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Research Article

Performance and Emission Characteristics of Low Heat Rejection Diesel Engine Fueled with Biodiesel and High Speed Diesel

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Abstract: Depleting petroleum reserves on the earth and increasing concerns about the environment leads to the question for fuels which are eco-friendly safer for human beings. The objective of present study was to investigate the effect of coating on cylinder head of a Diesel engine on the performance and emission characteristics of exhaust gases using Bio Diesel and High Speed Diesel (HSD) as a fuel. In this study the effect of Tin and Hard Chrome coating on the performance and emission characteristics of diesel engine was investigated using Bio Diesel and High Speed Diesel as a fuel. For this purpose the cylinder head of the test engine were coated with a Tin and Hard Chrome of 100 μ thick by the Electroplating method. For comparing the performance of the engine with coated components with the base engine, readings were taken before and after coating. To make the diesel engine to work with Bio Diesel and High Speed Diesel a modification was done. The engine's performance was studied for both Bio Diesel and High Speed Diesel with and without Tin, Hard Chrome coating. Also the emissions values are recorded to study the engine's behavior on emissions. Satisfactory performance was obtained with Tin and Hard Chrome coating compared with a standard diesel engine. The brake thermal efficiency was increased up to 2.08% for High Speed Diesel with Tin coating and there was a significant reduction in the specific fuel consumption. The CO emission in the engine exhaust decreases with coating. Using Bio Diesel and High Speed Diesel fuel for a LHR diesel engine causes an improvement in the performance characteristics and significant reduction in exhaust emissions.

Keywords: Emission characteristics, exhaust emissions, hard chrome, heat rejection, Low Heat Rejection (LHR), tin

INTRODUCTION

The rapid depletion of petroleum fuels and their ever increasing costs have lead to an intensive search for alternate fuels. The most promising substitutes for petroleum fuels are Bio Diesel. It has been predicted that by the year 2030 all the present sources of fossil fuels would get depleted and the world would come to a stand still for need of fuel power. So, it is high time that scientists and technologists developed an alternate fuel that would run on the existing engines without many modifications and also one that would cater to the ever increasing power needs of the countries and domestic market (Beele *et al*., 1999).

Biodiesel are derived from oil-rich crops, such as rapeseed, sunflower, palm, olive and Jatropha. Biodiesel can be used with little or no modification to the engine and can be mixed with ordinary diesel oil. Vehicles run on Biodiesel produce lower levels of toxic emissions and leakages are less harmful. It can also carbon-neutral in that the growing plants absorb an equivalent amount of CO_2 to that emitted by the vehicle in use and unlike diesel it is biodegradable. Bio Diesel is one of the possible fuel for diesel replacement in Compression Ignition (CI) engines. The application of Bio diesel as a supplementary compression-ignition fuel may reduce environmental pollution, strengthen agricultural economy, create job opportunities, reduce diesel fuel requirements and thus contribute in conserving a major commercial energy source. There is need to develop alternate fuels to cater to the needs of the thirsty industries (Modi and Gosai, 2010; Demirbas, 2007; Lin *et al*., 2007; Abdul and Van Gerpen, 2001; Tiwari *et al*., 2007). Existing research results shows that Bio diesel is the best alternate fuel. So, we need a Bio diesel for better performance.

The thermal efficiency of the diesel engines can be increased by reducing the heat loss to the surroundings by means of coolant and exhaust gases. The heat can be transfer from the combustion chamber to the piston, to the combustion chamber walls and finally to the cooling

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water circulated in the cooling water jacket around the cylinder. The heat transfer can be minimized by reducing the heat that is transferred from combustion chamber to the pistons. This leads to the idea of insulating the piston and cylinder walls. These types of engines are known as Low Heat Rejection (LHR) engines. This can be realized by coating the cylinder walls with Tin and Hard Chrome which can withstand high thermal stresses (Hoare, 1979). They have low thermal conductivity thus reducing the heat flux into the piston and thus reduction of heat transfer to the coolant is reduced. When cylinder cooling losses are reduced, more of the heat is delivered to the exhaust system. Thus, efficient recovery of energy of the exhaust improves the thermal efficiency of a low heat rejection engine. However, installing in the engine configuration even without heat recovery systems, some of the heat is converted to piston work and increases thermal efficiency. Therefore, LHR engines without exhaust heat recovery systems are worth studying (Kaleemuddin and Rao, 2009; Bekal and Babu, 2008; Garcia *et al*., 2008; Jaichandar and Tamilporai, 2003; Kamo *et al*., 2006).

The peak burned gas temperature in the cylinder of an internal combustion engine is 1200 K. Maximum metal temperatures for the inside of combustion chamber space are limited to much lower values by a number of considerations and the cooling for the cylinder head, cylinder and piston must therefore be provided. These conditions lead to heat fluxes to the chamber during the combustion period. The flux varies substantially with the location. The regions of combustion chamber that are contacted by rapidly moving high temperature burned gases generally experience highest fluxes. In regions of high heat flux, thermal stresses must be kept below levels that would cause fatigue failures. Heat transfer affects engine performance, efficiency and emissions. For a given mass of fuel within the cylinder, higher heat transfer to the combustion chamber walls will lower the average combustion gas temperature are pressure and reduce the work per cycle transferred to the piston. Thus the power and efficiency are affected by the magnitude of engine heat transfer. The exhaust temperature also governs the power that can be obtained from the exhaust energy recovery devices such as turbochargers. The fan and water pump power requirements are determined by the magnitude to the heat rejected. Lesser heat transfer require less cooling power requirements and hence smaller its size.

During the intake process, the incoming charge is usually cooler than the walls. During compression, the charge temperature rises above the wall temperature. Heat transfer is now from the cylinder gases to the chamber walls. During combustion, the gas temperature increase substantially and this is the period when the heat transfer rates are highest. During expansion, the gas temperature decrease and hence the heat transfer rates also decrease. Substantial heat transfer from the exhausting gases to the valves and ports occurs during the exhaust process.

Table 1: Properties of Jatropha bio diesel

Properties	Jatropha biodiesel
Density (g/cm^3 at 20°C)	0.879
Flash point (°C)	191
Fire point (°C)	207
Cetane number	57-62
Viscosity (mm²/sec at 40°C)	4.200
Calorific value (MJ/L)	32.800

This present study aims to investigate the effect of coating on cylinder head of a Diesel engine on the performance and emission characteristics of exhaust gases using Bio Diesel and High Speed Diesel (HSD) as a fuel.

MATERIALS AND METHODS

Two major obstacles of the LHR engine are component strength and tribology at high temperatures, where conventional metals and lubricants fail to perform at elevated temperatures, Tin and Hardchrome coating materials provide an alternative. These materials have provided the major impetus to LHR research and development in recent decades. Materials those are suitable as thermal barrier coating are Zirconium, Tin, Hard Chrome, Silicon Carbide, Aluminum Titanate, Silicon Nitride and Aluminum Magnesium Silicate. The materials selected for the project are Tin and Hard Chrome, since these have lesser thermal conductivity and property of withstanding high temperature up to 1800°C, moreover it has low specific heat, high strength, high fracture toughness, high thermal shock resistance, low friction and wear resistance, high temperature capability, high expansion coefficient and chemical inertness for high resistance to erosion and corrosion when compared to other materials. Conventional piston and cylinder stresses make the application of Tin and Hardchrome extremely challenging. It is another kind of high temperature resistant coating which has recently been developed. The main objective of this coating is to provide thermal insulation to cylinder components at elevated temperature especially for diesel engine applications. Improvement of thermal efficiency and reduction of the CO emission level in TBC coated piston heads of diesel engine have been studied.

Properties of bio diesel: The important properties of Bio Diesel are listed in the Table 1.

Experimental setup: The experimental work is conducted on four stroke, single cylinder, water cooled, direct injection diesel engine coupled on an eddy current dynamometer as shown in Fig. 1. The specification of the test engine is shown in Table 2. For measuring of exhaust temperature, Nox and CO level

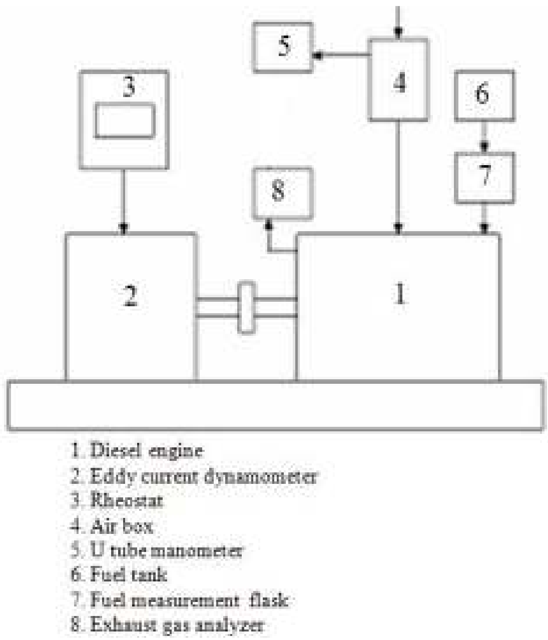

Fig. 1: Experimental setup

Table 2: Specification of engine

Parameter	Specification	Unit
Engine type	4 stroke, single cylinder, water cooled, CI engine	-
Stroke	110	mm
Bore	80	mm
Power	3.7	KW
Rated speed	1500	RPM
Loading type	Eddy current dynamometer	-

are made in the exhaust pipe. The exhaust temperature of the engine measured using digital chromel-alumel thermocouple. The NOX level is measured using NOX analyzer. The carbon monoxide is measured by using infrared analyzer. Fuel consumption is measured with the help of burette and digital stop watch. The experiments are conducted at various loads from no load to full load with uncoated cylinder head and coated cylinder head with different fuel (Bio Diesel, High Speed Diesel).

Experimental procedure: Initially fuel tank and auxiliary fuel tanks are filled with right amount of required fuel. Water pump is switched ON to cool the stator coils of the eddy current dynamometer which gets heated up while loading. The instruments such as Nox meter and CO analyzer are connected to the exhaust pipe. Eddy current dynamometer is switched ON and set to constant torque mode. The engine is started and allowed to run for 10 min to attain steady state condition. Now the time taken for 10 cc fuel consumption is noted using stop watch. Nox and CO emissions are noted using exhaust gas analyzer. Exhaust gas temperature is also noted. The procedure is repeated for the diesel fuel also.

The experiment is repeated for various loads and respective readings are taken. After taking the above reading the engine parts were dismantled. The coated cylinder head, piston head and walls were assembled. The same procedure was repeated to predict the performance of the engine with Tin and Hard Chrome coating.

RESULTS AND DISCUSSION

Brake thermal efficiency: Tin and Hard Chrome is a lesser thermal conductivity material. It will act as barrier for the heat transfer to the surroundings from the engine's combustion chamber and reduces the heat loss from the engine. Also as per first law of thermodynamics, the heat reduction in heat loss will ultimately increase the power output and thermal efficiency of the engine.

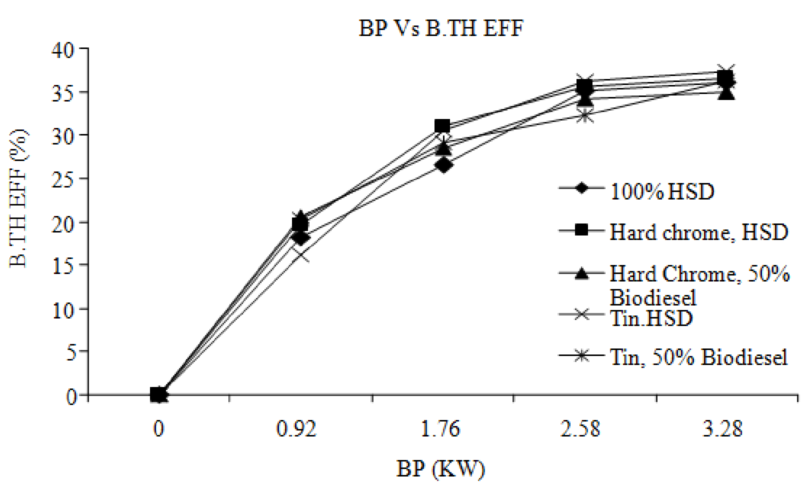

Fig. 2: Variation of brake thermal efficiency with Brake Power (BP)

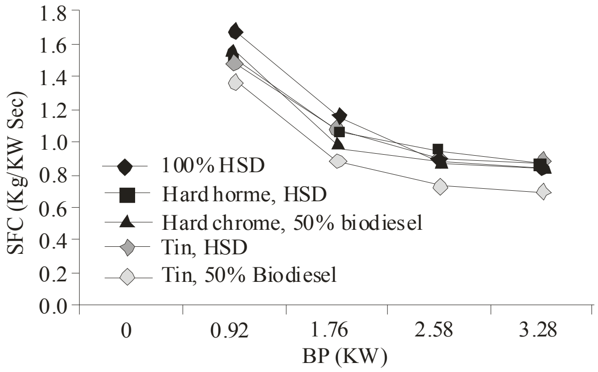

Fig. 3: Variation of specific fuel consumption with Brake Power (BP)

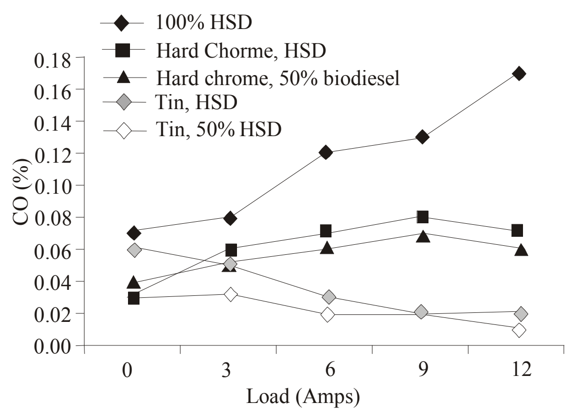

Fig. 4: Variation of CO with load (Amps)

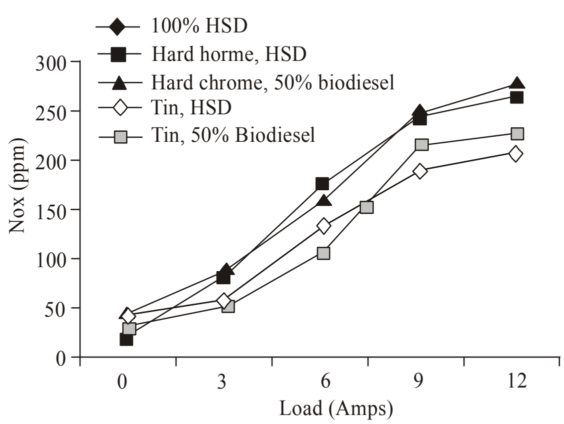

Fig. 5: Variation of NOx emissions with load (Amps)

From the Fig. 2, it is clear that the brake thermal efficiency of the engine are slightly increased after coating. The brake thermal efficiency for tin with HSD increases by 2.05% when compared with of Hard Chrome. And the brake thermal efficiency for tin with 50% HSD and 50% Biodiesel increases by 3.47% when compared with of Hard Chrome.

Specific Fuel Consumption (SFC): From the Fig. 3, it is clear that the Specific fuel consumption of the engine after coating is reduced. This will increase the brake thermal efficiency of the engine. This is due to the reduction of the heat loss to surroundings from the engine. From that, it is obvious that there will be an excess heat in the engine when compared with the amount of heat in the engine without coating, thereby increasing the brake thermal efficiency of the engine. Also it is suggested that the SFC is reduced up to some extent and it is increased for higher power requirement. There is slight variation in the curve for SFC before and after coating. The specific fuel consumption of hard chrome with HSD is 0.21% less than the hard chrome with 50% HSD and 50% Biodiesel and the specific fuel consumption of tin with 50% HSD and 50% Biodiesel is 20.14% less than the hard chrome with 50% HSD and 50% Biodiesel.

CO emissions: From the Fig. 4, it is clear that CO is decreased after the coating due to the complete combustion. The carbon monoxide, which arises mainly due to incomplete combustion, is a measure of combustion in efficiency. Generally oxygen availability in diesel is high so at high temperatures carbon easily combines with oxygen and reduces the CO emission. When compared to petroleum diesel, Biodiesel reduces emission of carbon monoxide by 44%. But in the case of engine with the Tin and Hard Chrome coating, the CO emission is reduced.

NOx emissions: From the Fig. 5, it is clear that there is a increase of Oxides of Nitrogen due to coating by 1.24%, because of the diesel engines always operate with excess air. The NOx emissions are mainly a function of gas temperature and residence time.

CONCLUSION

Thermal efficiency is the true indication of the efficiency with which the chemical energy input in the form of fuel is converted into useful work. Improvement in engine thermal efficiency by reduction of in-cylinder heat transfer is the key objective of LHR engine research. As a lesser thermal conductivity material, Tin and Hard Chrome is capable of reducing the heat loss from the cylinder to the surrounding this increases the life of the piston and piston rings. Due to the reduction in the heat loss to the surrounding, the power output and brake thermal efficiency of the engine is increased.

The specific fuel consumption is lower during operating range of the base engine in the case of the use of LHR. Similarly, the specific fuel consumption is reduced up to some extent and it is increased for higher power requirement.

NOx emissions are mainly a function of a gas temperature and residence time. Most of the earlier investigations show that NOx emission from LHR engines is generally higher. This is due to higher combustion temperature and longer combustion duration. But in the present investigation there was a increase of Oxides of Nitrogen due to coating.

The emission of CO is reduced because of the decreased quenching distance and increased lean flammability limit of LHR.

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