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Performance and Emission Characteristics of Low Heat Rejection Engine Using Biodiesel

B.Rajendra Prasath
Department of Automobile Engineering, Sriram Engineering College, Anna University, Chennai,India.

ABSTRACT

The use of methyl esters of vegetable oil known as biodiesel are increasingly popular because of their low impact on environment, green alternate fuel and most interestingly it does not require major modification in the engine hardware. The significance of low heat rejection (LHR) engine such as the higher brake thermal efficiency (BTE) and ability to handle the lower calorific value (CV) fuel may be considered as the advantageous factors to use biodiesel. The chemically treated non-edible vegetable oil form Jatropha is produced and used in LHR engine. The low heat rejection engine has been developed with uniform ceramic coating of combustion chamber (includes piston crown, cylinder head, valves and cylinder liner) by partially stabilized zirconia (PSZ) of 0.5 mm thickness. The performance and emission tests were carried out on a single cylinder water-cooled LHR engine. The performance characteristics of biodiesel fueled LHR engine under identical condition are quite similar to that of the conventional diesel fueled LHR engine. Carbon monoxide (CO) and Hydrocarbon (HC) emission levels are decreased but in contrast the oxides of nitrogen (NO_X) emission levels are increases due to the higher peak temperature. The results of this comparative experimental investigations reveals that, some of the drawbacks of biodiesel could be made as advantageous while using it as a fuel in the LHR diesel engine.

1. INTRODUCTION

The diesel engines are the dominating one primarily in the field of transportation and secondarily in agricultural machinery due to its superior fuel economy and higher fuel efficiency. The world survey explicit that the diesel fuel consumption is several times higher than that of gasoline fuel. These fuels are fossil in nature, leads to the depletion of fuel and increasing cost. It has been found that the chemically treated vegetable oil often called as biodiesel is promising fuel, because of their properties are similar to that of diesel fuel (DF) It is a renewable one and produced easily.

The basic concept of LHR engine is to suppress the heat rejection to the coolant and increases the useful power out put, it improves the thermal efficiency of the engine. However studies are revealed that the thermal efficiency variation of LHR engine not only depends on the heat recovery system, also depends on the engine configuration, operating condition and physical properties of the insulation material (1–3). Eventhough the high peak temperature leads to increase the NOx level. The potential techniques available for the reduction of NOx from diesel engines are exhaust gas recirculation (EGR), water injection, slower burn rate, reduced intake air temperature and particularly retarding injection timing [4–6]. It is strongly proven that the increasing the thickness of ceramic coatings arrest the heat leakage from the engine cylinder, in contrasts decreases the power and torque. The optimized coating thickness is to be identified by using the simulation techniques (7). The significance of the LHR engine is utilized by using the low calorific vale fuel such biodiesel produced from jatropha oil. Studies are revealed that the usage of biodiesel under identical condition in the conventional engine produces slightly lower performance and emission levels due to the mismatching of the fuel properties mainly low calorific value and higher viscosity. The problems associated with the higher viscosity in compression ignition (CI) engines are pumping loss, gum formation, injector nozzle clocking, ring sticking and incompatibility with lubricating oil (8-12). The identified problems by the use of biodiesel is conventional diesel engine can be reduced in LHR engines. Biodiesel is a chemically treated alternative fuel for use in CI engines, derived from vegetable oils and animal fats. Biodiesel is produced commercially by the transesterification of vegetable oils with alcohol such methanol or ethanol.

The present investigations involves the usage biodiesel produced form the non-edible vegetable oil such as Jatropha and compare the performance and emission levels with the diesel and biodiesel fueled in conventional and LHR engine.

2. FUEL PREPARATIONS AND CHARACTERIZATION

BIODIESEL PREPARATION

The vegetable oil was transesterified-using methanol in the presence of NaOH as a catalyst. The parameter involved in the processing such as catalyst amount, molar ratio of alcohol to oil, reaction temperature and reaction time (13-15) are shown in table 1.

Table 1 Optimized variables for biodiesel production

Variables	Jatropha oil
Catalyst amount, % by volume	1
Molar ratio (Alcohol to Oil)	3: 1
Reaction temperature, °C	60
Reaction time, min.	90

Known quantity of vegetable oil was taken in a three-necked round-bottomed flask. A water-cooled condenser and a thermometer with cork were connected to the side openings on either side of the round-bottomed flask. The required amount of catalyst (NaOH) was weighed and dissolved completely in the required amount of methanol by using a stirrer to form sodium methoxide solution in the case of base/alkali catalyst. Meanwhile, the oil was warmed by placing the round-bottomed flask in the water bath maintained at the selected temperature mentioned above. The sodium methoxide solution was added into the oil for vigorous mixing by means of a mechanical stirrer fixed into the flask. The required temperature was maintained throughout the reaction time and the reacted mixture was poured into the separating funnel. The mixture was allowed to separate and settled down by gravity settling into a clear, golden liquid biodiesel on the top with the light brown glycerol at the bottom. The glycerol was drained off from the separating funnel leaving the biodiesel/ester at the top. The raw biodiesel was collected and water washed to bring down the pH of biodiesel to 7. This pure biodiesel gives the ester yield measured on weight basis and the important fuel and chemical properties were determined and compared with the properties of raw oil and BIS standards.

It is evident that dilution or blending of vegetable oil with other fuels like alcohol or diesel fuel would bring the viscosity close to a specification range (16-17). Therefore, jatropha oil was blended with diesel oil in varying pro-portions with the intention of reducing its viscosity close to that of the diesel fuel. The important physical and chemical properties of the biodiesel thus prepared are given in Table 2.

Table 2 Properties of the diesel fuel and biodiesel

Characteristics	Diesel Fuel	B100
Density @ 15°C(kg/m^3)	800 -850	880
Viscosity @ 40°C(cSt)	4-8	4-6
Flash point (°C)	45-60	170
Cetane number	40-55	50
Lower Heating Value (MJ/kg)	42.49	38.45

ENGINE DEVELOPMENT

The engine combustion chamber is coated with partially stabilized Zirconia (PSZ) of 0.5 mm thickness uniformly includes the piston crown, cylinder head, valves and outside of the cylinder liner. The equal amount of material has been removed from the various parts and PSZ is applied uniformly.

3. EXPERIMENTAL PROCEDURE

The experimental setup and the specification of the engine are shown in Fig.1 and table 3 respectively.

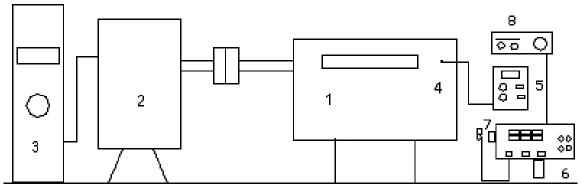

Fig. 1 Experimental setup

The engine was coupled with eddy current dynamometer brake powered by electrical resistance bank. Exhaust gas temperature was measured by an iron-constantan thermocouple. A mercury thermometer measured cooling water temperature.

A piezoelectric transducer was installed in the engine cylinder in order to measure the combustion pressure. Signal from the pressure transducer were fed to charge amplifier. A magnetic shaft encoder was used to give the signal for TDC and the crank angle. The signals from the charge amplifier and shaft encoder were coupled to data acquisition system

Both the fuels are used in the conventional diesel engine and the PSZ coated engine with different fuels such as diesel fuel and biodiesel. Cylinder pressure data were recorded and the other desired data's are collected.

The experiment was carried out on a Kirloskar, naturally aspirated air-cooled engine with the following specification

Table 3 Specification of test engine

No of stroke	4 stroke
No of cylinder	Single cylinder
Bore in mm	87.5
Stoke in mm	110
Compression ratio	17. 5: 1
Rated power	3.7 kW @ 1500 rpm
Injection Pressure in bar	200
Injection timing	24° BTDC

4. RESULTS AND DISCUSSIONS

BRAKE THERMAL EFFICIENCY

The variation of brake thermal efficiency with respect to brake power for different fuels and engines are considered for the analysis shown Fig. 2. In all cases, brake thermal efficiency has the tendency to increase with increase in brake power. The Maximum efficiency is obtained for LHR engine fueled with diesel is about 29.06 which quite higher than the LHR engine fueled with biodiesel and diesel engine fueled with diesel in the rage of 28.21 % and 27.72 % respectively. This is due to the reduction in heat loss to the cylinder walls. The molecules of biodiesel (i.e. methyl esters of the oil) contain some amount of oxygen, which takes part in the combustion process, which Promote the combustion process. The calorific value is acting as one of the limiting factor to estimate the thermal efficiency. This lower brake thermal efficiency obtained for conventional engine with diesel fuel is due to the comparable heat loss to the surroundings. In general, the main reason for getting high efficiency for LHR engine fueled with biodiesel is high cylinder temperature and availability of oxygen on the fuel itself.

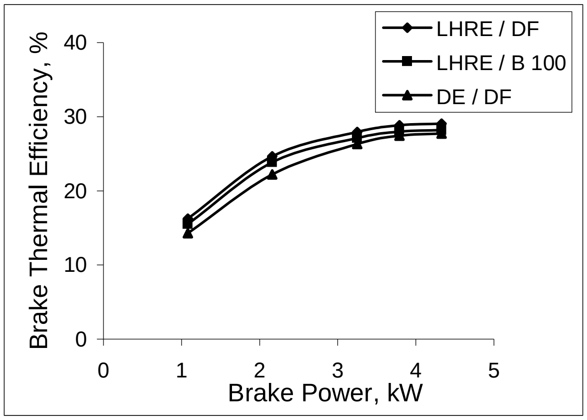

Fig. 2 Variation of Brake Power and Brake Thermal Efficiency

SPECIFIC FUEL CONSUMPTION

The variation of brake specific fuel consumption with brake power for different fuels is presented in Fig. 4.

For all the cases it is found that brake specific fuel consumption is decrease with increase in the brake power. This is due to the higher percentage increase in efficiency with brake power.

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The high rate of fuel consumption for the conventional engine is comparable with the LHR engine. At maximum brake power condition, the specific fuel consumption of biodiesel is hardly 4% more than that of diesel fuel

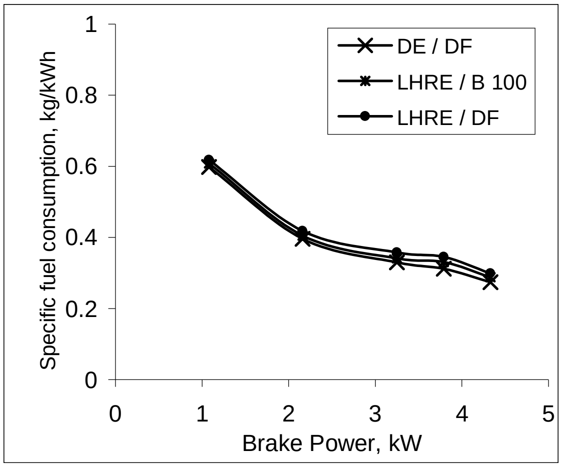

Fig. 4 Vriation of Brake Power and Brake Thermal Efficiency

CARBON MONOXIDE

The variation of carbon monoxide with brake power is presented in Fig. 3 shows the plots of carbon monoxide emissions at the rated engine speed of 1500 rpm at various brake power conditions. The fuels are producing low amount of carbon monoxide emission at lighter brake power levels and are giving more emissions at higher brake powering conditions. The carbon monoxide emissions are found to be increasing with increase in brake power. This is typical with all internal combustion engines since the air–fuel ratio decreases with increase in brake power. The CO emissions increase as the fuel–air ratio becomes greater than the stoichiometric value. CO concentration in the exhaust emission is negligibly small when a homogeneous mixture is burned at stoichiometric air–fuel ratio mixture or on the lean side stoichiometric. It is interesting to note that, crank angle obtained for the peak pressure starts move closely to TDC due to the early burning of fuel air mixture and availability of high temperature. The combustion duration may shorter, which leads to the reduction of recombination reaction, (i.e., formation of carbon dioxide by combining the oxygen and carbon monoxide during the cool expansion)

With increasing biodiesel percentage, CO emission level decreases. Biodiesel itself has about 11% oxygen content in it. This helps for the complete combustion. Hence, CO emission level decreases with increasing biodiesel percentage in the fuel. The higher viscosity and poor atomization tendency of biodiesel than diesel fuel leads to poor combustion and higher carbon monoxide emission.

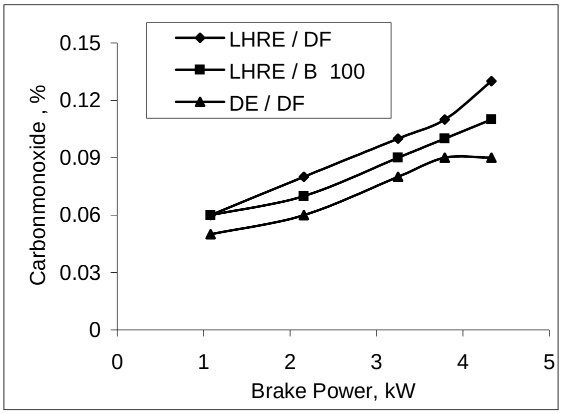

Fig. 5 Variation of Brake Power and carbon monoxide

UNBURNED HYDROCARBON

The variation of Hydrocarbon with respect to brake power for different fuels and engines are shown in Fig. 6.The high temperature in LHR engine consumes more parcel of air fuel mixture than the limited temperature operated condition as in the case of conventional engine.

The high cylinder wall temperature allows the more number fuel particle to participate in the combustion reaction and gets converted in to the products. The fuel particles accumulated in the crevice volume is reduced due to the high temperature and availability of oxygen.

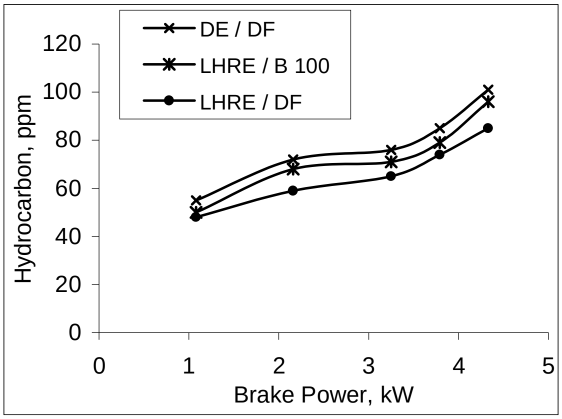

Fig. 6 Variation of Brake Power and Hydrocarbon

OXIDES OF NITROGEN

Fig.7 shows the variation trends of Oxides of nitrogen with brake power. The main reason for the formation of oxides of nitrogen in an IC engine is high temperature and an availability of oxygen. In LHR engine the conditions are in favor of NO species .The availability of oxygen in the fuel itself other than the oxygen available in the air enhance the NO species formation. In LHR engine, at maximum power out put condition it is about 14.5 % greater than the conventional engine with diesel fuel. The early burning of fuel air mixture of biodiesel further more promotes the NO formation. When the expansion starts the relatively higher temperature of gases even in the exhaust gas also increasing the NO formation.

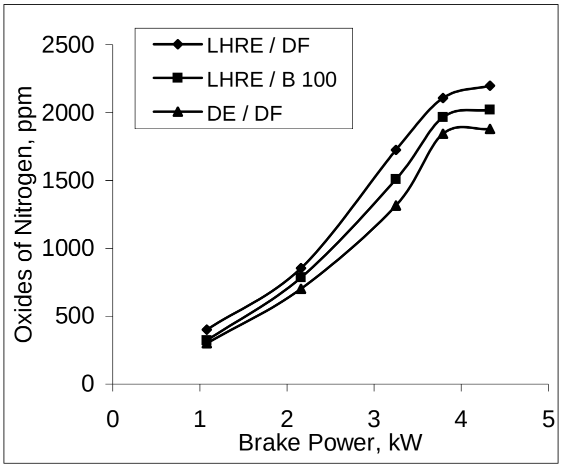

Fig. 5 Variation of Brake Power and Oxides of Nitrogen

5. CONCLUSION

The bio diesel is produced from jatropha oil by the known transesterification process, which reduces the viscosity of the oil in order to match the suitability of the fuel. The conventional engine is modified in to LHR engine by means of Partially Stabilized Zirconia (PSZ) coating. The comparatively low quality fuel (bio diesel) is used in the LHR engine and the followings results are summarized.

- The Thermal efficiency of LHR engine with diesel fuel is about 29.06 % and 28.21 for LHR engine with biodiesel, which is 1.7 % higher than the conventional engine with diesel fuel.
- The specific fuel consumption for the LHR engine with bio diesel is about 3.7 % lesser then the conventional engine with diesel fuel.
- Carbon monoxide levels are comparatively higher about 18 % due the high viscosity, poor atomization, reduction of combustion duration and high temperature.

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- The hydrocarbon level in the exhaust is about 11.5 % lesser than the conventional engine with diesel fuel.

- The Oxides of nitrogen is higher about 6.9 % for LHR engine with bio diesel than the conventional engine with diesel fuel.

The above study reveals that the possibility of using the bio diesel in LHR engine and the performance and emission curves shows the suitability of biodiesel in LHR engine.

CONTACT

B.Rajendra Prasath, Professor & Head, Department of Automobile Engineering, Sriram Engineering College, Anna University, Chennai, India.
Phone: +91-44-27689364, Mobile: +91-7639266278
E-mail: br_prasath@rediffmail.com.

REFERENCE

(1) Bryzik WR, Kamo R. TACOM/ Cummins adiabatic engine program. SAE paper 830314, February 1983.

(2) Woschni G, Spindler W, Kolesa K. Heat insulation of combustion chamber walls—a measure to decrease the fuel combustion of I.C. engines. SAE paper No.850359.

(3) Kamo R, Mavinahally NS, Kamo L, Bryzik W, Schwartz E. Injection characteristics that improve performance of ceramics coated diesel engines. SAE paper No.1999-01-0972.

(4) Aman CA. Promises and challenges of the low-heat-rejection diesel. J Eng Gas Turb Power 1988; 110:475–81.

(5) Herzog PL, Burgler L. NOx reduction strategies for DI Diesel engines. SAE 920470, 1992.

(6) Maramatsu G, Abe A, Yosdiha K. Catalytic reduction of NOx in Diesel exhaust. SAE paper No. 930135, 1993.

(7) P.Tamilporai, "Simulation and Analysis of combustion and heat transfer in low heat rejection diesel engine using two zone combustion model and different heat transfer models". Ph.D Thesis, Anna University, Feb 1998.

(8) Pryde EH. Vegetable oil as diesel fuels: overview. Papers from the symposium on vegetable oils as diesel fuels, presented at the 73rd AOCS annual meeting, Toronto, Canada. J. Am. Oil Chem. Soc. 1983; 60(8).

(9) Ryan TW, Dodge LG, Callahan TJ. The effects of vegetable oil properties on injection and combustion in two different diesel engines. J. Am. Oil Chem. Soc. 1984; 61(10): 1610–9.

(10) Ziejewski M, Kaufman KR. Laboratory endurance test of sunflower oil blend in a diesel engine. J. Am. Oil Chem. Soc. 1983; 60(8): 1567–73.

(11) Korus RA, Jaiduk J, Peterson CL. A rapid engine test to measure injector fouling in diesel engines using vegetable oil fuels. J. Am. Oil Chem. Soc. 1985; 62(11): 1563–4.

(12) Rewolinski C, Shaffer DL. Sunflower oil diesel fuel: lubrication system contamination. J. Am. Oil Chem. Soc. 1985; 61(7): 1120–4.

(13) Fangrui Maa, Milford A. Hannab:" Biodiesel production: a review" Bioresource Technology 70 (1999) 1-15.

(14) P. Chitra, P. Venkatachalam and A. Sampathrajan:" Optimisation of experimental conditions for biodiesel production from alkali-catalysed transesterification of Jatropha curcus oil" Article from Department of Bio-Energy, AEC & RI, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

(15) L.C. Meher a, Vidya S.S. Dharmagadda b, S.N. Naik a,¤" Optimization of alkali-catalyzed transesteriWcation of Pongamia pinnata oil for production of biodiesel" Bioresource Technology 97 (2006) 1392–1397

[16] Agarwal AK. Vegetable oils verses diesel fuel: development and use of biodiesel in a compression ignition engine. TIDE 1998;8(3): 191–204.

[17] Sinha S, Misra NC. Diesel fuel alternative from vegetable oils. Chem. Engg World 1997; 32(10): 77–80.