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Combustion and performance of a diesel engine with preheated *Jatropha curcas* oil using waste heat from exhaust gas

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HIGHLIGHTS

- Improvement in fuel properties by preheating.
- Utilization of heat from exhaust gas.
- Performance of preheated Jatropha oil vis-à-vis diesel.
- Lowered ignition delay for preheated Jatropha oil as compared to diesel.
- Lower emissions with preheated Jatropha oil as compared to diesesl.

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ABSTRACT

The viscosity and density of CJO (crude Jatropha oil) were reduced by heating it using the heat from exhaust gas of a diesel engine with an appropriately designed helical coil heat exchanger. Experiments were conducted to evaluate the combustion characteristics of a DI (direct injection) diesel engine using PJO (preheated Jatropha oil). It exhibited a marginally higher cylinder gas pressure, rate of pressure rise and heat release rate as compared to HSD (high speed diesel) during the initial stages of combustion for all engine loadings. Ignition delay was shorter for PJO as compared to HSD. The results also indicated that BSFC (brake specific fuel consumption) and EGT (exhaust gas temperature) increased while BTE (brake thermal efficiency) decreased with PJO as compared to HSD for all engine loadings. The reductions in CO_2 (carbon dioxide), HC (hydrocarbon) and NO_x (nitrous oxide) emissions were observed for PJO along with increased CO (carbon monoxide) emission as compared to those of HSD.

1. Introduction

The rapid depletion of conventional fuel and fluctuation of diesel price in the global market have promoted research for alternative fuels for diesel engine. Among the different alternative fuels, vegetable oil having fuel properties similar to diesel has an acceptable engine performance for short-term operation only [1]. However, long term endurance tests with vegetable oil reported some engine durability issues such as severe engine deposits, piston ring sticking, injector choking, gum formation and lubricating oil thickening [2]. These problems are primarily attributed to high viscosity and poor volatility of straight vegetable oils due to large molecular weight and bulky molecular structure. Higher viscosity of vegetable oil (30–200 cSt at 40 °C) as compared to mineral diesel (4 cSt at 40 °C) leads to unsuitable pumping and fuel spray characteristics. For long running, 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. Undoubtedly, transesterification is well accepted and best suited method of utilizing vegetable oils in CI (compression ignition) engine but this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs. The other alternative could be use of heated vegetable oils as petroleum fuel substitute. Further, heating of oil using exhaust gas from a diesel engine is an attractive proposition.

The viscosity of Jatropha oil was decreased remarkably with increase in temperature and it became close to diesel at temperature above 75 °C [3]. The density of Jatropha oil was reduced from 900.21 kg/m^3 to 883.97 kg/m^3 by raising the temperature of oil from 15 °C to 90 °C [4]. Heating the Jatropha oil between 90 °C and 100 °C was adequate to bring down the viscosity in close range to diesel [5]. Chauhan et al. [6] reduced the viscosity of oil by heating from exhaust gases before feeding to the engine with an appropriately designed shell and tube heat exchanger with exhaust bypass arrangement. Further, optimal fuel inlet temperature was found to be 80 °C considering the BTE and BSEC (brake specific energy consumption). However, combustion characteristics of

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Table 1
Fatty acid composition of crude Jatropha curcas oil.

Fatty acid	Systematic name	Formula	Structure[a]	wt.%
Oleic	*cis*-9-Octadecenoic	$C_{18}H_{34}O_2$	18:1	34.3–45.8
Linoleic	*cis*-9, *cis*-12-Octadecadienoic	$C_{18}H_{32}O_2$	18:2	29.0–44.2
Palmitic	Hexadecanoic	$C_{16}H_{32}O_2$	16:0	14.1–15.3

[a] xx: y indicates xx carbons in the fatty acid chain with y double bonds; Source: [12].

Table 2
Technical specifications of diesel engine.

Particulars	Details
Type	GF3BMG (TV1)
Number of cylinders	1
Bore × stroke (mm)	87.5 × 110
Cycle	4-stroke
Maximum power (kW)	5.5, naturally aspirated
Rated speed (rpm)	1500
Compression ratio	15.5:1
Injection timing (° before TDC)	24
Injection type	Direct injection
Nozzle opening pressure IMEP at 1500 rpm (bar)	5.08

Jatropha oil had not been reported. The ignition delay was shorter for neat rapeseed oil and its blends with diesel as compared to that of standard diesel. Peak cylinder pressure and maximum heat release rate were decreased with increase in neat rapeseed oil content in blends [7]. Qi et al. [8] reported similar kind of results using Soybean biodiesel and blends with diesel.

In recent years, several attempts have been made to use the esters of non-edible oils as substitute for diesel. Hence, it was decided to choose one such non-edible oil like Jatropha for further investigation which could provide a suitable substitute for diesel fuel.

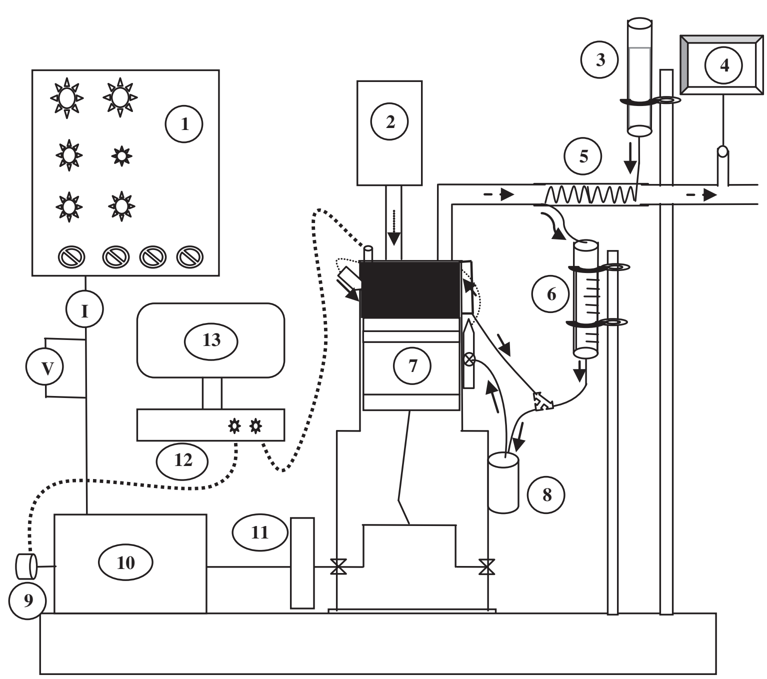
Jatropha oil contains higher percentage of oleic acid (34.3–45.8) followed by linoleic acid (29.0–44.2) and palmitic acid (14.1–15.3). The average saturated and unsaturated fatty acids constitute 20.1% and 79.9% of the oil, respectively. The maturity stage of the fruits at the time of collection is reported to influence the fatty acid composition of the oil [9]. Because of the presence of higher percentage of free fatty acids, it is not desirable to run the diesel engine directly with Jatropha oil. Therefore an attempt was made to utilize the heat from exhaust gas of diesel engine to reduce the viscosity of high viscous oil to improve its engine performance (see Table 1).

2. Materials and methods

2.1. Experimental setup

A typical engine system widely used in the agricultural sector was selected for present experimental investigations and its technical specifications are given in the Table 2. The experimental set-up comprised a constant speed, 5.5 kW, 4-stroke, single cylinder, water cooled, DI diesel engine. The engine was coupled to a three phase, 250 V AC generator. The generator was used for loading the engine through an electrical load bank comprising of four heating coils (1500 W, 925 W, 900 W and 875 W) and six electric bulbs (two 200 W, three 100 W and one 40 W). The schematic layout of the experimental setup for the present investigation is shown in Fig. 1.

The main components of the experimental setup were a diesel fuel tank, measuring cylinders to supply Jatropha oil before heating and after heating, a helical coil heat exchanger fitted inside the exhaust gas pipe line for heating Jatropha oil, oil supply line, and performance measurement equipments. The exhaust gas flowed through the pipe across the helical coil heat exchanger. Helical coil



1.Load bank 2. Air filter 3. Supply cylinder 4. Exhaust gas Analyzer 5. Heat exchanger
6. Measuring cylinder 7. Engine 8. Fuel filter 9. Rotary encoder 10. AC generator
11. Fly wheel 12. Data acquisition system 13. Computer.

Fig. 1. Schematic layout of the experimental setup.