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Use of Alternative Fuel in Lower Heat Rejection Engine with Different Insulation Levels

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Abstract

Efforts are being made throughout the World to reduce consumption of liquid petroleum fuels wherever it is possible. Bio-diesel is recently gaining much prominence in a substitute for petroleum based diesel mainly due to environmental considerations and depletion of vital resources like petroleum and coal. Under Indian conditions only such plants can be considered for bio-diesel, which produce non-edible oil in appreciable quantity and can be grown in large scale on non-cropped marginal lands and waste lands. Bio-diesel has became more attractive recently because of the fact that it made from renewable resources. The vegetable oils are the promising alternative among the different diesel fuel alternatives. However high viscosity, poor volatility and cold flow characteristics of vegetable oils can cause some problems such as injections choking, severe engine deposits filter gumming, piston ring sticking and thickening of lubricant oils from long term use in Diesel engineer. Such problems can be eliminated through low heat rejection engine.

The diesel engine rejects one third to the coolant and one one-third to the exhaust leaving only about one-third as fuel power output. If the heat rejection could be reduced then the thermal efficiency energy would be improved. LHR engine aims to this by reducing the heat lost to the coolant only non edible vegetable oils can be seriously be considered as fuel for engines as the edible oils are in great demand and for too expensive as fuels. Gum formation, filters clogging carbon deposits at the nozzle tips, higher exhaust emissions due to higher exhaust temperatures are some of the problems associated with these oils. Using vegetable oils in LHR engine is the only solution to over come problem of these oils.

Initial modifications are carried out by providing PSZ coated cylinder head and liner on the engine. Different pistons are arranged with proper coatings. The LHR engine configuration which gives the best performance is used for the subsequent investigations. Local available vegetable oils are tried with a view to identify the best one in terms of efficiency and emissions. Volumetric efficiency drop due to high temperature environment is the main problem associated with LHR engines. Hence, experiments are conducted with supercharging to compensate the volumetric efficiency drop. Break thermal efficiency of thumba fueled surcharged LHR engine is found to be higher than the base engine run by the same fuel by 7%. Among the vegetable oils testes, the exhaust temperatures are also found to be lowest in case of Tumba oil.

Keyword: Bio-Diesel, Conventional Engine, LHR Engine, different levels of insulation.

1. Introduction

The concept of LHR engine is to minimize the heat loss to the coolant by providing thermal resistance in the path of the coolant by which energy can be gained. Several methods adopted for achieving LHR to the coolant are i) using ceramic coatings on piston, liner and cylinder head ii) creating air gap in the piston and other components with low-thermal conductivity materials like superni, cast iron and mild steel etc. Investigations were carried out by various researchers on ceramic coated engines, and reported brake specific fuel consumption (BSFC) was improved in the range 5-9% and pollution levels decreased with ceramic coated engine. Investigations [1] were carried out with air gap insulated piston with nimonic crown with pure diesel operation, and reported brake specific fuel consumption was improved by 3%. Experiments were conducted [2] with air gap insulated piston with superni crown and air gap insulated liner with superni insert with varied injection liming and injection pressure with different alternate fuels like vegetable oils and alcohol and reported that LHR engine improved the performance with alternate fuels. Vegetable oils have cetane number comparable with diesel fuel, but they have high viscosity and low volatility. Experiments were also conducted with superni crown, air gap insulated liner with superni insert and ceramic coated cylinder head with varied injection time and injection pressure, and reported that LHR engine improved the performance of the engine when compared with pure diesel operation. Experiments were conducted with vegetable oils in CE, and reported that performance was deteriorated with CE. The present paper has taken all steps to evaluate the performance of LHR engine, with different degrees of insulation, with varied injection pressure, and compared with pure diesel operation on CE at recommended injection timing and injection pressure.

2. Experimental Setup

Engine used for investigation is of single cylinder water cooled, vertical injection C.I. engine.

2.1 Modification of Test Engine

The CI engine is converted into a LHR engine by applying a ceramic (PSZ) coating on the cylinder head and on the liner [3]. Five different pistons are used along with ceramic coated cylinder head and liner. The engine has a DC electrical dynamometer to measure its output. The dynamometer is calibrated statically before use. This dynamometer is reversible, i.e., it works as motoring as well as an absorbing device. The load is controlled by changing the field current.

The fuel injection pump element is changed from 7mm to 9mm diameter. Suitable changes are made on the rack setting to increase the fuel delivery. For supercharging the engine to a higher pressure an externally powered compressor is used. This can provide air at the rate of $50m^3$ / hr. The simplified sketch of the supercharging equipment. The device for charging of injection can change fuel injection timing from 55 before top dead center (TDC) to top dead center (TDC). The start of fuel injection timing which is used along with the dynamic injection time changing device indicates the start of fuel injection time in degrees of crank angle (CA), with an accuracy of 0.01° CA.

3. Experimentation

At a rated speed of 1500 rpm all the variable load tests are conducted. Injection timing, fuel injection pressure, electrical input to heater is the parameters which are varied during the course of experimentation. The outlet temperature of the cooling water is maintained at 70°C.

The load on the dynamometer, air flow rate, fuel flow rate, exhaust temperature, manifold pressure, cooling water flow rate, cylinder head and cylinder liner temperatures, pressure time signal, TDC marker signal, dynamic injection timing, HC, CO and smoke readings are noted and recorded after allowing sufficient time for the engine to stabilize. The cylinder head temperatures are measured at two locations (i) near the exhaust valve and (ii) on the other side of injector. The experiment is to find out the best performed LHR engine among five different insulation levels, after picking up of the most suited vegetable oil in terms of efficiency, emissions from different oils which are locally available, to see the effect of supercharging on the brake thermal efficiency.

4. Results and Discussions

During experimentation five different levels of insulations are tried on the test engine with an objective to find the best one in terms of performance, emissions and other combustion parameters. The Aluminium piston engine is chosen as a base engine. Also, there is no insulation over the piston. As an initial modification to this engine, PSZ coated cylinder head and liner is fitted. Then different insulation levels are tried by changing different pistons with (1) Cast iron piston (2) Cast iron piston coated with PSZ (3) Aluminium piston coated with PSZ (4) Cast iron piston with heat dam, the crown coated with PSZ and heat dam surfaces coated with PSZ and (5) Aluminum piston with heat dam, the crown coated with PSZ and the heat dam surfaces coated with PSZ.

In all these engines vegetable oil, thumba is used for the performance analysis and with a view to find out the best one, and the insulation thickness employed is 0.5mm. Most suitable vegetable oil can be selected from different vegetable oils by testing them in the best performed LHR engine. Their properties are similar to diesel, particularly cetane rating and heat values. However their viscosity values are higher but can easily overcome by heating them to the order of 60° to 100°C. Since these oils have slightly longer ignition delay, they are most suitable to use in low heat rejection engines. The different vegetable oils which are tried in the LHR test engine are Thumba oil, Simarouba oil, Neem oil, Cotton seed oil, Rapeseed oil, Karanja oil and Palm oil.

5. Comparison of Non-Edible Oils in LHR Engine

The above vegetable oils are tested in LHR engine for performance, emission and combustion characteristics. Optimum injection timings and pressures are employed for each of these fuel oils for better performance. The processed results of the experiments are displayed in the below figures.

5.1 Brake Thermal Efficiency

The brake thermal efficiency is estimated based on the high heating value of the fuel. The variation of brake thermal efficiency of seven vegetable oils tested in LHR engine with Brake Power output is shown in figure 5.1. The brake thermal efficiency of thumba oil is higher throughout the load range followed by simarouba oil. The thermal efficiency of thumba oil is significantly higher compared to other oils at part loads. This higher thermal efficiency of thumba oil in LHR engine is due to high in-cylinder temperature which helps in better vaporization and faster combustion of the fuel injected into the combustion chamber.

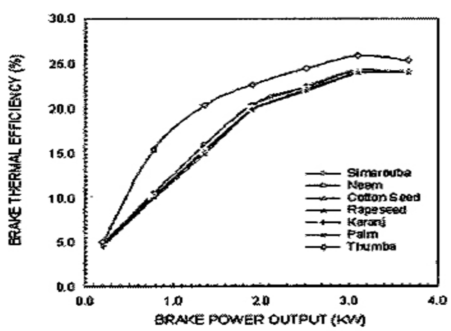

Figure.5.1 Comparison of Brake thermal efficiency with power output for different vegetable oils in LHR engine

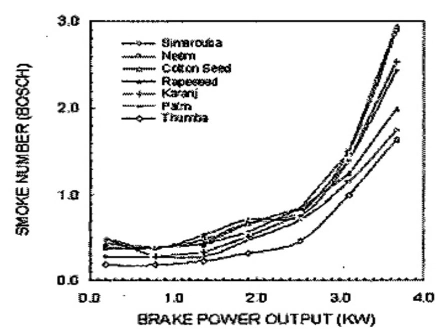

Figure 5.2 Comparison of Smoke number with power output for different vegetable oils in LHR engine

5.2 Smoke Emission

Lowest smoke emissions for thumba oil is due to better vaporization, faster and more efficient combustion of injected fuel in the hot environment inside the LHR test engine and also due to higher oxidation rate of the soot formed.

5.3 Unburnt-fuel

Un-burnt hydrocarbon emissions of all vegetable oils are marginally higher than thumba oil. Poor mixing of these oils with air may be one of the reasons for this. Due to insulation in LHR engine, combustion rate has increased very much in the case of thumba oil compared to combustion rates of other oils.

5.4 Carbon Monoxide

Carbon monoxide emission levels are also lower with thumba oil as compared to other vegetable oils as seen in the figure 5.4. The curves of other vegetable oils are almost merged and shown the similar trends that of thumba oil. Combustion duration is another parameter, which indicates the fastness of combustion. Figure 5.5 shows the variation of combustion duration with power output for all the vegetable oils tested in the LHR engine. The combustion duration is shortest for thumba oil throughout the power range and highest for palm oil in the full load range.

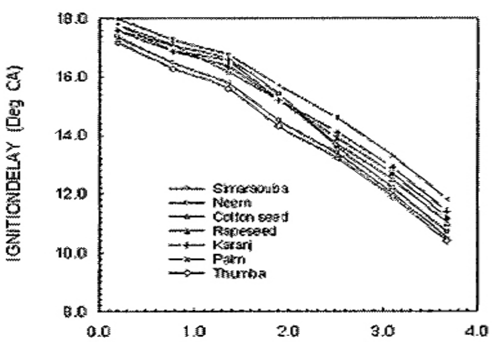

Figure 5.5 Comparison of combustion duration with power output for different vegetable oils in LHR engine

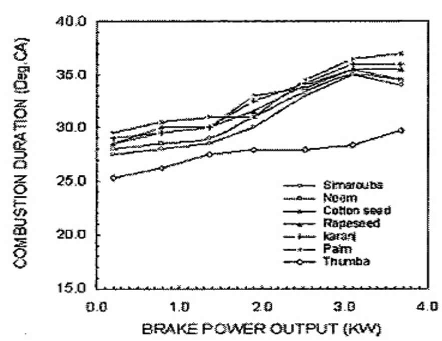

Figure 5.6 Comparison of ignition delay with power output for different vegetable oils in LHR engine

5.6 Ignition Delay

Figure 5.6 shows the variation of ignition delay with Brake Power output for all the vegetable oils. The test results indicate highest ignition delay for palm oil among all the vegetable oils. The ignition delay is shortest for thumba oil. However, the variation of ignition delay for other oils is in between.

5.7 Volumetric Efficiency

The variation of volumetric efficiency with power output is shown in figure 5.7. Relatively due to lower cylinder wall temperatures the volumetric efficiency is higher for thumba oil. The volumetric efficiency is badly affected in the case of Rapeseed, palm and Cotton seed oils. The volumetric efficiency drop is more for palm oil and less for thumba oil when observed for a complete power range.

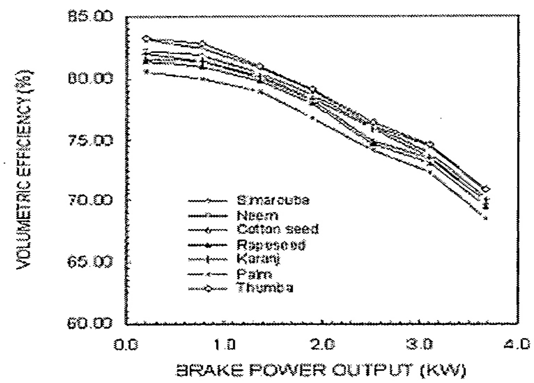

Figure 5.7 Comparison of volumetric efficiency with power output for different vegetable oils in LHR engine

5.8 Exhaust Temperature

Exhaust gas temperature variation with respect to Brake Power output for all the vegetable oils are compared in the figure 5.8. Exhaust temperature curves of thumba, simarouba oils have merged and difficult to differentiate them and expectedly lowest compared to other oils. Exhaust temperatures are highest in the case of palm oil.

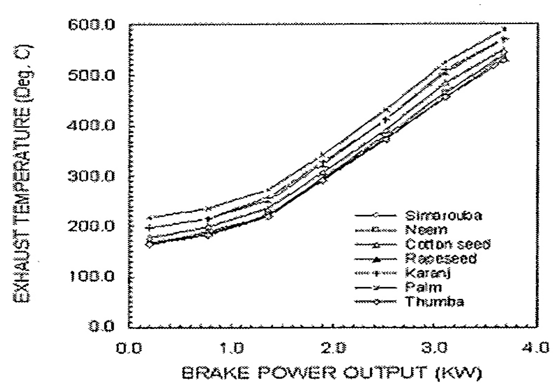

Figure 5.8 Comparison of exhaust temperature with power output for different vegetable oils in LHR engine

5.9 Effect of Low Heat Rejection on the Volumetric Efficiency

The volumetric efficiency is drastically affected by high in cylinder temperatures in LHR engines. The effect of LHR test engine (i.e. cast iron piston with heat dam, the crown coated with PSZ and the heat dam surfaces coated with PSZ) on the volumetric efficiency is studied. The variation of volumetric efficiency drop of the LHR engine compared with the base engine varies from 1.8% at 0.20 KW to 11.8% at 3.7 KW rated load. The drop in volumetric efficiency increases with the engine output.

6. Conclusion

Performance of Thumba oil is found to be superior compared to other oils when tested in the LHR test engine. The emissions like smoke, un-burnt fuel and carbon monoxide are found to be lowest with thumba oil. For other oils these emissions are higher. The combustion duration, ignition delay is also found to be shorter with this fuel which shows lesser tendencies towards knocking. The volumetric efficiency is higher with this Thumba oil. Among the vegetable oils tested, the exhaust temperatures are found to be lowest in the case of Thumba oil. Compared to Thumba fuelled base engine, the brake, thermal efficiency of a thuma fueled supercharged LHR engine is higher by 7% at full load.

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