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Investigation of Best Performing Biofuel Among Various Bio Oils Diesel Engine

Harishchandra V Astagi
Department of Mechanical Engineering,
PDA College of Engineering, Gulbarga,
Karnataka, India

Dr. Prashant Kamble
Professor, Department of Ind. & Production Engineering,
PDA College of Engineering, Gulbarga,
Karnataka, India

***Abstract*— The various available non-edible vegetable oils have been investigated experimentally for engine characteristics on a diesel engine. The non-edible straight vegetable oils used are Mahua, Neem, Castor and Linseed oil. These oils posed operational and durability problems with the long term usage. Poly-unsaturated character of straight vegetable oils, low volatility and, high viscosity are the main cause for poor performance. Hence, fuel pre-heating is done to reduce the viscosity of neat oils and experiment is carried out on single cylinder diesel engine. The various performance and emission parameters are investigated and compared with the baseline data of diesel. The experimental results showed the significant improvements found with use of neem oil and castor oil for performance and exhaust emissions characteristics of the engine.**

Keywords* — Engine, Non-edible vegitable oils, Performance characteristics, Exhaust Emission Characteristics

I. INTRODUCTION

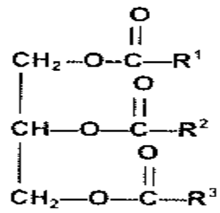
The limited resources of petroleum fuels and its products need for increasing concerns for environment, and steep rise in crude oil prices there has been renewed focus on vegetable oils as an alternative to petroleum fuels. Vegetable oil is environment friendly, renewable fuel and is easily available worldwide. These are the triggering factors to consider vegetable oils and their derivatives as substitute fuel to petroleum diesel. However, high viscosity and low volatility which are major disadvantages of vegetable oil cause poor fuel atomization, poor combustion, ring sticking, injector cocking, injector deposits, and lubricating oil dilution. The modern fuel injection system of engines is more sensitive to fuel viscosity. Viscosity of the vegetable oils needs to be reduced in order to improve fuel flow, combustion and engine performance. Heating is one of the methods adopted to reduce viscosity of vegetable oils. However transesterification and Blending with diesel are common methods used.

Though many researchers worked on the various bio oils and investigated that vegetable oils are feasible substitutes for diesel fuel, but still a lot of work that needs to be carried to use vegetable oil in diesel engine.

The literature review shows that many researchers have investigated non-edible vegetable oils such as Jatropha, kusum (Schlerlchera trijuga), Karanja (Pongamia glabra), Rice bran, linseed etc. and also some of the edible vegetable oils for the performance, combustion and emission characteristics of diesel engine. The present energy crisis inspired the authors to compare the engine characteristics of diesel engine using some of the non-edible oils such as Neem, Linseed, Mahua and Castor oil and select the best performing oil to be used as alternate fuel for diesel engine.

II. CHEMICAL COMPOSITION

Compared to conventional diesel, Vegetable oils have very low heat content, comparable cetane number, low volatality, and stoichiometric air/fuel ratio. Calorific value decreases with increasing un-saturation as a result of fewer hydrogen atoms in their molecular structure. The typical vegetable oil has following molecule structure:



The molecule of vegetable oil contains R1, R2 and R3 straight chain alkyl groups and free fatty acids. The vegetable oil poses high viscosity and low volatility compared to mineral diesel. Two types of problems are associated with the use of vegetable oils in the engines - operational and durability problems. Operational problems are related to starting ability, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injector tip, ring sticking and lubricating oil dilution. The extremely low volatility, high viscosity, polyunsaturated character of vegetable oils is the cause for the operational and durability problems. High viscosity of oils results in poor fuel atomization, large droplet size and thus high spray jet penetration. The jet tends to emerge in the form of solid stream instead of small droplets. This results in poor premixing and distribution with air in combustion chamber which lead to poor combustion, loss of power and economy.

Blending with diesel, cracking / pyrolysis of oil, emulsification or transesterification of vegetable oils may overcome these problems.

III. MATERIALS AND METHODS

The Mahua, Neem, Castor and Linseed oil used for this work were collected, crushed in mechanical expeller from the seeds collected from Biofuel centre, Gulbarga University, Kalaburagi (Karnataka).

IV. EXPERIMENTAL SET UP AND PROCEDURES

The experimental setup consists of a diesel engine fitted with an eddy current dynamometer. Fuel tank is fitted with thermostat-controlled heater with built in control panel. The setup has complete PC based data acquisition system. The fuel filters are fitted at the inlet and outlet of the fuel pump. Fuel flows to the injector pump under gravity. Thermocouple are used for measuring Lubricating oil temperature and water temperature. The constant flow rate of cooling water is maintained at temperature 65 to 70^{0}C throughout the experiment. The emission characteristics are analyzed by using 5- gas analyzer and smoke meter.

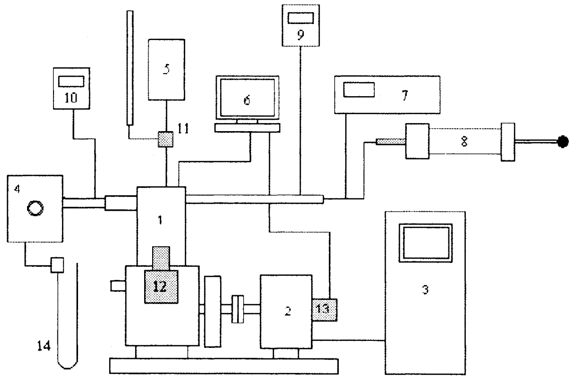


Fig. 1. Experimental test rig

1	Diesel engine	8	Exhaust gas calorimeter
2	Eddy current dynamometer	9	Exhaust temperature indicator
3	Dynamometer control	10	Air inlet temperature
4	Anti pulsating drum	11	Two way valve
5	Fuel tank	12	Fuel injection pump
6	Computer with DAQ	13	Crank angle encoder
7	Smoke meter	14	Manometer

EXPERIMENTAL SETUP AND PLAN:

The physical and chemical properties of various oils under test are measured in fuel testing laboratory as per Indian standards (IS) methods and are shown Table 1. Calorific value are measured found by using Bomb calorimeter and viscosity by Redwood viscometer. The flash point and fire point are evaluated by Pensky-Martens apparatus.

Table 1: Properties of vegetable oils and diesel.

Properties	Diesel	Castor	Neem	Mahua	Linseed
Viscosity, cSt (at 40°C)	5.031	78	16.24	35	29
Calorific Value, kJ/kg	42807	39300	40274	38100	36200
Sp. Gr. At 25°C	0.844	0.929	0.8745	0.927	0.976
Density, kg/m^3	836	918	875	927	946
Flash point, °C	79	179	109	267	330
Fire point, °C	86	197	---	299	355

The performance test on the engine are conducted at constant speed of 1500 rpm and varying load from 0 to full load. The performance parameters, such as brake thermal efficiency, fuel consumption, sp. Fuel consumption and exhaust gas temperature are evaluated. The exhaust gas emissions were measured by 5 gas analyser. All the observations and results are analyzed on data acquisition system.

ENGINE SPECIFICATIONS:

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV-SR II, naturally aspirated
Engine	Single cylinder, DI
Bore / stroke	87.5mm/110mm
Compression ratio	16.5:1
Speed	1500 r/min, constant
Rated power	5.2kW
Working cycle	four stroke
Injection pressure	200bar/23° deg BTDC
IVO/ IVC	4.5° BTDC/35.5° ABDC
EVO/ EVC	4.5° BTDC/35.5° ABDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle
Resolution of 1 degree	360˚ encoder with a resolution of 1^0

V. RESULTS AND DISCUSSIONS

5.1 Kinematic viscosity

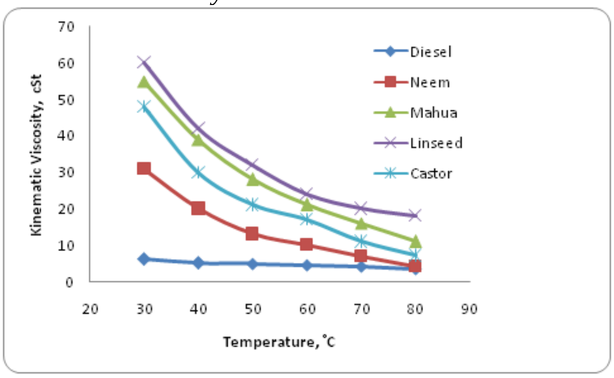


Fig 2 Effect of temperature on kinematic viscosity

Figure-2 shows the effect of temperature on kinematic viscosity of different neat vegetable oils under test. Result shows that the viscosity of oils is approximately close to that of diesel at the temperature of 80°C. This shows that preheating is required all the oils for easy flow through pump and nozzle.

5.2 Brake thermal efficiency

Figure-3 shows variation of brake thermal efficiency with brake power for diesel and different vegetable oils. Brake thermal efficiency of Linseed, mahua, and castor are very less and neem has higher efficiency and very close to diesel for entire range of operation. Maximum brake thermal efficiency of Neem, Castor and Mahua,are 27% , 25.12% and 23.03% respectively against 30.95% of diesel oil, which are well comparable with diesel

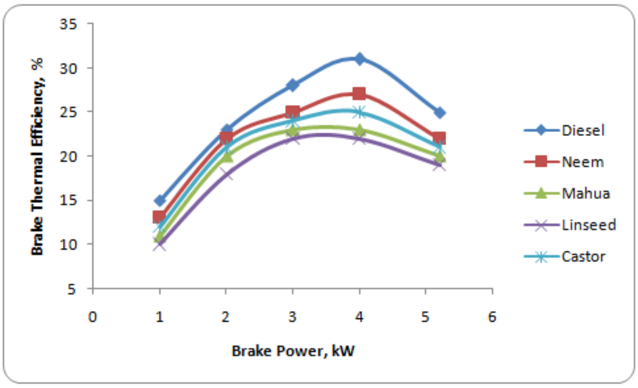


Fig 3: Brake thermal efficiency with brake power.

. The drop in brake thermal efficiency is attributed due to high viscosity and poor volatility of the vegetable oils, which leads to poor combustion. It seen that the thermal efficiency of neem oil is better in comparison to all oils, due to its higher calorific Value.

5.3 Brake Specific Fuel Consumption:

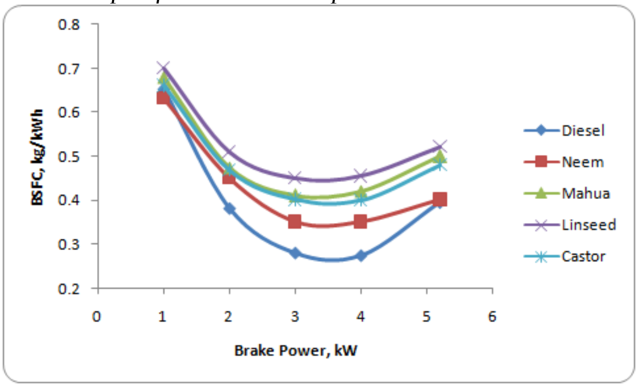


Fig 4. Brake specific fuel consumption vs brake power

Figure-4 shows variation of Brake specific fuel consumption of different vegetable oils with brake power. BSFC of Neem oil is found close to diesel. Neem, Castor oil have minimum BSFC of 0.349 and 0.399 kg/kW-hr respectively against 0.275 kg/kW-hr diesel. It was observed that sfc of the preheated oil was higher than diesel. Due to lower calorific values, higher density, higher viscosity and oxygen content of the vegetable oils, more quantity is required to be injected to produce same amount of power. Poor volatility leads to the poor combustion characteristic of vegetable oils and hence drop in thermal efficiency and increase in BSFC.

5.4. Exhaust gas temperature

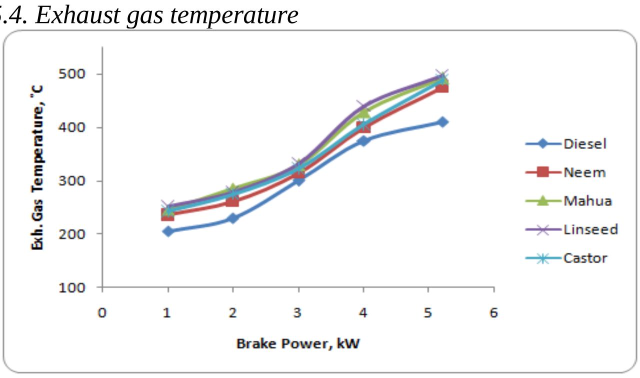


Fig. 5. Exhaust temperature vs brake power.

Figure-5 shows variation of exhaust temperature with brake power for vegetable oils under test. Exhaust temperature of Neem is almost same as that of diesel through out the operating range. This is an indication of lower exhaust loss and could be possible reason for higher performance. Linseed and mahua shows higher exhaust temperature compared to diesel.

5.5 Smoke density

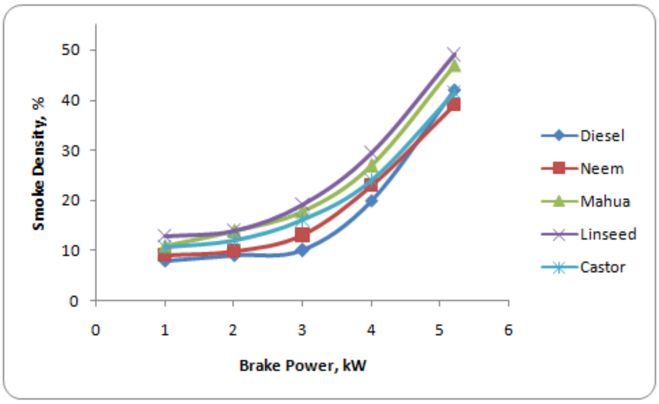


Fig 6. Smoke emission vs brake power

Figure 6 indicate smoke emission with brake power for Diesel and vegetable oils under test. Smoke emission of neem is close to the diesel for entire range of operation. Linseed oil has more smoke emission among all the test oils. The higher viscosity and higher composition of CO in preheated oils lead to incomplete combustion. Hence, smoke composition was found much higher in vegetable oil.

VI. CONCLUSIONS

Experimental investigations on Neem, Mahua, Linseed and Castor are carried out on a single cylinder DI diesel engine to find their suitability to use as alternate fuels. Further the performance and emission characteristics are evaluated and compared with diesel and best performing fuel is determined.

From the investigations, it is concluded that:

- The physical and chemical properties like viscosity, density, flash point and fire point of vegetable oils under test are higher. Calorific values are lower than that of diesel.
- Neem, Mahua and linseed oil attain viscosity very close to the diesel when heated at at 80^{o}C. Hence preheating of oils is required for smooth flow and injection.
- Neem, Castor and Mahua are found to be better in performance and emission characteristics compared to other fuels.
- Smoke emission of Castor and Neem are well comparable compared with other oils. The smoke emission of Linseed oil is on higher side for entire range of operation.

From the above discussion, it may be concluded that that Neem with preheating has acceptable performance with lower emissions. Hence it can be substituted as fuel for diesel engine without any modification.

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