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Effects of thermal barrier coating on single cylinder C.I engine fueled with diesel and biodiesel

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ABSTRACT

Demand for energy around the world is increasing due to rapid industrialization and increase in vehicular population for transportation; specifically the demand for diesel is very high due to wide use of diesel engines. The high price of the diesel and high pollution levels from diesel engines have caused for the search of renewable and alternative fuels to diesel. Usage of pure biodiesel as fuel in conventional diesel engine results in combustion problems which led to use the biodiesel in low heat rejection (LHR) diesel engine. In this work, Jatropha Biodiesel and its blends are used as fuel in both conventional and LHR diesel engine. The LHR engine was obtained with uniform ceramic coating of combustion chamber which includes piston crown and cylinder head by partially stabilized zirconia of 0.5 mm thickness. In this investigation, performance and emission analysis were carried out in a diesel and biodiesel fueled conventional and LHR engine under various load conditions. Using LHR engine operated with biodiesel, the brake thermal efficiency is decreased marginally than LHR engine operated with diesel. CO and HC emission levels are decreased but in contrast, NO_X emission level was increased due to the higher peak cycle temperature. The test results of biodiesel fueled LHR engine were quite identical to that of the conventional diesel engine. Comparing the results of this experimental investigation using biodiesel fuel, some of the drawbacks could be made as advantageous factors while using it as a fuel in the LHR diesel engine.

KEY WORDS: Alternate fuels, Ceramic Coating, Diesel engine, Jatropha Biodiesel.

1. INTRODUCTION

Diesel engines are found to be dominating one, were found to be used in various fields like transportation and agricultural machinery due to its superior power output and higher fuel efficiency. It is quite known fact that consumption of diesel fuel is somewhat high when compare with petrol. Due to high production cost and more usage of fossil fuels leads to search of alternate fuels.

In several previous works chemically treated vegetable oil often called as biodiesel was used as an alternative fuel, since it is renewable, low production cost and also its properties are similar to that of diesel fuel. Considering other scenario, thermal energy generated in IC engines is not utilized effectively. It includes various losses like energy transferred to coolant, due to frictional energy losses and heat lost through exhaust.

In accordance to above losses, it is necessary to concentrate on reduction of energy losses to improve the fuel economy. In order to reduce the energy losses, due to coolant and friction the various parts of engine like cylinder head, piston crown, are partially insulated in nano sized form. The core concept of LHR engine is that it retains the heat energy inside cylinder and it leads to decrease in amount of heat rejected to coolant and ultimately rises engine thermal efficiency.

Inspite of its several advantages of LHR engine has few drawbacks which needs to be addressed carefully. The operation of LHR engine depends upon several factors which includes the configuration of engine, physical properties of the insulation material and operating conditions. Another drawback is that since LHR engine produces high in cylinder temperature leads to increase in Nox emission level. Currently available techniques to reduce Nox emission levels includes Exhaust gas recircuation, using water emulsified fuels, retarding injection timing, reduced inlet air temperature and slow burn rate. Considering in another aspect while increasing the coating thickness above desired level will restricts heat loss from engine cylinder more there by overall power and torque reduces. The main advantage of LHR engine is that fuels with low calorific such as biodiesel can be used without major modifications. Usage of biodiesel in diesel engines causes various problems which includes pumping loss, gum formation, ring sticking, injector nozzle choking and incompatibility with lubricating oil.

These problems can be rectified by using the biodiesel in LHR engines except the injection parameters problem. In this work biodiesel was used in both conventional and LHR DI diesel engines and the corresponding performance and emission parameters are compared. Due to wide increase in number of automobiles in last several decades results in great demand of petroleum products. The rapid crude oil depletion and scarity of nonrenewable resources leads to search of alternate sources like biodiesel, LPG gas, hydrogen fuels etc. Among those biodiesel plays a major role and consider as viable alternative fuel while comparing with diesel. Biodiesel has several advantages it can be used in diesel engine without any major alternations. Another key factor is that it has no sulphur content aromatic hydrocarbons, metals or crude oil residues. Since biodiesel is naturally oxygenated fuel it emits very low amount of CO and soot particles while comparing with diesel fuel. Biodiesel is self-lubricating fuel so prolong usage won't affect the durability of diesel engine.

While considering various advantages of biodiesel it has several drawbacks. Biodiesel in its fuel structure has contains tri-glycerides of fatty acids The molecular weight of these tri-glycerides would be high, so these fats have high viscosity causing major problems for usage as fuel in diesel. So biodiesel needs to be chemically modified and make them as lighter fuels by following various methods. It includes Pyrolysis, Micro emulsification, Dilution and Transesterification. Among these, transesterification is considered as a commercially used method to produce biodiesel in surplus manner. In transesterification process the fatty acid triglycerides contains heavy molecules are chemically spitted give rise to simple esters. This process is accomplished by reacting triglycerides with a suitable alcohol with the presence of catalyst for some period of time under a control temperature. After the end of the process results in final products which consist of Alkyl esters and Glycerin. Alkyl esters have desirable properties as fuels to be used in diesel engines. Glycerin considered as a bi product and can be used to make several other products.

Biodiesel – Alternate Sources: Due to wide increase in number of automobiles in last several decades results in great demand of petroleum products. The rapid crude oil depletion and scarity of nonrenewable resources leads to search of alternate sources like biodiesel, LPG gas, hydrogen fuels etc. Among those biodiesel plays a major role and consider as viable alternative fuel while comparing with diesel. Biodiesel has several advantages it can be used in diesel engine without any major alternations. Another key factor is that it has no sulphur content aromatic hydrocarbons, metals or crude oil residues. Since biodiesel is naturally oxygenated fuel it emits very low amount of CO and soot particles while comparing with diesel fuel. Biodiesel is self-lubricating fuel so prolong usage won't affect the durability of diesel engine.

Production of biodiesel: While considering various advantages of biodiesel it has several drawbacks. Biodiesel in its fuel structure has contains tri-glycerides of fatty acids The molecular weight of these tri-glycerides would be high, so these fats have high viscosity causing major problems for usage as fuel in diesel. So biodiesel needs to be chemically modified and make them as lighter fuels by following various methods. It includes Pyrolysis, Micro emulsification, Dilution and Transesterification.

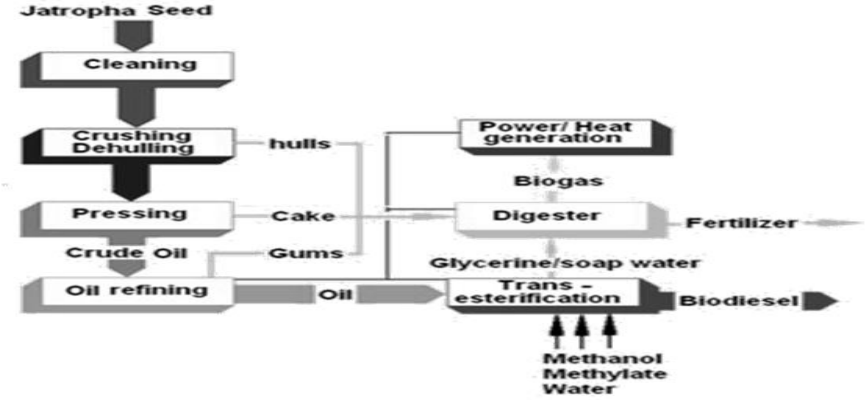

Figure.1. Biodiesel Production Method

Modifying the vegetable oils (to make them lighter) can be achieved in many ways, including; Pyrolysis, Micro emulsification, Dilution and Transesterification. Among these, transesterification is the most commonly used commercial process to produce clean and environment friendly light vegetable oil fuel that is biodiesel.

Transesterification: Among these, transesterification is considered as an commercially used method to produce biodiesel in surplus manner. In transesterification process the fatty acid triglycerides contains heavy molecules are chemically spitted give rise to simple esters. This process is accomplished by reacting triglycerides with a suitable alcohol with the presence of catalyst for some period of time under a control temperature. After the end of the process results in final products which consist of Alkyl esters and Glycerin. Alkyl esters have desirable properties as fuels to be used in diesel engines. Glycerin considered as a bi product and can be used to make several other products.

Table.1. Properties of the diesel and biodiesel fuel

Characteristics	Diesel	Jatropha
Density @ 15°C(kg/m^3)	836	873
Viscosity @ 40°C(cst)	3.2	4.9
Flash point (°C)	65	176
Cetane number	47	50
Calorific Value (MJ/kg)	42	39.5

Development of LHR Engine: In order to convert conventional diesel engine to LHR engine the engine combustion chamber was coated with partially stabilized zirconia (PSZ) of 0.5 mm thickness. The various parts of combustion chamber like piston crown, cylinder head and valves were coated. The equal amount of material has

been removed from the various parts of the combustion chamber and PSZ was uniformly coated by Plasma spray method.

2. EXPERIMENTAL PROCEDURE

In this work single cylinder, four stroke, constant speed naturally aspirated, water cooled direct injection engine was used. Over all specification of engine tested is shown in table 2 and its experimental set is shown in figure 2.

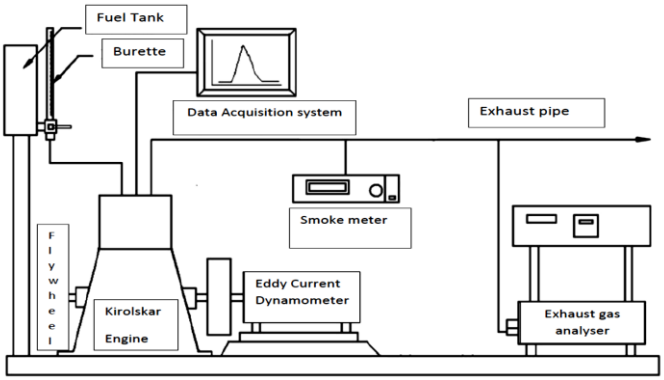

Figure.2. Experimental setup

In order to acquire combustion parameters engine is coupled with proximity sensor and pressure pickup and it is analysed using lab view software. Combustion pressure is acquired using pressure pick up and the crank shaft position is detected using proximity sensor. Signals obtained from various sensors were amplified using charge amplifier and is processed using Lab view software. The various emissions like HC, CO and Nox were measured using di gas analyzer.

Table.2. Specification of test engine

Make	Kirolskar AV1
No of stroke	4 Stroke
No of cylinder	One
Bore, mm	80
Stroke, mm	110
Compression ratio	16. 5: 1
Rated power output	3.74kW@1500 rpm
Injection Pressure, bar	200
Injection timing	23° BTDC

Initially engine is started and it warmed up for about 10 to 15 minutes. Then the load to engine was given using eddy current dynamometer which operates under the principle of faradays law. In order to acquire performance parameters the time taken for consumption of 10 cc of fuel was noted using stop watch.

A Probe is attached to the tail pipe extension; a filter is used to prevent the foreign particle entering into the analyzer. It gives the values of CO and CO_2 in % by volume, HC and NOx in ppm. This procedure is repeated by changing the loads from No load, 5 Nm, 10 Nm, 15 Nm, and 20 Nm. Corresponding readings were taken using Diesel and biodiesel as a fuel in both conventional and LHR diesel engine and results were compared.

3. RESULTS AND DISCUSSIONS

Brake Thermal Efficiency: Brake thermal efficiency variation with power output is shown in figure 3 at high load conditions. It shows that the brake thermal efficiency of conventional engine with diesel as fuel is higher than LHR engine with biodiesel as a fuel. . In overall, it is evident that, the thermal efficiency obtained in the case of LHR engine fueled with biodiesel is within the power output range of the test engine.

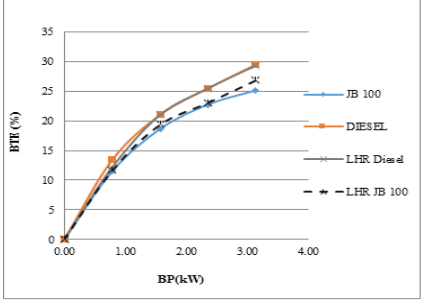

Figure.3. Variation of brake thermal efficiency with engine power output

Specific Fuel Consumption: Brake specific fuel consumption (BSFC) varition with engine power output for different fuels at high load conditions are presented in figure 4.From the figure clearly indicates that BSFC of LHR engine fueled with biodiesel more or less same while compared with LHR engine fueled with diesel and conventional engine fueled with diesel and biodiesel. This shows clearly that drawback of lower calorific value of biodiesel has been overcome by LHR engine. The main reason behind this is partially insulated combustion chamber retains and utilizes the heat energy produced properly.

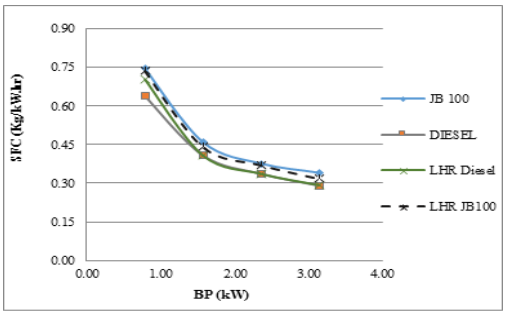

Figure.4. Variation of Specific fuel consumption with engine power output

Specific Energy Consumption: The variations of brake specific energy consumption (SEC) with engine power output for different fuels at high load conditions are presented in figure 5. The heat input required to produce unit quantity of power is proportionately varying with SFC. The figure revivals that the energy consumed during low load increases and it decreases in high load conditions. From the figure clearly indicates that the LHR engine fueled with biodiesel has higher SEC while compare with conventional engine fueled with diesel and slightly lower than for LHR engine with diesel.

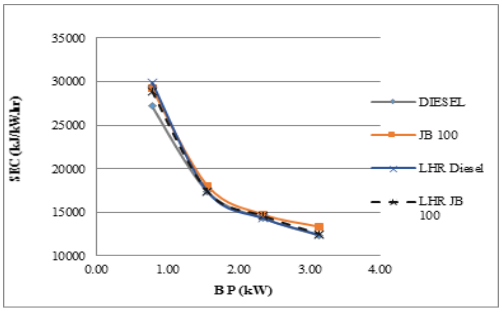

Figure.5. Variation of specific energy consumption with engine power output

Exhaust Gas Temperature: The variation of exhaust gas temperature with engine power output is shown in Figure 6.LHR engine fueled with biodiesel has low exhaust gas temperature when compared with conventional engine fueled with diesel and biodiesel respectively. This scenario occurs since LHR engine produces high in cylinder temperature so the exhaust gas temperature increases. Since biodiesel has low colorific value and high viscosity emits less heat release rate during combustion and so Exhaust gas temperature reduces.

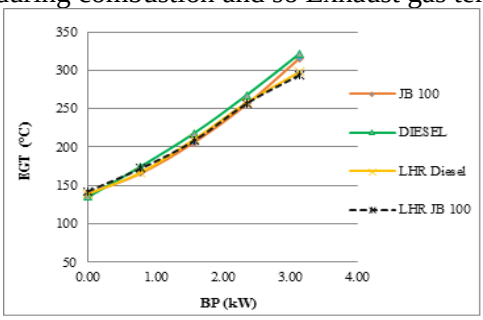

Figure.6. Variation of exhaust gas temperature with engine power output

Carbon Monoxide: Figure 7 shows the variation of carbon monoxide (CO) with engine power output .Trend shows the amount of CO emitted is high at low load conditions and decreases gradually at higher loads. The main reason behind this scenario occurs since at high load conditions more amount of fuel is injected leading to richer mixture and corresponding CO emission increases. During high load conditions CO emitted for LHR engine fueled with biodiesel is lower while compared with LHR engine with diesel, conventional engine fueled with biodiesel and diesel. The main reason behind this is that biodiesel is an naturally oxygenated fuel which contains 11% oxygen by weight. This oxygen content helps for complete combustion of fuel and hence CO emissions reduces with increasing bio diesel percentage in the fuel

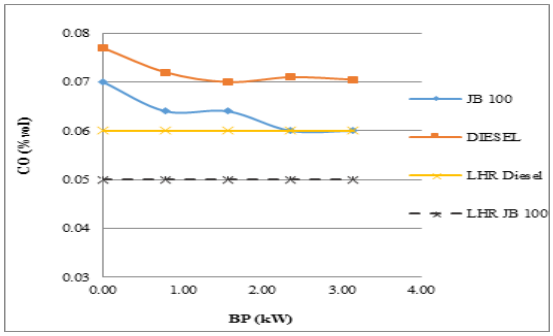

Figure.7. Variation of carbon monoxide with engine power output

Unburned Hydrocarbon: Figure 8 shows value of hydrocarbon (HC) with respect to engine power output for different fuels. The trend shows that LHR engine operated with biodiesel as a fuel shows minimum HC emission when compared with LHR engine fueled with diesel and conventional engine fueled with diesel and biodiesel respectively. The core reason behind this is that since LHR engine operated at high temperature leads to complete burning of fuel while compared with limited operating condition of diesel fuel. Unburned hydrocarbons formed in crevice volume are reduced due to LHR engine higher operating conditions and oxygen availability of fuels.

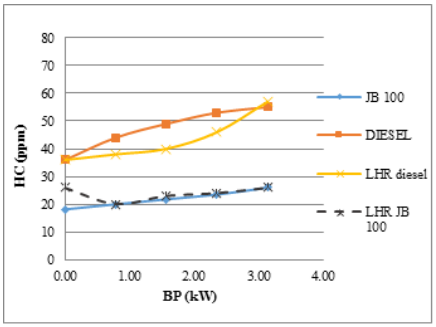

Figure.8. Variation of hydrocarbon with engine power output

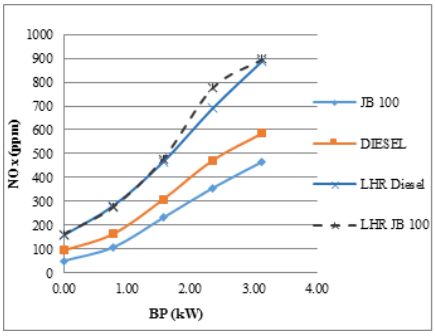

Figure .9. Variation of oxides of nitrogen with engine power output

The variation of oxides of nitrogen with engine power output shown in figure 9.Trend shows that the Nox value increases gradually when engine load increases for both the engines. LHR engines operated with biodiesel as an fuel shows higher value while compared with other two modes. The core reason for this scenario is that LHR engine in cylinder temperature increases due to insulation coating and oxygen availability in biodiesel.

4. CONCLUSION

In this work the conventional diesel engine was modified into LHR engine by coating various parts of engine like cylinder head, values and piston crown. Partially stabilized zirconia (PSZ) was used as a coating material and it was coated for various thickness. Jatropha was used as an biodiesel and it has obtained by using transesterification process to reduce the viscosity of the oil in order to match with properties of diesel fuel. The various parameters like performance, Combustion and emission parameters were studied and analysed and summarized as follows.

The brake thermal efficiency of conventional engine with diesel as fuel is higher than LHR engine with biodiesel as a fuel. LHR engine fueled with biodiesel has low exhaust gas temperature when compared with conventional engine fueled with diesel and biodiesel respectively. BSFC of LHR engine fueled with biodiesel more or less same while compared with LHR engine fueled with diesel and conventional engine fueled with diesel and biodiesel. This shows clearly that drawback of lower calorific value of biodiesel has been overcome by LHR engine .LHR engine fueled with biodiesel has higher SEC while compare with conventional engine fueled with diesel and slightly lower than for LHR engine with diesel. While considering CO emissions amount of CO emitted is high at low load conditions and decreases gradually at higher loads. The main reason behind this is that biodiesel is an naturally oxygenated fuel which contains 11% oxygen by weight which helps for reduction. In Case of HC emissions the trend shows that LHR engine operated with biodiesel as a fuel shows minimum HC emission. Since LHR engine operated at high temperature leads to complete burning of fuel while compared with limited operating condition of diesel fuel. Regarding Nox emissions level it increases gradually when engine load increases for both the engines. Since LHR engine in cylinder temperature increases due to insulation coating and oxygen availability in biodiesel leads to increase in Nox emission level.

The above comparative study concludes that LHR engine operated with biodiesel as an fuel has many core advantages in terms of its both performance and emission parameters. In future work water emulsion along with

biodiesel will be used to control the Nox emission level in acceptable limits.

REFERENCES

Abedin M.J, Mohd. F. Shair, Combustion, performance, and emission characteristics of low heat rejection engine operating on various biodiesels and vegetable oils, Energy Conversion and Management, 85, 2014.

Agarwal D, and Agarwal A.K, Performance and emissions characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine, Applied thermal engineering, 27, 2007, 2314-2323.

Forson F.K, Oduro E.K, and Donkoh E.H, Performance of Jatropha oil blends in a diesel engine, Renewable Energy, 29, 2004, 1135-1145.

Jaichandar S, and Annamalai K, The Status of Biodiesel as an Alternative Fuel for Diesel Engine– An Overview, Journal of Sustainable Energy & Environment, 2, 2011, 71-75.

Jinlin Xue S, Zannikos, Effect of biodiesel on engine performances and emissions, Renewable and Sustainable Energy, 2011.

Kalligeros S, Zannikos F, Stournas S, Lois E, Anastopoulos G, Teas C, and Sakellaropoulos F, An investigation of using biodiesel/marine diesel blends on the performance of a stationary diesel engine, Biomass and Bioenergy, 24, 2003, 141 – 149.

Kandpal J.B, and Madan M, Jatropha curcas: a renewable source of energy for meeting future energy needs, Renewable Energy, 6 (2), 1995, 159-160.

Leung DYC, Luo Y, Chan TL, Optimization of exhaust emissions of a diesel engine fuelled with biodiesel, Energy Fuels, 2006.

Parlak A, Yasar H, and Sahin B, Performance and exhaust emission characteristics of a lower compression ratio LHR Diesel engine, Energy Conversion and Management, 44, 2003, 163–175.

Pi-Qiang Tan, Oduro E.K, Exhaust emissions from a light-duty diesel engine with Jatropha biodiesel fuel, Energy, 2012.

Rajasekar E, Review of combustion characteristics of CI engines fueled with biodiesel, Renewable and Sustainable Energy, 35, 2014.

Rajendra Prasath B, Analysis of combustion, performance and emission characteristics of low heat rejection engine using biodiesel, International Journal of Thermal Sciences, 2010.

Rajendra Prasath B, Mohd. F. Shair, An Experimental Comparison Of Combustion, Performance And Emission In A Single Cylinder Thermal Barrier Coated Diesel Engine Using Diesel And Biodiesel, Global Journal of Science Frontier Research, 10 (4), 2010.