Use of Vegetable oils and its Derivatives in CI Engines-A Review

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ABSTRACT

Due to the scarcity of the readily diminishing fossil fuels, the need to explore viable alternative energy resources to fuel modern CI engines has become the burning need of the hour. One such relevant alternative is the use of bio fuels and vegetable oils. Since these are renewable and eco-friendly they cause less environmental damage and green house gases than diesel. It was observed that with a little power loss vegetable oils can prove to be a satisfactory substitute for diesel fuel. The power loss is due to the fact that the oils have slightly higher viscosity than diesel, thereby resulting in a lesser degree of atomization through the fuel injector in the combustion chamber. However the performance of these oils is enhanced as they are heated further. This is due to the reduced viscosity of the oils as their temperature is increased.

Keywords: CI engine, alternative fuel, engine performance, biodiesel, jatropha

1. INTRODUCTION

Under the depleting conditions of petroleum products a search for an alternative fuel for CI engines is in progress. Vegetable oils are good alternatives to diesel oil since they are renewable and can be produced in rural areas where there is critical need for modern forms of energy. This was stated with remarkable foresight by, Dr. Rudolf Diesel, more than hundred years ago, "The diesel engine can be fed with vegetable oils and would help considerably in the development of the countries which will use it.", [4].For developing countries, fuels of bio-origin, such as alcohol, vegetable oils, biomass, biogas, Synthetic fuels, etc. are becoming important. Such fuels can be used directly, or with some modification as substitutes of diesel fuels.The known world wide reserves of petroleum are 100 billion barrels and these petroleum reserves are predicted to be consumed in about 40 years [5, 6]. So the availability of petroleum is uncertain in the future.

2. ALTERNATIVE DIESEL FUEL

Alternative fuels should be easily available, environment friendly and techno-economically competitive. One of such fuels is triglycerides (vegetable oils/animal fats) and their derivatives. Vegetable oils, being renewable, are widely available from a variety of sources and have low sulphur contents close to zero. Since there is ever increasing demand for edible vegetable oils for food purposes, we can think only of non-edible oils for this field.

2.1. Vegetable oils (triglyceride) as diesel fuels

The use of vegetable oils, such as palm, soya bean, sunflower, peanut, and olive oil, as alternative fuels for diesel engines dates back almost nine decades, but due to the rapid decline in crude oil reserves, it is again being promoted in many countries. Depending upon the climate and soil conditions, different countries are looking for different types of vegetable oils as substitutes for diesel fuels. The following table shows the production oil seeds in India, [7, 8].

Table 1 Production of oilseeds in 2002–2003 in India

Oilseed	Production (million tones)		Total oil availability (million tons)	% Recovery	Oil cost (Rs. per ton)
	World	India			
Soya bean	123.2	4.30	0.63	17	4300
Cottonseed	34.3	4.60	0.39	11	3200
Groundnut	19.3	4.60	0.73	40	6200
Sunflower	25.2	1.32	0.46	35	5360
Rapeseed	34.7	4.30	1.37	33	5167
Sesame	2.5	0.62	-	-	6800
Linseed	2.6	0.20	0.09	43	-
Castor	1.3	0.51	0.21	42	-
Rice bran	-	-	0.60	15	2000
Total	253.6	21.18	4.92	-	

2.2 Use of vegetable oils as diesel fuel

It has been found that these neat vegetable oils can be used as diesel fuels in CI engines, but this leads to a number of problems. The injection, atomization and combustion characteristics of vegetable oils in diesel engines are significantly different from those of diesel. The high viscosity of vegetable oils interferes with the injection process and leads to poor fuel atomization. The inefficient mixing of oil with air contributes to incomplete combustion, leading to heavy smoke emission, and the high flash point attributes to lower volatility characteristics. These disadvantages, coupled with the reactivity of unsaturated vegetable oils, do not allow the engine to operate trouble free for longer period of time. These problems can be solved, if the vegetable oils are chemically modified to biodiesel, which is similar in characteristics to diesel. Table 2, [8, 14] shows the properties of vegetable oils in relevance of its use in C.I. engine as fuel.

Table 2 Properties of Vegetable oils

Vegetable oil	Kinematic vis-cosity at 38 °C (mm^2/s)	Cetane No. (°C)	Heating value (MJ/kg)	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Density (kg/l)
Corn	34.9	37.6	39.5	-1.1	-40.0	277	0.9095
Cottonseed	33.5	41.8	39.5	1.7	-15.0	234	0.9148
Crambe	53.6	44.6	40.5	10.0	-12.2	274	0.9048
Linseed	27.2	34.6	39.3	1.7	-15.0	241	0.9236
Peanut	39.6	41.8	39.8	12.8	-6.7	271	0.9026
Rapeseed	37.0	37.6	39.7	-3.9	-31.7	246	0.9115
Safflower	31.3	41.3	39.5	18.3	-6.7	260	0.9144
Sesame	35.5	40.2	39.3	-3.9	-9.4	260	0.9133
Soya bean	32.6	37.9	39.6	-3.9	-12.2	254	0.9138
Sunflower	33.9	37.1	39.6	7.2	-15.0	274	0.9161
Palm	39.6	42.0	–	31.0	–	267	0.9180
Babassu	30.3	38.0	–	20.0	–	150	0.9460
Diesel	3.06	50	43.8	-	-16	76	0.855

2.2.1. Derivatives of vegetable oils as diesel fuels

Considerable efforts have been made to develop vegetable oil derivatives that approximate the properties and performance of the hydrocarbon-based diesel fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. These can be changed in at least four ways: pyrolysis; micro emulsification; dilution; and transesterification.

2.2.1.1. Pyrolysis

Pyrolysis refers to a chemical change caused by the application of thermal energy in the presence of air or nitrogen sparge. Many investigators have studied the pyrolysis of triglycerides to obtain products suitable for diesel engines.

2.2.1.2. Microemulsification

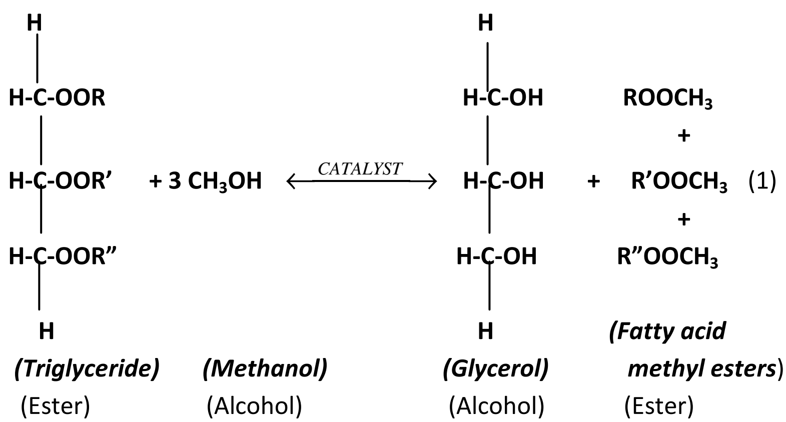
Micro emulsions are isotropic, clear, or translucent thermodynamically stable dispersions of oil, water, surfactant, and often a small amphiphilic molecule, called cosurfactant [10, 11]. Microemulsions because of their alcohol content have lower volumetric heating values than diesel fuels, but the alcohols have high latent heat of vaporization and tend to cool the combustion chamber, which would reduce nozzle coking.

2.2.1.3. Dilution

Dilution of vegetable oils can be accomplished with such materials as diesel fuels, a solvent or ethanol. The dilution of sunflower oil with diesel fuels in the ratio of 1:3 by volume has been studied and engine tests were carried out by Ziejewski et al. [12]. The viscosity of this blend was 4.88 cSt at 40^{o}C. They concluded that the blend could not be recommended for long-term use in the direct injection diesel engines because of severe injector nozzle coking and sticking.

2.2.1.4. Transesterification

Transesterification [9, 13] is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except than an alcohol is used instead of water.The transesterification reaction is represented by the general equation.



The fatty acid methyl esters (known as biodiesel) are attractive as alternative diesel fuels.

3. EXPERIMENTAL SETUP

The objectives of the present work are to evaluate the performance and exhaust emission characteristics of a CI engine with different blends of Jatropha and diesel. To achieve the above-mentioned goal, biodiesel made from Jatropha is prepared and subjected to emission and performance tests on the unmodified diesel engine running at 1500 rpm. The testing was done in

Center of Advanced Studies & research in Automotive Engineering, Mechanical Engineering Department, Delhi College of Engineering, Delhi. Engine performance and exhaust emission data were recorded and relevant parameters like BMEP, BSFC, BSEC and thermal efficiency etc were calculated. Based on these parameters, various curves were drawn and engine performance was thus calculated.

For fuel characterization of Jatropha methyl ester, the samples were subjected to several property tests in accordance with standard testing procedures. These tests included higher calorific value, specific gravity, kinematic viscosity at 40°C, and flash points. Results are tabulated below in Table 3.

Table 3

S. No	Fuel sample	Flash Point (°C)	Calorific Value KJ/Kg	Specificgravity (gm/cc)	Kinematic Viscosity (40°C)(cSt)
1.	H.S.D.	68	42450	0.832	4.623
2.	J.M.E.	169	37250	0.879	6.848

3.1. Engine System

The engine selected for emission and performance testing is manufactured by Kirloskar India Limited and has the following specifications:

Table 4: Engine Specifications

No. of Cylinders	1
No. of strokes	4
Fuel	H.S. diesel
Rated power	5.2 KW @ 1500 rpm
Cylinder diameter	87.5 mm
Stroke length	110 mm
Compression Ratio	17.5 : 1
Orifice diameter	20 mm
Inlet Valve Opens	4.5° Before TDC
Inlet Valve Closes	35.5°After BDC
Fuel Injection	23° Before TDC
Exhaust Valve opens	35.5° Before BDC
Exhaust Valve Closes	4.5° After TDC

3.2. Test Procedure

The engine is started at no load by pressing the inlet with decompression valve lever and it is released suddenly when the engine is hand cranked at sufficient speed. Feed controlled is adjusted to obtain the engine rated speed and it is allowed to run for about 30 minutes till the steady state conditions reached. To assess the present condition of the engine, a constant speed test with diesel as a fuel is carried out and base line data is generated. Test results with all other fuels are compared with base line data to evaluate the performance of the engine. With the help of fuel measuring device and stopwatch, the time elapsed for consumption of 20cc of fuel is measured. RPM, power output (in terms of weight applied and spring scale reading) and smoke density are also measured. The engine is loaded gradually keeping the rated speed within variation of permissible range and the observations of various parameter are recorded. Short-term performance test are carried out on the engine with various blend of biodiesel and diesel.

4. RESULTS AND DISCUSSIONS

The variations in the values of Thermal Efficiency with respect to BMEP are shown in figure 1. Among the all blends of Biodiesel, JME10 has the highest value of thermal Efficiency for a given BMEP. The lead diversifies as the Brake Mean Effective Pressure increases. High Thermal Efficiency can be interpreted as the cause of complete combustion, hence meager requirement of fuel for the same power output. The reduction in the mass flow rate of various blends due to better Combustion is counter acted by the reduction in the Calorific Values of the same. Hence, a drastic difference is not observed in the values of thermal efficiencies. After, JME10 the next higher thermal efficiency is of JME30, JME5 and JME20. It can be observed from the graph that at low load there is small increase in thermal efficiency as soon the load is further increased; there is sudden rise in thermal efficiency till certain point, as the load is increased further thermal efficiency decreases. It is also seen that diesel has least value of thermal efficiency in comparison to all other biodiesel blends.

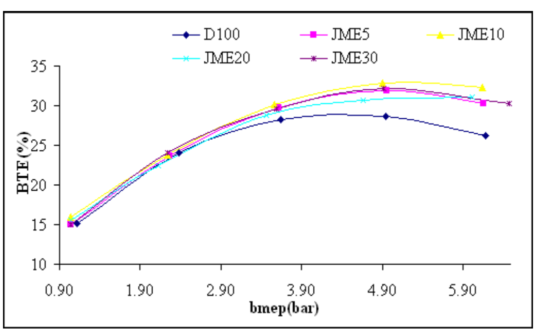


Figure 1: effect of BTE vs. bmep

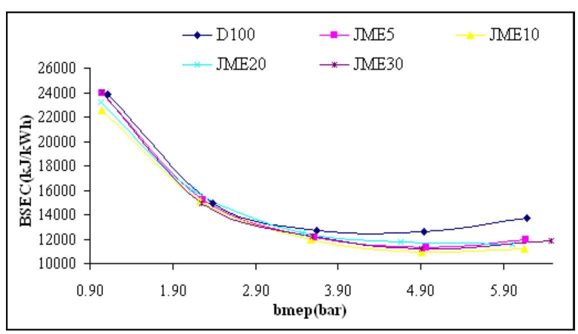


Figure 2: effect of BSEC vs. bmep

BSFC is not a very reliable parameter to compare the two fuels as the calorific values and specific gravity of the blends follow different trends. Hence, brake specific energy consumption is more reliable parameter for comparison. The figure 2 presents the variation of BSEC w.r.t. BMEP for various blends & neat diesel. Brake Specific Energy Consumption is a function of BSEC & Calorific Value. As it can be observed from the graph JME10 has the lowest BSEC closely followed by JME20, JME30 & JME5. All the blends have their BSEC lower than neat diesel. At lower load minimum BSEC of JME10 is due to better combustion of fuel & higher cetane no. of fuel.

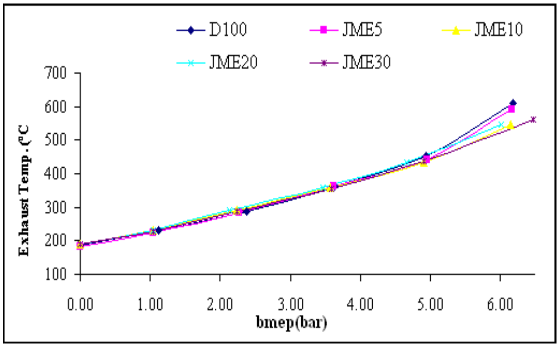


Figure 3: effect of Exhaust temp. vs. bmep

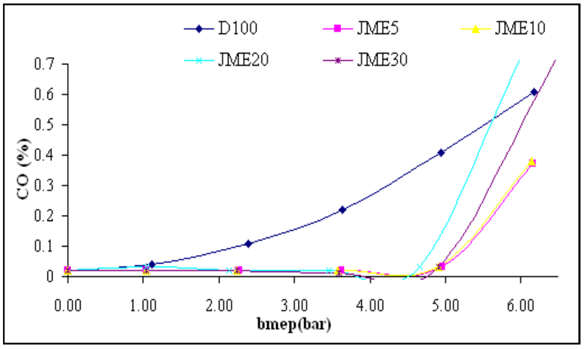


Figure 4: effect of CO vs. bmep

Figure 3 shows the variation of exhaust temperature for various blends and diesel.It is evident that there is very little variation in exhaust temperature.This could be because of same quantity of fuel being consumed per hour for both diesel and biodiesel in the engine setting.

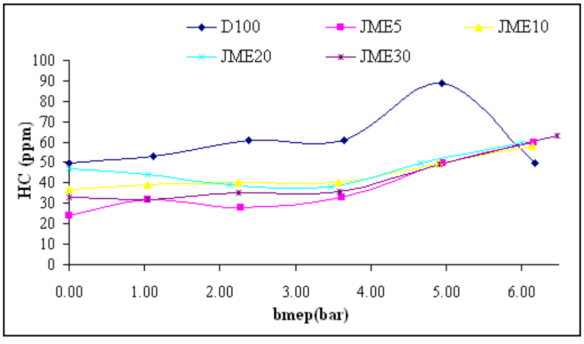


Figure 5: effect of HC vs. bmep

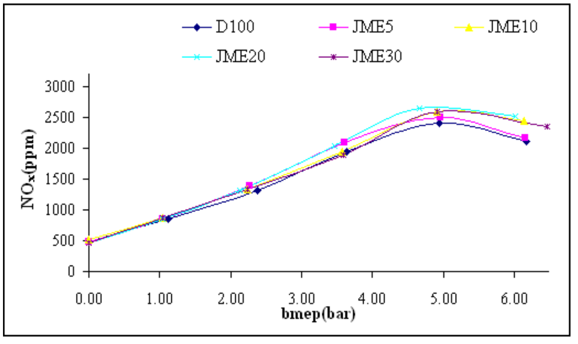


Figure 6: effect of NO_x vs. bmep

The variation of CO produced by running the engine is compared in figure 4. There is a drastic decrease in CO production in combustion when compared with diesel fuel. This is due to the presence of oxygen in the biodiesl. This oxygen helps in complete combustion of the fuel and emission of CO_2 only. At very high loads there is increase in the CO emission.

The variation of HC emissions in combustion process in the engine is shown in the figure 5. At very low load there is a variation of HC emissions from different blends but the values are very low compared to diesel fuel. As the load increases HC emission becomes same for all biodiesel blends with little increase in its value. Again the lesser values of this emission are the result of complete combustion due to presence of oxygen in biodiesel. The variation of NOx emission is shown here in figure 6. There is very little difference in the values for various blends and diesel. In the general curve of NOx production, the amount increases at higher loads.

5. CONCLUSION

In view of environmental considerations, the derivative of triglyceride, biodiesel is considered ‘carbon neutral’ because all the carbon dioxide released during consumption had been sequestered from the atmosphere for the growth of vegetable oil crops. In comparision to diesel fuel, a little amount of power loss happened with vegetable oil fuel operations. Particulate emissions of biodiesel fuels were higher than that of diesel fuel, but on the other hand, NOx emissions were less. Jatropha oil Methyl Esters gave performance and emission characteristics closer to the diesel fuel. So, they are more acceptable substitutes for diesel fuel.

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