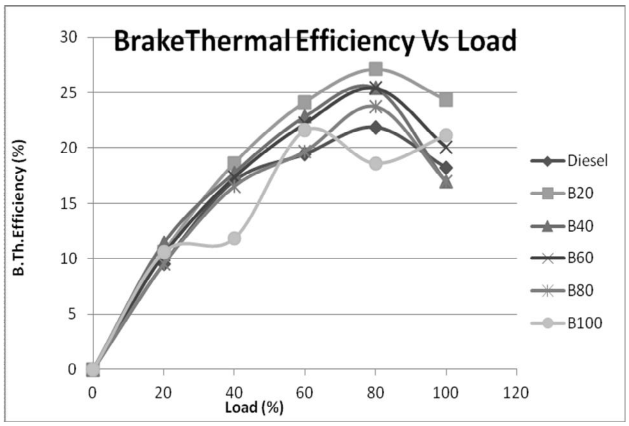


Fig. 3.Variation of brake specific fuel consumption with respect to load.

It is seen that the blend B20 shows minimum brake specific fuel consumption. Brake specific fuel consumption (BSFC) is a measure of volumetric fuel consumption for any fuel (Figure 3). It is also seen that up to 80% loading B40 shows less brake fuel consumption than diesel. At lower loads (20% max. load) the BSFC was 0.8659 kg/kW hr for diesel and for B20 it was 0.8609 kg/kW hr. At full load, the BSFC was 0.4522 kg/kW hr for diesel and for B20 it was 0.3743 kg/kW hr. This is mainly due to combined effects of fuel density, viscosity and heating value of blends.



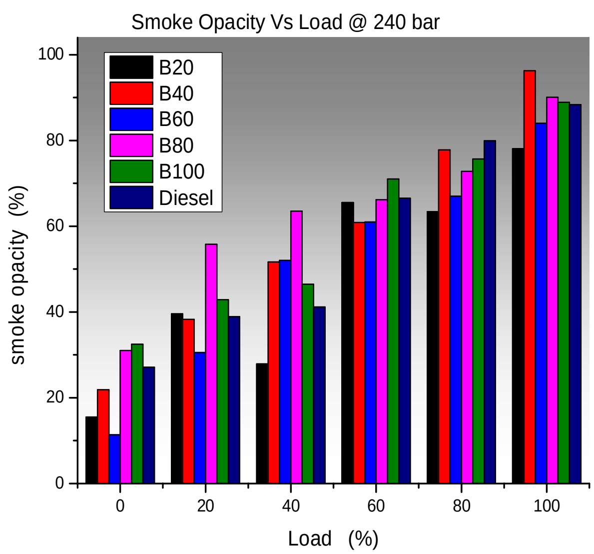


Fig. 4.Variation of brake thermal efficiency with respect to load.

Figure 4 shows the variation of brake thermal efficiency with load. Brake thermal efficiency is an indication of the performance of the engine. Except with the pure safflower oil, for the entire safflower diesel blends the diesel engine is performing better than that of diesel. Brake thermal efficiency of the engine is maximum with the fuel, B20 with an increase of 5.2% (from 21.9% with diesel to 27.1% with B20) is obtained at 80% load. The combined effects of higher oxygen content and improved spray characteristics [8] may result in higher burning rate of the blend over the diesel and pure safflower oil at higher loads contributing to the observed increase in thermal efficiency.

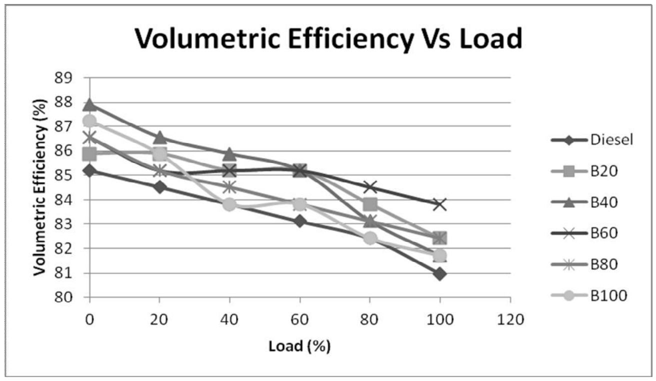


Fig. 5. Variation of volumetric efficiency with respect to load.

The above figure shows the comparison of volumetric efficiency with load. The volumetric efficiency of the engine is more with all the blends than diesel (Figure 5).

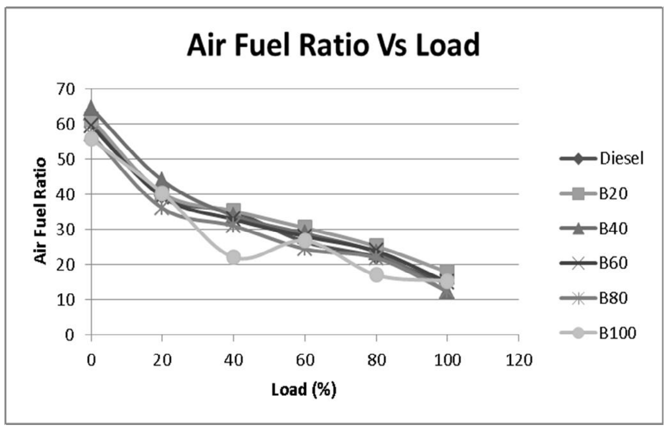


Fig. 6.Variation of Air Fuel Ratio with respect to load.

Figure 6 shows comparison of air fuel ratio with load. It is observed that with blend B20 the air fuel mixture taken by the engine is more than that of diesel, which mean that the engine was run with lean mixture at higher loads. Volumetric efficiency of the engine with all the blends is high compared to that of standard diesel fuel operation because of the reason that the biodiesel blends have low heating value than that of diesel. Low heating value results in low exhaust gas temperatures and less heat transfer to the engine components, which has been the main obstacle for the higher air flow rates.

The formation of smoke primarily results from the incomplete burning of the hydrocarbon fuel and the partially reacted carbon content in the liquid fuel [9]. The results of smoke opacity were depicted in Figure 7.The smoke opacity increased with the increase of the engine load as shown in Figure 7. The formation of smoke strongly depends on the engine load. As the load increases, more fuel is injected, and this increases smoke formation [10]. It is seen that with the fuel B20, smoke opacity is lower than that of diesel at all the loads i.e., from no load to maximum load. The engine can run with B60 as the smoke opacity of the engine with B60 is lower than diesel fuel at all the loads except 40% loading. Safflower oil in its pure form can be used as fuel at higher loading (80% to 100%) without any increase in smoke opacity.

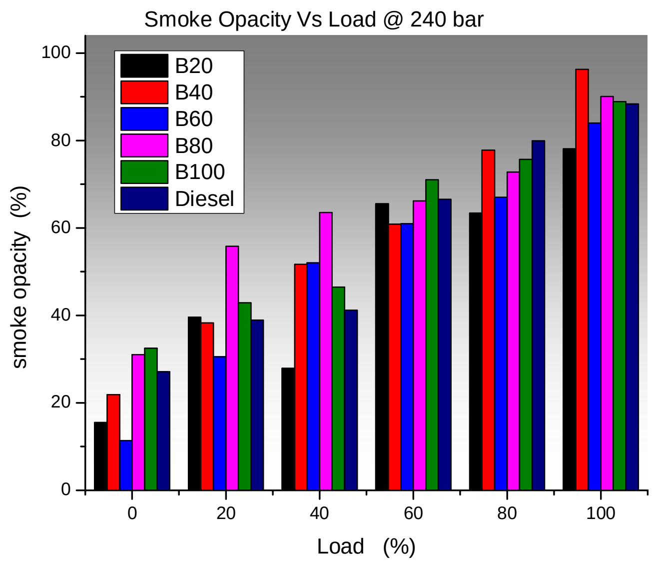


Fig. 7. Variation of smoke opacity with respect to load.

5. CONCLUSIONS

From the detailed experimental tests conducted with the safflower oil diesel blends the following conclusions can be made:

- The engine ran successfully during tests with safflower diesel blends and requires no modification in engine hardware.
- Performance and emission characteristics of safflower oil and its blends were found to be comparable to that of mineral diesel.
- The blend B20 is the best fuel with minimum fuel consumption and minimum brake specific fuel consumption.
- The blend B20 is the best fuel with 5.2 % higher brake thermal efficiency (21.9% to 27.1%) than that of diesel fuel at 80% full load.
- All the blends had better volumetric efficiency than diesel.
- The engine was run at higher air fuel ratio with all the blends than diesel.
- Smoke opacity of the engine is low with the fuel B20.
- Safflower oil and its blends can be used as an alternative fuel in future.

From the above, it is concluded that fuel B20 is the best substitution because it gives better performance and less smoke as compared to that of diesel fuel.

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