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EXPERIMENTAL INVESTIGATION OF A MIXTURE OF A NON-EDIBLE PLANT OIL AND AN ADDITIVE AS A STRAIGHT FUEL IN C I ENGINE OF AN IRRIGATION PUMP SET

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ABSTRACT

Straight vegetable oils (SVOs) are currently the best alternative energy options for tropical and sub-tropical countries such as India. However, the high viscosity of SVOs often causes blockages if it is fed at room temperature to the engine. It has been proven in repeated studies that the viscosity of SVOs can be brought to very nearly that of diesel by heating them to a sufficient temperature (around 160 °C). This has lead to the development of inline-heaters. All currently available inline-heaters however, only heat the oil up to about 80 °C which is ineffectual in bringing the viscosity of pure oil to the required range. Volatility of the SVO is however rarely addressed. In this work the viscosities and flash point temperatures were found for the three most popular non-edible oils such as Pongamia oil, Castor oil and Neem oil with 3% or 5% of Kerosene or Petrol as additives. Pongamia oil with 3% Petrol as the additives was tested in a diesel engine and found to be a satisfactory replacement of diesel fuel requiring no further heating of the fuel mixture. Therefore the paper addresses the task of developing an alternative fuel which can be used directly into a diesel engine without further processing or heating. Such an engine can be suitable to use for irrigation water pumps to run on locally obtainable non edible oil, such as Pongamia oil with small proportion of additives such as Petrol.

Keywords— Irrigation pump set, Pongamia oil, Straight vegetable oil, Petrol, Kinematic viscosity.

1. INTRODUCTION

Gradual depletion of world petroleum reserves, increase in crude oil prices and impact of environmental pollution have motivated the scientific community all over the world to look for suitable alternative fuels. This results in renewed focus on vegetable/plant oils. Several researchers have made systematic efforts to use plant oils and their esters as fuel in diesel engines [1]. The use of non-edible vegetable oils as compared to edible oils is very significant in developing countries because of the tremendous demand for edible oils as food and hence they are far too expensive to be used as fuel at present. Here an experimental investigation has been made to develop a suitable mixture of non-edible plant oil as straight fuel. The non-edible plant oils include Pongamia oil, Castor oil and Neem oil in major proportion as fuel and a small quantity (3% or 5%) of Petrol or Kerosene as additives [2]. Viscosity and Flash point tests were carried out for the twelve different samples (mixture of non-edible plant oil and additives) in SAYBOLT viscometer and Cleaveland open cup flash and fire point apparatus respectively. The best fuel mixture among the test samples were identified based on the kinematic viscosity of fuel mixture whose viscosity is equivalent to that of petroleum diesel. Further a 5 hp water cooled diesel engine was run at 60% load condition with heated pure Pongamia oil. Heating is done by an external source up to 160 °C and the hot oil is poured directly into the fuel tank, because at this temperature viscosity of pure Pongamia oil reduces to the viscosity of the petroleum diesel. The engine was run with heated pure Pongamia oil for the duration of 10 hours. After the completion of test, the engine components were dismantled and the depositions on fuel injector and exhaust valve were observed [3]. Finally the same engine was run at 60% loading condition [4] with best fuel mixture identified from the earlier testing (mixture of non-edible plant oil and additive) without heating for the duration of 10 hours. After the completion of test, again dismantled engine components were observed for depositions on the fuel injector and exhaust valve.

2.EXPERIMENTAL SETUP

The engine used is a Kirloskar AV-1 and the specifications for the engine are listed in Table 1 below. The engine is meant for the agriculture sector and comes with various attachments like water pumps, threshers, etc. In this case, the engine was connected to an A.C. generator. Fig 1 and Fig 2 show the experimental setup which includes a 5 hp diesel engine with generator attachment, an ammeter and an electric heater for loading the generator. All together form a complete circuit which is used to measure the power generated by the engine with stipulated conditions. As the engine used was part of a generator set, the loading system comprised of a 2.5 kW electric stove with 2.22 kW power rating when the engine is running at ~1500 rpm. The load on the diesel Engine is about 60%.

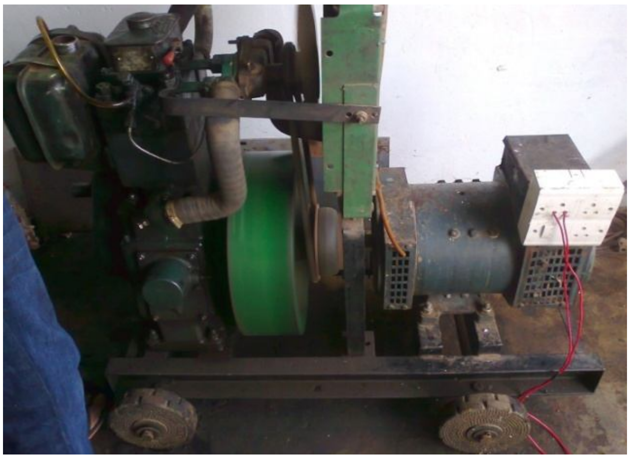

Fig 1: Diesel generator set used for the test

Fig 2: Load given to an engine during running on fuel mixture

Table 1: Specifications of the diesel engine

Cooling	Water-Cooled Engine
Model	AV1
No. of Cylinders	1
Cubic Capacity (cc)	553
Rated Speed (rpm)	1500
Governing	Class"B1"

2.1 Engine tests with heated pure Pongamia oil

The diesel engine is run with 60% load condition using heated pure Pongamia oil as follows.

- Heating is done using an external source and then the hot oil is poured into the fuel tank.
- The engine is run for the duration of 10 hours with heated Pongamia oil and the fuel consumption is noted down.
- After the completion of the test the engine head is dismantled to observe the depositions on components such as piston top, fuel injector and exhaust valve.

2.2 Engine tests with fuel mixture

Using a particular fuel mixture selected as described below, the engine was again run at about 60% load and similar observations were made on the earlier engine components.

- Based on viscosity and flash point measurements, suitable fuel mixture whose viscosity is closer to that of the petroleum diesel is chosen for this test.
- The chosen fuel mixture composed of 97% of Pongamia oil and 3% of petrol. This fuel mixture has a kinematic viscosity of 2.3 cSt at 40 °C, whereas for petroleum diesel the kinematic viscosity at 40 °C is 2.27 cSt.
- The engine was run for 10 hours and fuel consumption was noted. After the run, the engine head was dismantled and the observations on piston top, fuel injector and exhaust valve were again noted.

3.VISCOSITY MEASUREMENT OF DIFFERENT FUEL SAMPLES

Kinematic viscosity of any fuel is a very essential property which decides the flow characteristics of the fuel and affects the injection of fuel in injector nozzle. Kinematic viscosity is determined by using SAYBOLT viscometer for different temperature ranges. Kinematic viscosities of different fuel mixtures with temperature variation are shown in the table 2. Kinematic viscosity is calculated based on the measured time to collect 60 ml of oil through the viscometer using variable coefficients as given below.

1. For $t < 100$ seconds, Kinematic viscosity $\nu = 0.226t - 195/t$ cSt (1)

2. For $t > 100$ seconds, Kinematic viscosity $\nu = 0.220t - 135/t$ cSt (2)

Where t = SAYBOLT time in seconds to collect 60 ml of oil in the flask of the viscometer.

Table 2: Kinematic viscosity of different fuel mixtures (non-edible oils with additives)

Sl. No.	Samples of fuel mixture	Kinematic viscosity in cSt at constant temperature	Kinematic viscosity in cSt at varied temperature
1	Pongamia (97%) + Kerosene (3%)	24.3 (At 303 K)	4.1 (At 313 K)
2	Pongamia (95%) + Kerosene (5%)	21.1 (At 303 K)	2.3 (At 313 K)
3	**Pongamia (97%) + Petrol (3%)**	**18.9 (At 303 K)**	**2.3 (At 313 K)**
4	Pongamia (95%) + Petrol (5%)	10.8 (At 303 K)	1.1 (At 313 K)
5	Castor (97%) + Kerosene (3%)	51.1 (At 303 K)	7.4 (At 338 K)
6	Castor (95%) + Kerosene (5%)	48.9 (At 303 K)	5.8 (At 338 K)
7	Castor (97%) + Petrol (3%)	46.6 (At 303 K)	4.8 (At 338 K)
8	Castor (95%) + Petrol (5%)	39.2 (At 303 K)	4.1 (At 338 K)
9	Neem (97%) + Kerosene (3%)	7.4 (At 303 K)	4.1 (At 311 K)
10	Neem (95%) + Kerosene (5%)	5.5 (At 303 K)	3.4 (At 311 K)
11	Neem (97%) + Petrol (3%)	4.8 (At 303 K)	2.7 (At 311 K)
12	Neem (95%) + Petrol (5%)	4.1 (At 303 K)	2.3 (At 311 K)

Graphical representation for the values of kinematic viscosity with respect to the temperature for different fuel mixture is plotted in the Fig 3. The upper horizontal line in the Fig 3 represents the maximum viscosity value allowed by the diesel standard ASTM D-975. This value is shown as a horizontal line and it is at 4.5 cSt. Similarly, the lower horizontal line represents 2 cSt. The nature of kinematic viscosity decrement with increase in temperature can be observed for four fuel mixtures.

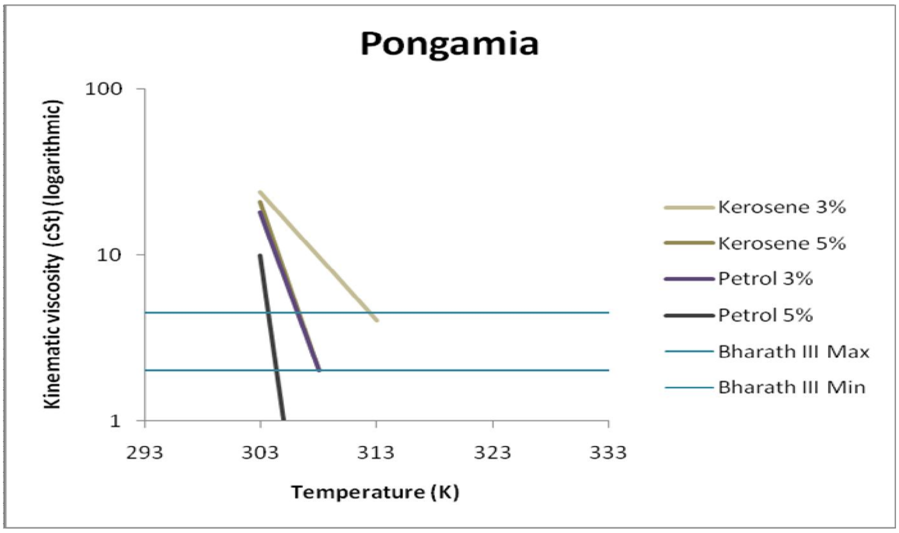

Fig 3: Semi-log plot of viscosity variations with temperature for Pongamia with additives

4.FLASH POINT MEASUREMENTS

Flash point of the fuel mixtures are measured using the Cleave-land flash and fire point apparatus. The measured values are shown in table 3

Table 3: Flash point temperatures of fuel mixtures (non-edible oils with additives)

Sl. No.	Samples of fuel mixture	Flash point in °C
1	Pongamia (97%) + Kerosene (3%)	268
2	Pongamia (95%) + Kerosene (5%)	238
3	**Pongamia (97%) + Petrol (3%)**	**190**
4	Pongamia (95%) + Petrol (5%)	172
5	Castor (97%) + Kerosene (3%)	288
6	Castor (95%) + Kerosene (5%)	260
7	Castor (97%) + Petrol (3%)	220
8	Castor (95%) + Petrol (5%)	200
9	Neem (97%) + Kerosene (3%)	172
10	Neem (95%) + Kerosene (5%)	138
11	Neem (97%) + Petrol (3%)	115
12	Neem (95%) + Petrol (5%)	95

5.EXPERIMENTAL RESULTS

A digital multi-meter was used to measure the voltage across the circuit during running the engine and to ensure that there is no shorting or open circuit in the load. An ammeter is used to measure the current across the circuit in terms of amperes. The ammeter used in the experiment had capacity to measure the current up to 30 amperes. Table 4 shows the test fuel mixture, which appears most suitable for running the engine compared to other fuel mixtures.

Table 4: Optimum Test fuel mixture

Testing fuel	Flash point temperature (°C)	ν (cSt)	
		At 30 °C	At 40 °C
Pongamia oil (97%) + Petrol (30%)	190	18.9	2.3

After continuous running of the test engine for the duration of 40 minutes, the temperature of radiator water reaches to 80 °C-which could be used to maintain the temperature of fuel mixture to 40 °C, the desired temperature to be maintained in order to reduce the viscosity to 2.3 cSt. Table 5 shows the measured values of an experiment carried out for optimum test fuel mixture.

Table 5: Measured values during experiment for optimum test fuel mixture

The rate of fuel consumption recorded	1.8 litres/hour
Ammeter reading	9 amperes
Digital multi meter reading	250 Volts
Power generated	2.22 KW
Density of measured purified Pongamia oil	930 kg/m^3
Density of optimum fuel mixture	900 kg/m^3

Fig 4: Fuel Injector- With sticky carbon depositions

Fig 5: Exhaust valve - With sticky carbon depositions

Fig 6: Fuel injector: After cleaning

Fig 7: Exhaust Valve: After cleaning

Fig 8: Fuel injector: carbon deposits after 10 hours test on fuel mixture

Fig 9: Exhaust Valve: After 10 hours test on fuel mixture

6.CONCLUSSIONS

In this work the viscosities and flash point temperatures were found for the three most popular non-edible oils namely Pongamia oil, Castor oil and Neem oil with 3% or 5% of Kerosene or Petrol as additives. Pongamia oil with 3% Petrol as the additives was tested in a diesel engine and found to be a satisfactory replacement of diesel fuel with no further heating of the fuel mixture. A visual comparison of the carbon depositions on fuel injector and exhaust valve was made for an engine when it runs with heated pure Pongamia oil only and with a mixture of Pongamia and 3% Petrol as additives- the former case being unsatisfactory and the latter in the acceptable range.

- This is a huge breakthrough for the use of these oils in diesel engines in Indian villages as it requires no processing and no modifications to the engine and the oil seeds can be easily grown there.
- The study compares fuel injector fouling with Petroleum diesel, heated pure Pongamia oil and fuel mixture composed of 97% Pongamia oil and 3% of Petrol.
- It was found that when a 5 hp diesel engine is run with vegetable oil mixture (97% of Pongamia oil 3% of Petrol), the output performance of engine obtained were same as that obtained with conventional petroleum diesel.
- Fuel consumption for 60% load condition for **Petroleum diesel** as fuel was 1.4 litres/hour and nature of depositions on fuel injector and exhaust valve was observed as dry fine particles of carbon.

- Fuel consumption for 60% load condition for **heated pure Pongamia oil** as fuel at 160 °C was 2 litres/hour and the nature of depositions on fuel injector and exhaust valve was observed as Sticky carbon deposits as shown in Fig 4 and Fig 5 respectively. Fig 6 and Fig 7 show the cleaned fuel injector and exhaust valve, prior to testing with tested fuel mixture.
- Fuel consumption for 60% load condition for **tested fuel mixture** (97% of Pongamia oil and 3% of Petrol) as fuel was 1.8 litres/hour and the nature of depositions on fuel injector and exhaust valve was observed as soot depositions similar to the nature of petroleum diesel fuelled depositions as shown in Fig 8 and Fig 9 respectively.
- The work reported requires extensive testing to obtain the complete engine map and homologation trials to establish firmly the fuel use practice. However based on the results obtained here, villagers could start using the mixture when diesel is unaffordable.

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