Performance Analysis of Diesel Engine with Blends of Waste Vegetable Oil and Diesel

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Abstract: **Diesel engines are generally heavy duty vehicles used in transportation and agricultural sectors. Diesel engines meet their energy requirement from natural petroleum products. The problems associated with diesel fuels are their increasing price, atmospheric pollution and lack of sufficient availability in next few years. The vegetable oils stands as alternate fuels for natural fuels as physical and combustion properties are close to the diesel fuel. However the viscosity of the vegetable oils is higher than diesel fuel. In the present investigation waste sunflower oil is taken as alternate fuel. The high viscosity of sun flower oil is decreased by blending with diesel in various proportions and heated prior to the combustion in the cylinder. The fuel blends were heated by means of the cooling water of the engine. The blends of the varying proportions of sunflower oil and diesel were prepared, analysed and compared with diesel fuel. The effect of temperature on the viscosity of fuel blends was also studied. The performance of the engine using fuel blends were evaluated in a single cylinder C I engine and compared with the performance obtained with the pure diesel. The experiments were performed on the four stroke engine at various loads by maintaining constant speed. The fuel blends supplied to the engine are S 10 (10% of sunflower oil and 90% of diesel), S 25, S 50.It is observed that the performance of the engine is almost same up to S 25 fuel blend without much preheating, compared to pure diesel engine. The maximum brake thermal efficiency obtained is 30.3% for S 25 blend while it is 32.6% for pure diesel. The brake specific fuel consumption and maximum exhaust temperature obtained were 0.262 kg/kWh and 292 C respectively for S 25 fuel blend, while they are 0.248 kg/kWh and 242 C for pure diesel.**

Keywords: **vegetable oil blends with diesel, bsfc, brake thermal efficiency and exhaust gas temperature**

I. INTRODUCTION

Due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is a need for suitable alternate fuels for use in diesel engines. In view of this, vegetable oil is a promising alternative, because it has several advantages like it is renewable, environmental friendly, nontoxic and biodegradable. In addition to this it is produced easily in rural areas, where there is a need for modern forms of energy. Therefore, in recent years systematic efforts have been made by several researchers to use vegetable oils as fuels in engines. In the year 1900 Rudolf diesel demonstrated a new engine that run on a peanut oil. In 1912 Rudolf diesel stated that the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in course of time as important as petroleum products of present time. The fuel crisis of 1970s and 1980s focused attention on the desirability to develop alternative fuels and decrease the dependency on petroleum-based fuels. The instability of conventional petroleum sources, recent increase in petroleum prices and uncertainties concerning petroleum availability have generated renewed interest in vegetable oil fuels for diesel engines. Vegetable oils are the best candidates as alternative or emergency fuel for diesel engines.

Vegetable oils have heat contents approximately 90% of the diesel fuel. Several vegetable oils like soya bean, cottonseed, sunflower, rapeseed, peanut oils can be used as alternative fuels in diesel engines. Production of bio-fuels is costly. The fuel cost is offer the largest part of the operating cost of a diesel power plant and thus the fuel price directly correlates to the profitability of the plant. Even though operation on bio-fuels has several advantages like how exhaust emission, no global warming etc. If waste cooking oils in used which is free or very low price, the engine can run with low overall fuel cost.

Characteristics of vegetable oils

Petroleum based diesel fuel have different chemical structures than vegetable oils. The diesel contains mostly of saturated hydrocarbon comprises only carbon and hydrogen atoms which are arranged in normal or branched chain structures as well as aromatic structure. Diesel fuel can contain both saturated and straight or unbranched chain unsaturated hydrocarbons, but in little amount. On the other hand vegetables oils are acids. These fatty acids vary in their carbon chain length and in number of double bonds. Their high molecular weights, oxygen contents and unsaturation assure that they differ from those of hydrocarbon fuels like diesel. Both diesel and vegetable oils are made of chain hydrocarbons. They consist of carbon atoms surrounded hydrogen atoms. Petrol varies from 7 to 10 hydrocarbons long. The shorter the chain of carbons, the more explosive the fuel is and more power is offers in an engine. Diesel has hydrocarbons 15 long and vegetable oil has 14 to 18 long. Therefore vegetable oil has a close chemical structure as diesel fuel. Vegetable oils consist of hydrocarbons are also called as triglycerides.The triglyceride composition in unique for every oil type. Triglyceride molecules consist of glycerol bound to three fatty acid molecules. In practice always they are a mixture of triglycerides in different compositions. In some oils on triglyceride is dominating, but there is no oil that naturally consists of just one triglyceride type. The different triglycerides have different physical properties.

The oxygen contents are the most important difference in chemical composition between fossil oils and vegetable oils. Vegetable oils contain 10-12% of oxygen, whereas fossil oil normally contains just insignificant amounts of oxygen. The oxygen content affects both the specific energy and the combustion properties of the oils. Typically vegetable oils do not contain any sulphur, contrary to heavy fuel oil. Another important difference is that vegetable oils do not contain any aromatic groups while mineral oils typically contain 20-40% aromatic compounds.

1. The viscosity of the vegetable oils is significantly higher while the densities are only moderately higher.
2. Vegetables have lower heating values. They have heat contents approximately 90% of that diesel fuel.
3. Vegetable oils raise the stoichiometric fuel/air ratio due to the presence of molecular oxygen.
4. Vegetable oils may experience thermal cracking at the temperature encountered by the fuel spray in naturally aspirated diesel engines.

Viscosity reducing methods

The viscosity of the vegetable oils can be reduced mainly in two ways.

1. Transesterification to make bio-diesel.
2. Blending the vegetable oil with biodiesel and preheating.

In the Transesterification process, the vegetable oil is reacted with methyl alcohol or ethyl alcohol in the presence of a catalyst commonly used catalysts are potassium hydroxide or sodium hydroxide. During the chemical reaction the bio-diesel and glycerine are produced. The viscosity of the biodiesel is low and almost same as diesel. The problems with this process are the methyl alcohol in highly toxic in nature and it is flammable. The chemical process is complicated and suitable for the bulk production only. The production cost of the bio diesel is also high.

The other method of reducing the viscosity is, blending the vegetable oil with diesel and preheating when mixing the vegetable oil with diesel, the viscosity of the blend reduces significantly. When the blend is heated the viscosity further reduces which will improve ignition qualities. Now the blend is suitable to use directly in the compression ignition engines. The blends can be made in any convenient proportions.

In the present investigation blends S 10% (10% of sunflower oil+90% of diesel), S 25, and S 50 are prepared. The performance of the engine is examined operating on each blend and compared with pure diesel performance. The blends are heated by means of engine coolant before going to the combustion chamber.

II. EXPERIMENTAL EQUIPMENT

Engine type : Direct injection 4-stroke vertical diesel engine.

Make : Kirloskar

No. of cylinders: One

Cooling : Water cooling

Power : 5 hp

Rate speed : 1500 rpm

Bore : 80mm

Compression Ratio : 15:1

Stroke : 110 mm

Type of loading : rope breaks arrangement

Charging : naturally aspirated

Viscosity measuring instrument : standard redwood viscometer

Viscosity measurement of blends: The viscosity was determined by redwood viscometer for various fuel blends. They were prepared on volume basis and represented as follows.

10% sunflower oil + 90% diesel (S10)

25% sunflower oil + 75% diesel (S25)

50% sunflower oil + 50% diesel (S50)

60% sunflower oil + 40% diesel (S60)

75% sunflower oil + 25% diesel (S75)

Pure sunflower oil(S 100)

Properties of the fuel blends

It has been absorbed that the blends containing more than 25% sunflower oil have high viscosity compared to diesel. The viscosity of these bonds needed to be reduced more in order to make it suitable to use in the diesel engine If the blends are heated the viscosity will be reduced. Therefore the viscosity of the blends were measured at varying temperatures in the range of 25°C to 75°C by using a standard redwood viscometer.

Conducting performance test on the engine

The tests are conducted on a 4-stroke, single cylinder diesel engine. It consists of a fuel tank, pump, fuel filter, injector, lubricating oil filter, air cleaner. A rope brake dynamometer is arranged to measure the torque. A 75cc burette and 3-way cock arrangement is provided for fuel measurement. A chromel-alumel thermocouple is arranged to measure exhaust gas temperature. A thermometer is used to measure the temperature of cooling water. Whenever the test is conducted on fuel blends, a copper tube of 12mm diameter made like a coil and fitted in the fuel blend tank. This copper tube coil is connected to the engine cooling system. The hot coolant flows through the tube and heats the fuel blend before entering in to the cylinder. The temperature of the coolant noted is about 58°C during running of the engine.

III. EXPERIMENTAL PROCEDURE

The engine is started and allowed to run for 19 minutes at no load, to warm up and to attain rated speed. The time taken to consume 10cc of fuel is noted for every load at constant speed. Between each load application the engine is allowed to run 10 minutes to attain the rated speed 1500 rpm. Firstly the test was conducted on the pure diesel and calculated all the performance parameters when the test is conducted on the fuel blends the engine was started with diesel and run for some time. After running for some time, the engine coolant is heated such that the heat can be utilized to heat the fuel blend sufficiently. Then the fuel line is switched over for the supply of fuel blend to the engine .The time is noted to consume amount of oil at each load and calculated the fuel consumption, brake thermal efficiency and also measured the exhaust gas temperatures. During running of the engine, continuous supply of cooling water provided for brake drum. The performance tests were conducted only on the fuels blends S 10, S 25, S 50. Because the maximum temperature of the coolant water is only 58°C.This amount of heat is sufficient to heat the fuel blends up to S 50 only to achieve the viscosity close to the diesel. In order to heat S 60 and above blends more amount of heat is required which is not possible by the cooling medium. Therefore the exhaust gases heat can be utilized for those fuel blends.The sunflower oil used to blend was, waste cooking oil taken from a fast food centre. The oil is cleaned and filtered through a 5 micron bag filter and blended with diesel in various proportions.

IV. RESULTS AND DISCUSSIONS

Effect of temperature on viscosity of various blends

The various blends were heated and examined. The kinematic viscosities are calculated for the blends at each temperature and shown in table. Relation between viscosity and temperature is shown fig 1 .The fuel blends S 10, S 25 and S 50 are achieving the viscosities almost same as pure diesel (4 mm²/s) when they are heated to about 55°C.The fuel blends S 60, S 75, S100 are not getting the viscosity values close to diesel at 55°C.They need be heat 100°C to achieve same viscosity as diesel. The engine coolant water temperature is about 58°C. Therefore heat available in the engine coolant water is sufficient only to heat the fuel blends S 10, S 25, S 50 in order to use in the engine. Therefore performance test is conducted on engine for S 10, S 25, S 50 blends only. In order to test the other blends of S 60, S 75 they have to be heated more, which is possible by the heat available in the exhaust gas temperature. In the present investigation only heat available in the engine coolant water is utilized.

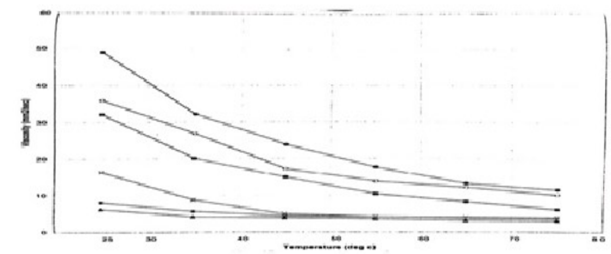

Figure 1

Effect of brake power on brake specific fuel consumption

Figure 2 compares the brake specific fuel consumption of diesel and various blends of sunflower oil at different brake loads. It was absorbed that the specific fuel consumption of the diesel as well as the blends were decreased with increasing load from 0.507 to 2.53 kW of brake power. The *bsfc* increased with further increase in brake power. The fuel consumptions were also found to increase with higher proportion of sunflower oil in the blend. Though the blends maintained a similar trend to that of diesel, the *bsfc* in the case of blends was higher compared to diesel oil in the entire load range. This may be due to the combined effects of the relative fuel density, viscosity and heating values of the blend. However the blends S 10 and S 25 have *bsfc* values found 0.262 and 0.268 kg/kWh at 2.53 brake power. The corresponding value for the diesel is 0.248 kg/kWh at the brake power. the specific fuel consumption of 0.310 kg/kWh was absorbed for the blend S 50 which a considerable value and comparable to the *bsfc* obtained with the diesel under the same load .The higher density of blends containing a higher percentage of sunflower oil has led to more discharge of fuel for the same displacement of the plunger in the fuel injection pump thereby increasing the *bsfc*. High carbon residue in the vegetable oil may cause it the increase of *bsfc* for fuel blends.

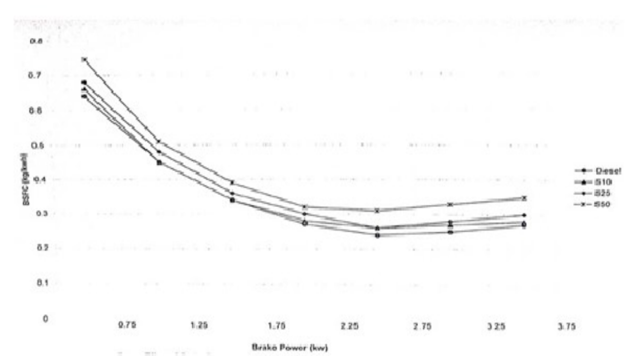

Figure 2

Effect of brake power on brake thermal efficiency

The variation of brake thermal efficiency of the engine with various blends as increasing the load and constant speed is shown in Figure 3 and compared with brake thermal efficiency obtained with pure diesel. From the results it was observed that initially with increasing brake power the brake thermal efficiencies were increased and the maximum thermal efficiencies were obtained at brake power of 2.53kW.Then the thermal efficiencies decrease with further increase in brake power .The brake thermal efficiencies of the blends are lower than that of diesel throughout entire range. The maximum thermal efficiencies of blends S 10 and S 25 are very close to the maximum thermal efficiency obtained by the diesel .The maximum break thermal efficiencies are 31.7% and 30.8% for S 10 and S 25 respectively at a brake power of 2.53 kW .For diesel the maximum thermal efficiency obtained is 32.6% at the same brake load .A reasonable thermal efficiency of 27.08% was observed for the S50 fuel blend. The drop in thermal efficiency with increasing in proportion of vegetable oil must be attributed to the poor combustion characteristics of vegetable oils due to their high viscosity and poor volatility.

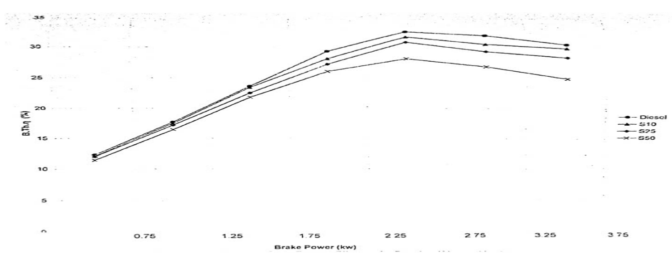

Figure 3

Effect of brake power on exhaust gas temperature

Figure 4 shows the variation of exhaust gas temperature with load for diesel and various blends. The results shows that the exhaust gas temperature increase the within increased in brake load in all the cases. The exhaust gas temperature for blend S 10 was observed to close to the exhaust gas temperature of diesel oil. The maximum exhaust gas temperature is 263°C for S 10 blends and while it is 242°C for diesel. The maximum exhaust gas temperatures were observed as 292°C and 334°C for S 25 and S 50 blends respectively. The exhaust gas temperature with blends having higher percentage of sunflower oil was found to be higher at the entire load in comparison to diesel, but deviation was observed to be greater at higher brake powers. The higher exhaust temperature with blend S 50 is indicative of lower thermal efficiencies of the engine. At lower thermal efficiency less of the energy input in the fuel is converted to work, thereby increasing exhaust gas temperature

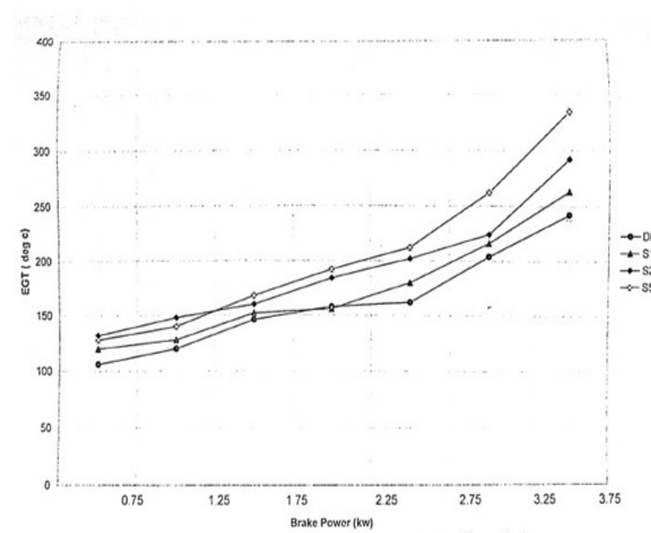

Figure 4

V. CONCLUSIONS

In the present study, the high viscosity of the waste sunflower oil is reduced by blending it with diesel and then preheated by the engine coolant, to make it suitable for using CI engine. The performance of the blends were studied and compared with pure diesel.

- The blends containing waste sunflower oil up to 50 %(S 50) have viscosities very close to the diesel when they are heated in the temperature range of 45°C to 55°C. The blends above S 50 were needed to heat about 75°C to achieve the viscosity is nearer to the diesel.
- The brake thermal efficiency of the fuel blends are lower compared to diesel. It may be due to high viscosity and poor volatility of the vegetable oils. But S 10 and S 25 blends got brake thermal efficiency is very close to the diesel.
- The exhaust has temperatures are increasing as the percentage of vegetable oil is increasing in the blends. The S 10 and S 25 blends are showing reasonable increase in exhaust gas temperature, while it is very high for S 50.
- The break specific fuel consumption of the fuel blends are higher compared to diesel. It may be due to higher fuel density and lower heating value of fuel blends S 10 and S 25 got *bsfc* values close to that of diesel.
- The mixing of vegetable oils with lighter diesel fuels improves the lubricating properties of the blends.

- The fuel blends containing up to 25% sunflower oil (S 25) can be used in diesel engines without any engine modification as their performance is same as diesel.
- As the sunflower oil taken was waste cooking oil from a restaurant and fast food centre, the cost is very cheap compared to diesel or biodiesel.
- Lower emissions, environmental friendly, non toxic no global warming are some other advantages of vegetable oils.
- As vegetable oils are agricultural products, the need for vegetable oils will become a great encouragement to the agricultural sectors.

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