PERFORMANCE, EMISSION AND CHARACTERISTICS OF A LOW HEAT REJECTION ENGINE USING PLASTIC OIL

P.Saravanan[1], M.Kannan[2],
Department of Mechanical Engineering, [1]Mailam Engineering College, Chennai, India.
[2]Adhiparasakthi Engineering College

ABSTARCT

Internal combustion engine with its combustion chamber walls insulated by thermal barrier coating materials is referred to as Low Heat Rejection engine (LHR). The main purpose of this concept is to reduce engine coolant heat losses, hence improving engine performance. Most of the researchers have reported that the thermal coating increases thermal efficiency, and reduces exhaust emissions. In contrast to the above expectations, a few researchers reported that almost there was no improvement in thermal efficiency. A wide range of coating materials were studied in order to justify their feasibility of implementation in engine. The in fluency of coating material, thickness, and technique on engine performance and emissions have been studied critically to accelerate the LHR engine evolution. The properties of the oil derived from waste plastics were analyzed and compared with the petroleum products and found that it has properties that are similar to that of diesel. The objectives of higherthermal efficiency, improved fuel economy, and lower emissions are accomplishable but much more investigations with improved engine modification, and design are required to explore full potentiality of LHR engine.

Keywords: Low heat rejection engine, Thermal barrier coating, Thermal spraying technique, Engine performance, Exhaust emission, Plastic oil

INTRODUCTION

Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines. The diesel engine generally offers better fuel economy than its counterpart petrol engine. Even the diesel engine rejects about two thirds of the heat energy of the fuel, one-third to the coolant, and one third to the exhaust, leaving only about one-third as useful power output. Theoretically if the heat rejected could be reduced, then the thermal efficiency would be improved, at least up to the limit set by the second law of thermodynamics. Low Heat Rejection engines aim to do this by reducing the heat lost to the coolant. The concept of LHR engine is to provide thermal insulation in the path of heat flow to the coolant and increase thermal efficiency of the engine. LHR engines are classified into low grade, medium grade and high grade engines depending on degree of insulation. Low grade engines consist of thermal coatings on piston, liner, cylinder head and other engine components, medium grade engines provide an air gap in the piston and other components with low-thermal conductivity materials like cast iron and mild steel etc and high grade engines are combination of low and medium grade engines.

Thermal barrier coatings are duplex systems, consisting of a ceramic topcoat and a metallic intermediate bond coat. The topcoat consists of ceramic material whose function is to reduce the temperature of the underlying, less heat resistant metal part. The bond coat is designed to protect the metallic substrate from oxidation and corrosion and promote the ceramic topcoat adherence. Ceramic coatings are widely used in industry for providing valuable improvements against wear, corrosion, erosion, and heat in designs. The bottle neck is that coatings must maintain intended performance during their life cycles. Although coatings exhibit excessive variability and unpredictability in nature, thermal barrier coating in internal combustion engine is a subject of research for many investigations especially reducing in-cylinder heat rejection of adiabatic engines because ceramic coatings demonstrates good thermal barrier properties. Therefore, thermal barrier coating (TBC) technology is successfully applied to the internal combustion engines, in particular to the combustion chamber. Insulation of the combustion chamber components of low heat rejection (LHR) engines can reduce the heat transfer between the gases in the cylinder and the cylinder wall and thus increase the combustion temperature. The LHR engine concept is based on suppressing this heat rejection to the coolant and recovering the energy in the form of useful work. Thermal barrier coatings on the elements of combustion chamber of internal combustion engine offer advantages including fuel efficiency, multi fuel capacity and high power density. Insulation of the combustion chamber may provide not only reduced heat rejection but also thermal fatigue protection of the underlying metallic surfaces in engines as well as possible reduction of engine emissions. However, the insulation of the combustion chamber influences the combustion process and the exhaust emission characteristics.

Thermal barrier coating consisting of metallic bond coat on the substrate and ceramic top coat on the bond coat to increase the thermal efficiency or to reduce the fuel consumption of engines leads to the adoption of higher compression ratios in order to reduce in-cylinder heatrejection. Both of these factors cause increases in mechanical and thermal stresses of materials used in the combustion chamber. In particular, durability concerns for the materials and components in the engine cylinders, which include pistons, rings, liners and the cylinder heads, limit the maximum in-cylinder temperatures. The application of TBC on the surfaces of such components enhances high temperature durability by reducing the heat transfer and lowering the temperature of the underlying metal.

Waste plastic oil in LHR engine

LHR engines are most preferred power plants due to their excellent drivability and higher thermal efficiency. Despite their advantages, they emit high levels of NOx and smoke which will have an effect on human health. Hence, stringent emission norms and the depletion of petroleum fuels have necessitated the search for alternate fuels for LHR engines. On the other hand, due to the rapid growth of automotive vehicles in transportation sector, the consumption of oil keeps increasing. Most of the research work has been done by mixing oil developed from waste plastic disposal with heavy oil for marine application. The results showed that waste plastic disposal oil when mixed with heavy oils reduces the viscosity significantly and improves the engine performance. However, very little has been done to test their use in high-speed HCCI engines. A pilot level method of recycling waste plastic disposal in India produces waste plastic oil of 25,000 liter/day. The kind of plastic materials are Polyethylene, Polypropylene, Teflon Nylon and Dacron. For application, waste plastic oil is used in HCCI engine.

Experimental setup

Technical specifications:

Engine: Water cooled 4- stroke direct injectiondiesel engine.
Cylinder: Vertical twin cylinders with individual Cylinder head.
Engine power: 10 HP
Engine speed: 1560
Bore: 80
Stroke: 110
Compression ratio: 16:1
Lubricating oil: 20x40, quantity required 7 liters.
Cooling type: Water cooling.
Electrical dynamometer: 6 KVA capacity alternator coupledto the engine with load bank.
Measurement: Calibrated burette for fuel intake measurement. Orifice meter fitted to the air inlet tank with watermanometer for air intake measurement. Multichannel digital temperature indicator formeasurement of temperature at various points. Exhaust gas calorimeter to measure heat carried away byexhaust gas.Measure the water flow rate of engine jacket andcalorimeter.

Fig. 1 Experimental setup

RESULTS AND DISCUSSION

A series of performance, emission and combustion tests were carried out on a various speed engine using LHR and waste plastic oil and the results are presented.

Property	Diesel	Waste plastic oil
Density @ 30 C in (g/cc)	0.820	0.8355
Ash content (%)	0.002	0.00023
Gross calorific value (kJ/kg)	9957	44,340
Kinematic viscosity, cst @ 40 C	3.6	2.52
Cetane number	48	51
Flash point (C)	55	42
Fire point (C)	56	45
Carbon residue (%)	0.20	82.49
Sulphur content (%)	30	0.030
Distillation temperature (C) @ 85%	341	344
Distillation temperature (C) @ 95%	360	362

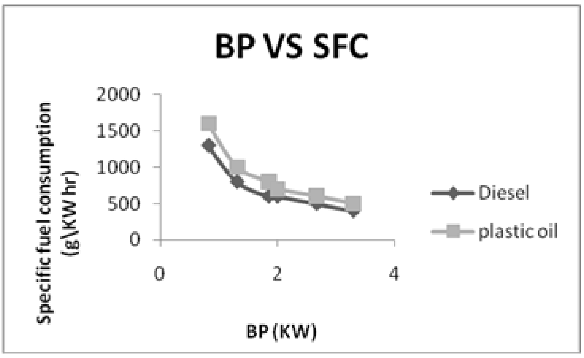
Table 2 Gaseous product of the waste plastic oil.

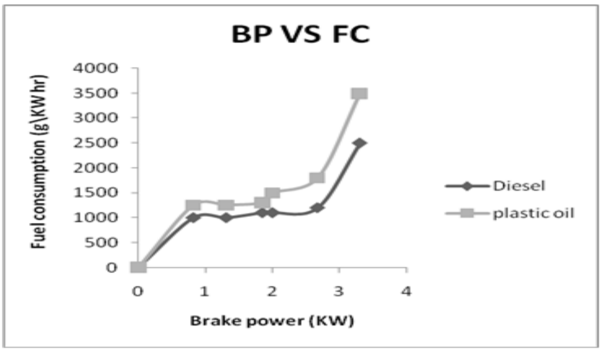
Component	Quantity (wt%)
Methane	6.6
Ethane ethylene	10.6
Propane	7.4
Propylene	29.1
Iso-butane	1.9
n-Butane	0.9
C4 (unsaturated)	25.6
Iso C5–n-C5	0.1
C5+higher	15.3
Hydrogen	2.5
CO/CO2	<400 ppm

Table 3 Chemical composition of waste plastic oil.

Composition	Percentage
C10	**61**
C10–C13	**2.4**
C13–C16	**8.5**
C16–C20	**4.1**
C20–C23	**7.6**
C23–C30	**16.4**

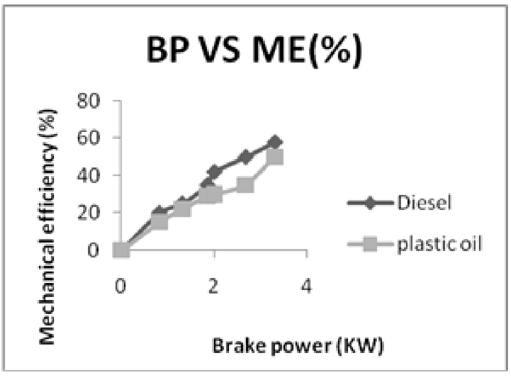
Performance

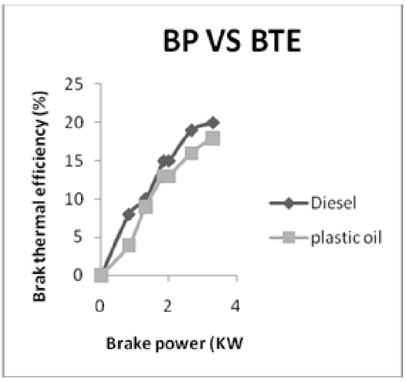




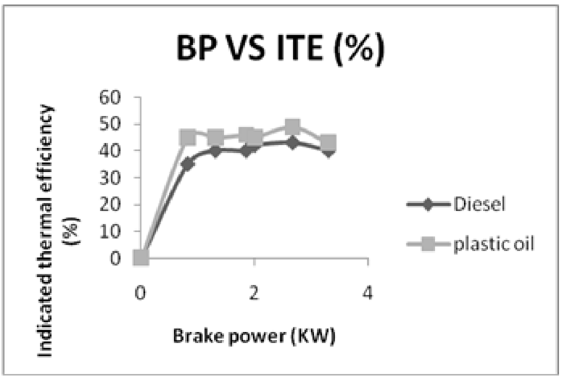
Specific fuel consumption with brake power: The variation of specific fuel consumption (SFC) with brake power for diesel fuel and plastic oil shown .The specific fuel consumption (SFC) reduced with brake power for plastic oil fuel modes. The SFC of diesel, plastic oil at different load were estimated. In comparison of diesel a slightly increased (10-15 %) of SFC was found for plastic oil through all loads.

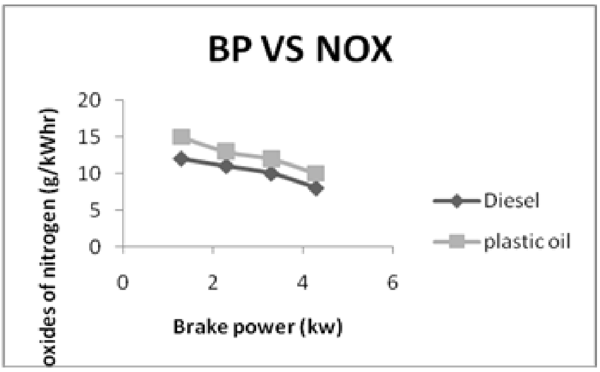
Fuel consumption with brake power: The variation of fuel consumption with brake power for diesel fuel and different Fuel consumption of the fuel increased with load for two fuel modes. The plastic oilis higher than that of the conventional diesel fuel over the entire range of the brake power. The maximum fuel consumption increase (10-20 %) was at the full load of than the diesel fuel.



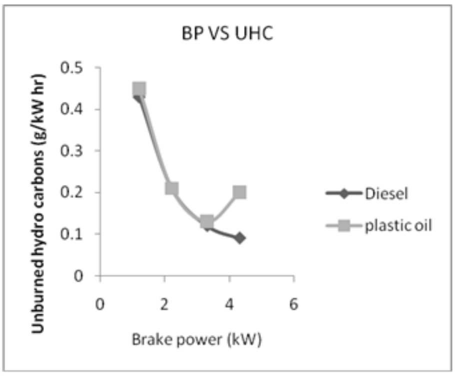


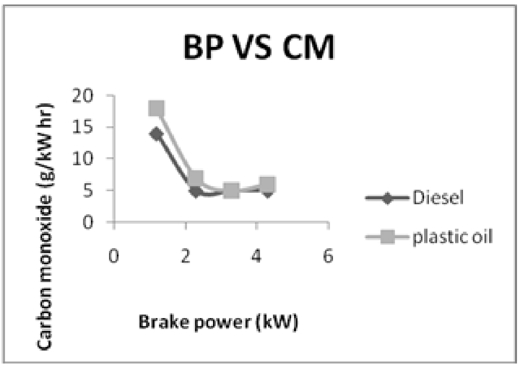
Mechanical efficiency with brake power: The variation of mechanical efficiency ($\eta_{mech.}$) with brake power for diesel fuel and plastic oil are compared. The mechanical efficiency increased with load for all fuel modes. Mechanical efficiency of the different fuels was lower than that of the diesel fuel. The maximum increased efficiency was found (10-15 %) at 100 % diesel fuel than the plastic fuel.





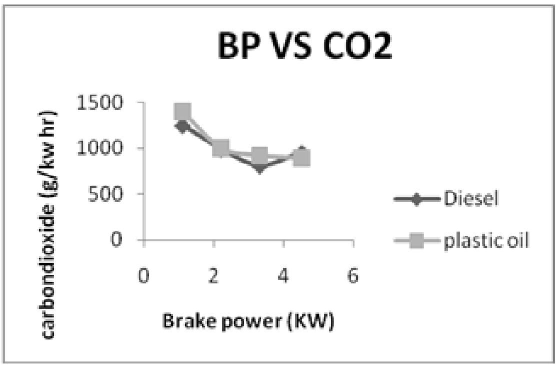
Brak thermal efficiency with brake power: The variation of brake thermal efficiency (η_{bth}.) with brake power for diesel fuel and plastic oil as shown. The brake thermal efficiency increased with brake power for plastic oil mode modes. The brakes thermal efficiency of plastic oil is (5%) lower than that of the diesel fuel with respect to all loads. The reason may be the extended ignition delay and the leaner combustion of diesel fuel, resulting in large amount of fuel burned in the mode of diesel fuel. It may be due to the reduction in the density and viscosity of the diesel fuel than the plastic oil.

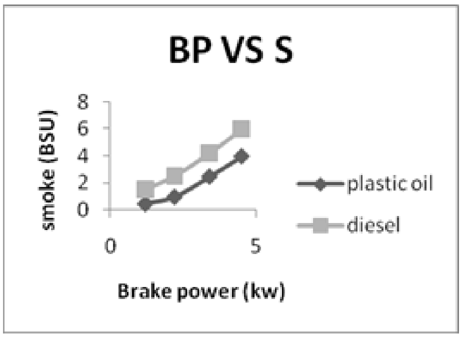




Indicated thermal efficiency with brake power: The variation of indicated thermal efficiency (ηith.) with brake power for diesel fuel and plastic fuel as shown. The indicated thermal efficiency increased with brake power for all fuel modes. The indicated thermal efficiency of diesel fuel is lower than plastic fuel.

EMISSIONS





oxides of nitrogenwith brake power: The oxides of nitrogen in the emissions contain nitric oxide(NO) and nitrogen dioxide (NO_2). The formation of NOx is highlydependent on in-cylinder temperature, oxygen concentration andresidence time for the reactions to take place. The comparison of oxides of nitrogen with brake power. It can benoticed that the NOx emission increases in the waste plastic oiloperation. The reason for the increased NOx is due to the higherheat release rate and higher combustion temperature. LHR enginesare always run lean and emit high amounts of NOx nonetheless. At high load, with higher peak pressures, and hence temperatures and larger regions of close to stoichiometric burned gas, NO levels increase. Increased ignition delay of waste plasticoil promotes premixed combustion, by allowing more time forfuel to be injected prior to ignition, may also be another reasonfor increased NOx.

Unburned hydro carbonswith brake power: The variation of unburned hydrocarbon with brake power for tested fuels is shown. Unburned hydrocarbon is a usefulmeasure of combustion inefficiency. Unburned hydrocarbon consistsof fuel that is incompletely burned. The term hydrocarbonmeans organic compounds in the gaseous state and solid hydrocarbons are the particulate matter. From the results, it can be noticed thatthe concentration of the hydrocarbon of waste plastic oil is marginallyhigher than diesel. The reason behind increased unburnedhydrocarbon in waste plastic oil may be due to higher fumigation rate and non-availability of oxygen relative to diesel. At lighterloads due to charge homogeneity and higher oxygen availability, the unburned hydrocarbon level is less in the case of waste plasticoil, whereas at higher load ranges due to higher quantity of fuel admission, unburned hydrocarbon increases.

Carbon monoxide with brake power: The variation of carbon monoxide with brake power is shown. LHR engine operates with lean mixtures and hence the CO emission would be low. CO emission is toxic and must be controlled. It is an intermediate product in the combustion of a hydrocarbon fuel, so its emission results from incomplete combustion. Emission of CO is therefore greatly dependent on the air fuel ratio relative to the stoichiometric proportions. Rich combustion invariably produces CO, and emissions increase nearly linearly with the deviation from the stoichiometry. The results show that CO emission of waste plastic oil is higher than diesel. The reason behind increased CO emission is incomplete combustion due to reduced in-cylinder temperatures. The drastic increase in CO emission at higher loads is due to higher fuel consumption.

Carbon dioxide with brake power: Carbon dioxide occurs naturally in the atmosphere and is a normal product of combustion. Ideally, combustion of a HC fuel should produce only CO2 and water (H2O). The variation of carbon dioxidewith brake power is shown. From the results, it is observed that the amount ofCO2 produced while using waste plastic oil is lower than diesel. This may be due to late burning of fuel leading to incomplete oxidation of CO.

Smoke with brake power: Smoke is nothing but solid soot particles suspended in exhaust gas. The variation of smoke with brake power. It is evident that the smoke level for waste plastic oil is lower than diesel. The reason for the reduced smoke is the availability of premixedand homogeneous charge inside the engine well before the commencement of combustion. Higher combustion temperature, extendedduration of combustion and rapid flame propagation arethe other reasons for reduced smoke. However, at higher loadrange due to non-availability of sufficient air and abnormal combustionthere was a visible white smoke emission. Another reasonfor lower smoke may be better and complete combustion of fueldue to the oxygen present in the waste plastic oil.

CONCLUSION

From the tests conducted with waste plastic oil and diesel on aLHR engine, the following conclusions are arrived:

- Engine was able to run with 100% waste plastic oil.
- Ignition delay was longer by about 2.5
- CA in the case of waste plastic oil compared to diesel.
- NOx is higher by about 25% for waste plastic oil operation than that of diesel operation.
- CO emission increased by 5% in waste plastic oil compared to diesel operation.
- Unburned hydrocarbon emission is higher by about 15%.
- Smoke reduced by 40% at rated power in waste plastic oil compared to diesel operation.
- Engine fueled with waste plastic oil exhibits higher thermal efficiency upto 75% of the rated power.

REFERENCES

A P Sathiyagnanam, C G Saravanan and S Dhandapani "Effect of thermal-barrier coating plus fuel additive for reducing emission from di diesel engine," Proceedings of the World Congress on Engineering WCE, London, U.K., Vol 2, 2010, pp 978-988.

EkremBuyukkaya, TahsinEngin, MuhammetCerit, Effects of thermal barrier coating on gas emissions and performance of a LHR engine with different injection timings and valve adjustments, Energy Conversion and Management 47, 2006, pp 1298- 1310.

Ioannis S. Arvanitoyannis, PersefoniTserkezou, Cereal waste management: treatment methods and potential uses of treated waste, Waste Management for the Food Industries (2008) 629–702.

Isabel de Marco Rodriguez, M.F. Laresgoiti, M.A. Cabrero, A. Torres, M.J. Chomon, B. Caballero, Pyrolysis of scrap tyres, Fuel Processing Technology 72 (2001) 9–22.

J.B. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill, New York, 1988.

J.B. Holman, Experimental Techniques for Engineers, McGraw Hill, 1988.

Murthy P.V.K, Murali Krishna M.V.S., SitaramaRaju A, Vara Prasad C.M., Srinivasulu N.V., Performance Evaluation of Low Heat Rejection Diesel Engine with Pure Diesel, International journal of applied engineering research, Dindigul, 2010, pp 428-451.

P. Lawrence, P. Koshy Mathews and B. Deepanraj, Experimental Investigation on Performance and Emission Characteristics of Low Heat Rejection Diesel Engine with Ethanol as Fuel, American Journal of Applied Sciences, 2011, pp 348-354.