academicJournals

Vol. 4(7), pp. 119-124, July 2013
DOI: 10.5897/JPTAF 10.004
ISSN 2360-8560 ©2013 Academic Journals
http://www.academicjournals.org/JPTAF

Journal of Petroleum Technology and Alternative Fuels

Full Length Research Paper

Experimental investigation on compression ignition engine powered by preheated neat jatropha oil

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Accepted 13 June, 2013

In the present study, the high viscosity of the jatropha curcas oil was decreased by preheating. The effect of fuel inlet temperature on performance of diesel engine is evaluated. A single cylinder, four stroke, constant speed, air cooled, direct injection diesel engine developing a power output of 3.7 kW at 1500 rev/min typically used in agricultural sector was tested using neat jatropha oil as fuel. Experiments were conducted for the fuel inlet temperatures of 30°C (J-00), 50°C (J-50), 70°C (J-70), 90°C (J-90) and 110°C (J-110). The acquired data was analyzed for various parameters. The performance of the engine using neat jatropha oil was evaluated and compared with the performance obtained with methyl-ester of Jatropha oil (JME) and diesel fuel. The engine performance parameters with neat jatropha oil were found to be comparable to the performance obtained with mineral diesel and Jatropha methyl ester. The exhaust gas temperature was observed to be lower at all fuel inlet temperature except for fuel inlet temperature of 110°C, compared to the diesel fuel operation. The brake specific fuel consumption (BSFC) of neat jatropha oil vary with fuel inlet temperature. Acceptable thermal efficiencies of the engine were obtained. From the properties of neat jatropha oil and engine test results, it was observed that fuel inlet temperature of 90°C is an optimal preheating temperature for neat jatropha oil and can be substituted for diesel without any engine modification. However, for higher value of fuel inlet temperature above 90°C, performance was observed to be marginally inferior.

Keywords: Alternative fuel, biodiesel, jatropha oil, preheating, fuel inlet temperature.

INTRODUCTION

Transportation fuels produced from biomass are commonly called biofuels. First-generation biofuels are mostly produced from feedstock that is also used for food products. Such biofuels are ethanol from sugar cane or corn, biodiesel from canola seeds or soybeans, and others. They are commonly produced all over the world. The second-generation biofuels, which come from non-edible sources, have high potentials as renewable transportation fuel (Tuomo and Reijo, 2009).

India being a predominantly agricultural country requires major attention for the fulfillment of energy demands of farmers. But at the same time, diesel fuel consumption must be kept to a minimum level because of its price and shortage in supply. The increased use of diesel in agriculture and transportation sectors has resulted in diesel crisis (Banapurmath et al., 2008). Vegetable oils hold good promise as alternative fuel for diesel engines. They are biodegradable and renewable fuels. The flash point of vegetable oils is high and hence it is safe to use them (Pramanik, 2003). Vegetable oils typically have large molecules with carbon, hydrogen, and oxygen being present (Kumar et al., 2010). They

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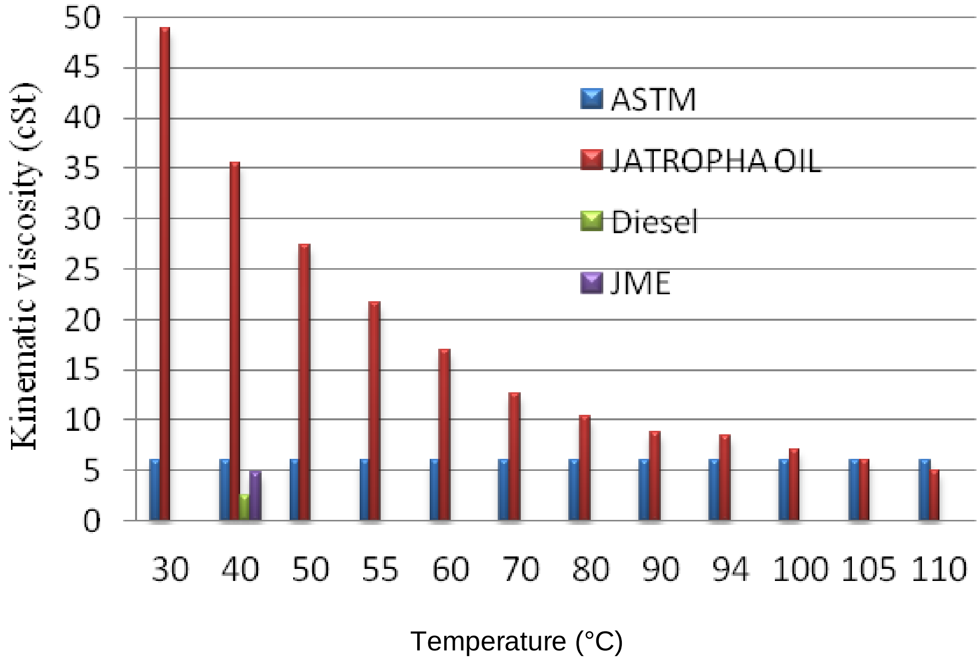

Figure 1. Effect of temperature on viscosity of Jatropha oil.

have a higher molecular mass and viscosity. Contrary to fossil fuels, vegetable oils are free from sulfur and heavy metals (Agarwal et al., 2007).

A number of vegetable oils like rapeseed oil, neem oil, palm oil, karanji oil, coconut oil, cottonseed oil, jatropha oil, etc., were tested to evaluate their performance in diesel engines. Among these, jatropha oil was found as the most suitable for diesel (Kumar et al., 2010). As a compression ignition engine fuel, jatropha oil has a high cetane number, which is very close to diesel (Agarwal et al., 2008). The flash point of jatropha oil is around 230°C high as compared with 71°C for diesel approximately. Due to its high flash point, jatropha oil has certain advantages like greater safety during storage, handling, and transport. However, this may create problems during starting. The viscosity of jatropha oil is less compared with other vegetable oils but higher than diesel (Kumar et al., 2010).

The main problem associated with the use of vegetable oils is their high viscosity and poor volatility. Since straight vegetable oils are not suitable as fuels for diesel engines, they have to be modified to bring their combustion related properties closer to diesel. This fuel modification is mainly aimed at reducing the viscosity to eliminate flow/atomization related problems (Pramanik, 2003). Different methods have been tried towards the efficient use vegetable oils. Some of them are as follows:

(1) Heating/pyrolysis
(2) Transesterification with alcohols
(3) Dilution/blending with diesel/alcohol
(4) Dual fueling with gaseous and liquid fuels,
(5) Micro-emulsion, and
(6) Use of additives, etc.

Heating method was used to lower the viscosity of Jatropha oil in order to eliminate various operational difficulties. Forson et al. 2004 used Jatropha oil and diesel blends in compression ignition engines and found its performance and emissions characteristics similar to that of mineral diesel at low concentration of Jatropha oil in blends. Agrawal et al. 2007 and Pramanik, 2003 tried to reduce the viscosity of Jatropha oil by heating and also blending it with mineral diesel. Viscosity of Jatropha oil was measured at different temperatures in the range of 30–110°C using Redwood viscometer 1. The kinematic viscosity values are plotted in Figure 1.

Viscosity of Jatropha oil decreases remarkably with increasing temperature. The prescribed American Society for Testing and Materials (ASTM) limit of viscosity for C.I. Engine fuels is 6 cSt. Viscosity of Jatropha oil was found to be 5.9 cSt at 105°C. Hence, Jatropha oil should be heated to 105°C in order to bring its viscosity within the ASTM limit. The viscosity of diesel was 2.44 cSt at 40°C which is well within the ASTM limit.

Fuel properties

The important chemical and physical properties of Jatropha curcas oil were determined using standard ASTM and American Oil Chemists Society (AOCS)

Table 1. Properties of mineral diesel and Jatropha oil.

Property	Fuel		
	Mineral diesel	**Jatropha oil**	**JME**
Density (kg/m^3)	840±1.732	917±1	880
Kinematic viscosity at 40°C (cSt)	2.44±0.27	35.98±1.3	4.84
API gravity	36.95±0.346	22.81±0.165	-
Cloud point (°C)	3±1	9±1	-
Pour point (C)	6±1	4±1	3±1
Flashpoint (C)	71±3	229±3	191
Fire point (C)	103±3	274±3	-
Conradson carbon residue (%,w/w)	0.1±0.0	0.8±0.1	0.01
Ash content (%,w/w)	0.01±0.0	0.03±0.0	-
Calorific value (MJ/kg)	45.343	39.071	37.2
Carbon (%,w/w)	80.33	76.11	-
Hydrogen (%,w/w)	12.36	10.52	11.81
Nitrogen (%,w/w)	1.76	0	-
Oxygen (%,w/w)	1.19	11.06	10.91
Sulfur (%,w/w)	0.25	0	<0.001
Cetane Number	46	23-41	51.6

Table 2. Engine Specification.

Item	Technical Data
Model	VCR 1
Make	COMET
Rated BHP/kW	5.0/3.7
Bore x Stroke (mm)	80.0 x110.0
Swept Volume (CC)	553
Compression Ratio	17.5:1
Rated RPM	1500
No. of cylinder	1
Method of cooling	Air
Beaning type	Bush
Sp. Fuel consumption gms / Kwr	251
Lubrication system	Plunger pump
Crank shaft height (mm)	203

methods and compared with diesel shown in Table 1. The heating value of the vegetable oil is comparable to the diesel oil and the cetane number is lower than the diesel fuel. However, the kinematic viscosity and the flash point of Jatropha oil are several times higher than the diesel oil.

METHODOLOGY

A naturally aspirated direct injection diesel engine is more sensitive to fuel quality. The main problem of using neat Jatropha oil in a diesel engine is its high viscosity. Therefore, it is necessary to reduce the fuel viscosity before injecting it in the engine. In this work, heating method has been used to decrease the viscosity of neat jatropha oil. Load on the engine is varied from partial to full load condition. Engine parameters are measured for varied fuel inlet temperatures. For comparison, the engine was also tested with diesel and Jatropha methyl ester (JME). The engine specifications are given in Table 2. The engine was loaded with a single phase alternator (6 kVA, 50 Hz, 1500 rpm); a gravimetric type fuel sensor was used to measure fuel flow and the temperature of exhaust gas was measured using PT 100 RTD (resistance temperature detector).

RESULT AND DISCUSSION

Fuel inlet temperature

The test results cover the effect of increasing fuel inlet temperature on the viscosity of neat jatropha oil and its

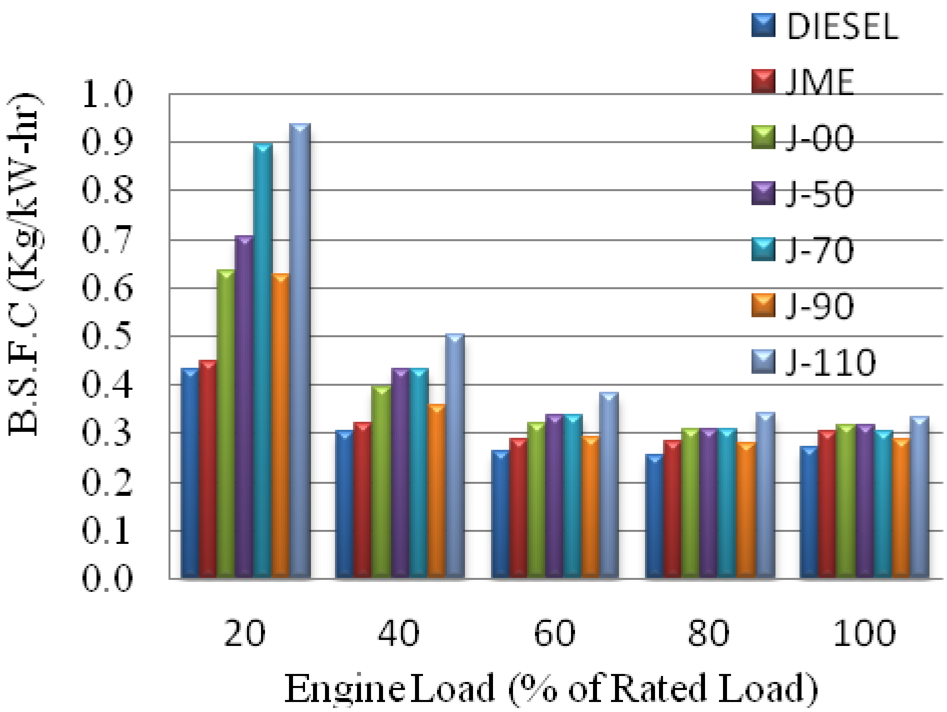

Figure 2. Variation of specific fuel consumption with load at elevated fuel inlet temperatures.

performance in a single cylinder unmodified diesel engine. The upper limit of fuel inlet temperature tested was 110°C. According to the test results showed in Figure 1, heating of neat Jatropha oil to a temperature above 105°C brings its viscosity within ASTM limit, that is, 6 cSt.

Engine performance

The performance parameters considered are Brake-specific fuel consumption (BSFC) and Brake Thermal efficiency (BTE). These engine parameters are evaluated with neat jathropha oil, jathropha methyl ester (JME) and diesel as fuels. The load on the engine was varied from 20% to 100% in steps of 20%. Preheating of neat jatropha oil was done from ambient temperature of 30°C (denoted as J-00), 50°C (J-50), 70°C (J-70), 90°C (J-90) and 110°C (J-110). For all fuel inlet temperatures, the performance of engine was evaluated and compared.

Brake-specific fuel consumption

Brake-specific fuel consumption is the ratio between mass fuel consumption and brake effective power; and for a given fuel, it is inversely proportional to thermal efficiency (Lapuerta et al., 2008). The results for the variation in the brake specific fuel consumption with increasing load on the engine up to full load are presented in Figure 2. For all fuel inlet temperatures, the specific fuel consumption varies with increasing load. For neat jatropha oil fuel, brake specific fuel consumption had high value at low load at all fuel inlet temperature but decreased as the load increased, and then it reaches the value to that of a diesel fuel operation. It was observed at all loading conditions, that fuel consumption shows an increasing trend with preheating up to 70°C of fuel inlet temperature after that it decreased up to 90°C of fuel inlet temperature. Highest values of fuel consumption was observed at 110°C preheated condition of fuel, this may be due to leakage of fuel; a part of the fuel being burnt or evaporated at very high temperature; or an error in measuring fuel consumption by gravimetric type fuel sensor, because as its volume increases, the fuel might have overflown from the measuring beaker/jar.

Brake thermal efficiency

Thermal efficiency is the ratio between the power output and the energy introduced through fuel injection, the latter being the product of the injected fuel mass flow rate and the lower heating value. Thus, the inverse of thermal efficiency is often referred to as brake-specific energy consumption (Hamdan et al., 2010). It can be seen from the Figure 3, that the brakes thermal efficiency is slightly lower than that of the corresponding diesel fuel, at higher

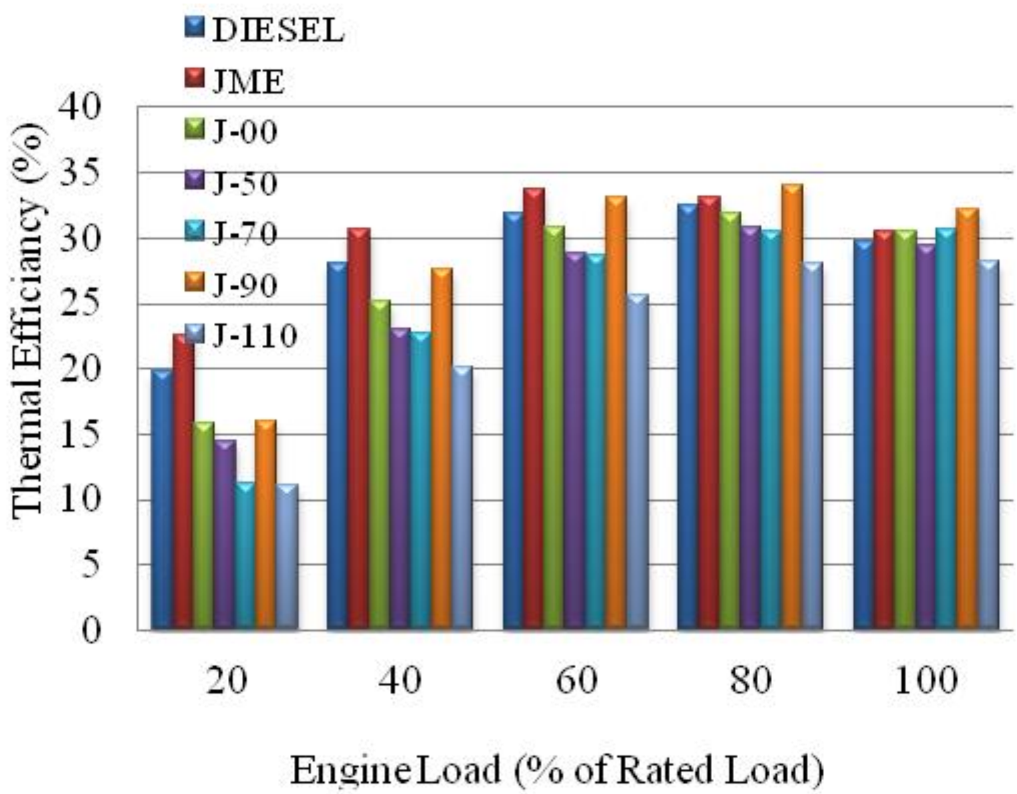

Figure 3. Variation of engine thermal efficiency with load at elevated fuel inlet temperatures.

fuel inlet temperature and at higher load on the engine. As can be seen from the graph, efficiency was found higher than mineral diesel for methyl ester of jatropha oil at all loading conditions of the engine. It may also be noticed that efficiency obtained with neat jatropha oil showing decreasing trend as the fuel inlet temperature increased except for 90°C of fuel inlet condition. This decrease is observed less at full load or efficiency is quite close to that of a diesel fuel operation, and for 90°C preheating, efficiency is still higher at full load. This means that the increase of brake specific fuel consumption is lower than the corresponding decrease of the lower calorific value of the neat vegetable oil.

Exhaust gas temperature

The variation of exhaust gas temperature for different fuel inlet temperature with respect to the load is indicated in Figure 4. The exhaust gas temperature for the fuels tested increases with increase in the load. The amount of fuel injected increased with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rose with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber (Suresh et al., 2008). At all loads, diesel was found to have the higher temperature and the temperatures for the neat jatropha oil and its methyl ester showed a downward trend. The exact reason for lower exhaust temperatures compared to diesel could not be identified. However, it may be due to lesser calorific value of Jatropha oil. As can be seen from the figure, the variation in exhaust temperature is more at higher load with respect to the lower loading condition of the engine. However, it shows a decreasing trend up to 90°C preheated condition; after that increasing trend up to 110°C, this variation is more after 40% of engine loading condition was up to full load.

Conclusions

(1) The BSFC is decreased with increase in fuel inlet temperature of Jatropha oil except for 110°C. The BSFC was observed lowest at 90°C fuel inlet temperature.
(2) Vegetable oil fuel produced the same brake thermal efficiency at high load. However it is observed that with jatropha methyl ester, it is higher at all loading conditions. Performance obtained with neat jatropha oil is lower than diesel fuel and jatropha methyl ester at low loading condition of the engine at all fuel inlet temperature. For 90°C preheated condition of neat jatropha oil, it is found higher among all fuel inlet temperature and at all loading condition.

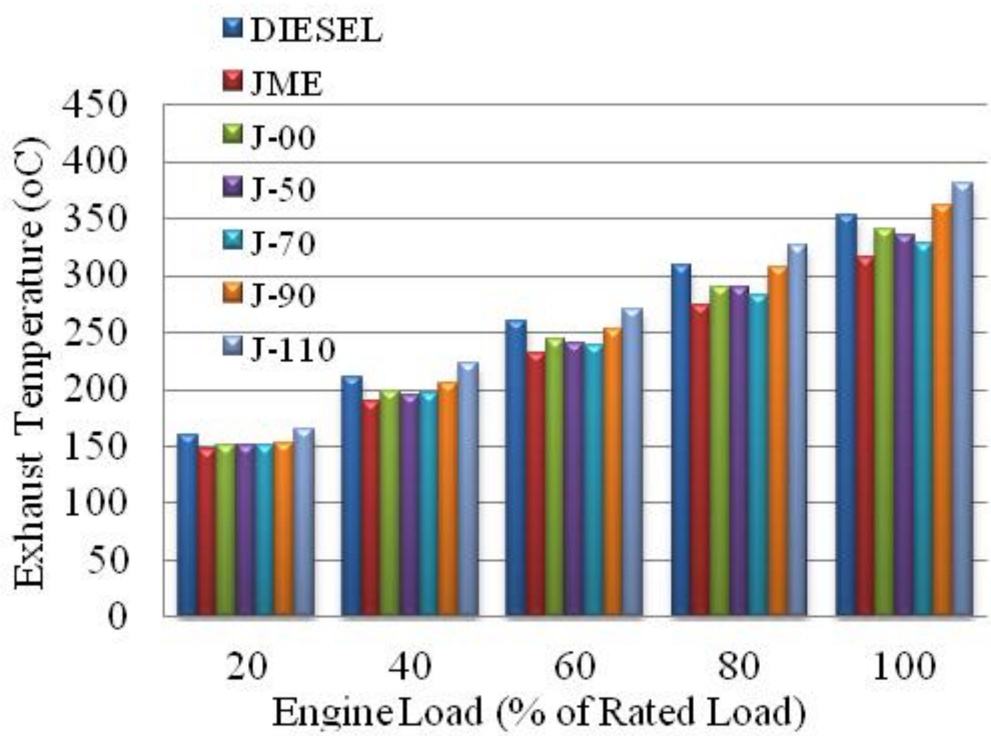

Figure 4. Variation of Exhaust gas temperature with load at elevated fuel inlet temperatures.

(3) It was observed that the exhaust temperatures were low for jatropha methyl ester at all loading conditions of the engine than diesel fuel operation. For neat jatropha oil, exhaust temperature was found lower than the mineral diesel at all fuel inlet temperature and at all loading conditions except for 110°C fuel inlet temperature. At 90°C of fuel inlet temperature, exhaust gas temperature was nearly the same to diesel fuel operation at full load and found less at all other loading conditions of the engine.

(4) It can be concluded from the obtained results that 90°C preheating is sufficient to bring physical and chemical properties of neat jatropha oil close to diesel for safe operation of fuel without any engine modification.

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