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Analysis of Performance Characteristics of Thermal Barrier Coated Diesel Engine Fuelled with Karanja Bio-Diesel

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***Abstract*-In the last few years demand of petroleum products is increasing day by day. As the fossil fuels are getting depleted day by day, there is an increase in crude oil price. As a result biodiesel is making its place as a future fuel. Biodiesel is popular as a pure fuel alternative (B100) or as blend with petroleum based diesel fuel. When biodiesel is blended with petroleum based diesel, it adds lubricity, a desirable feature, decreased when sulphur is removed. Thermal barrier coatings (TBC) are materials which are applied on the metallic surfaces, such as on engine components, operating at elevated temperatures. These coatings insulate engine components from large and prolonged heat loads by utilizing thermally insulating materials which can sustain an appreciable temperature difference between the load bearing alloy and the coating surface .In this work, the comparative effect of performance characteristics of standard compression ignition engine (STD) and zirconia coated low heat rejection (LHR) engine using both diesel and karanja oil are investigated. Plasma spray technique is used to deposit zirconia on piston of the test engine. The effect of Karanja biodiesel is analysed.The experimental work is carried out on 4 stroke single cylinder diesel engine. The result showed improved efficiency, reduced heat transfer to coolant and low emission.**

Key words: TBC, Low Heat Rejection Engine, Karanja Oil

1. INTRODUCTION

Diesel engines are more fuel efficient than other fueled engines because of high calorific value of diesel. The leading role of diesel engine in both transport and agriculture sector is because of its good fuel economy and lower running cost. However, diesel engines can only convert one third of fuel energy into useful work and the remaining two third is lost as waste through coolant and exhaust. The piston crown and cylinder head of diesel engines are coated with thermal barrier materials to reduce heat transfer to the coolant and also to improve power output along with an increase in the exhaust energy [1].

Thermal efficiency of the diesel engine would be improved, if the rejected could be reduced. It is better to reduce temperature levels by insulating CC walls, instead of providing extensive cooling.

Biodiesel, being renewable and ecofriendly, act as an alternative fuel to their diesel counterpart. Bio diesel is described as fatty acid methyl or ethyl ester obtained from vegetable oil or animal fats. It is renewable and biodegradable source of energy. Many researches pointed out that biodiesel might help to reduce green house gas emissions, promote proper combustion, and improve income distribution; there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. For example, the reduce of engine power for biodiesel, as well as the increase of fuel consumption, is not as much as anticipated; the early research concluded that it is more prone to oxidation for biodiesel which may result in insoluble gums and sediments that can plug fuel filter, and thus it will affect engine durability.

The first stage tests will be performed at different engine speeds and loads. The experiments will be conducted at four load levels. The required engine load percentage is adjusted by using the eddy current dynamometer. These procedures are repeated to cover the engine speed range at the specified load.

The second stage concerns an investigation of heat losses when combustion chamber insulation is applied. Stock aluminum pistons, cylinder head and valves were modified for coating with ceramic material. A 0.5 mm super alloy bond coating (NiCrAl) was first applied to these engine components. The cylinder head and valves were then coated with a 0.35 mm thin coating of $CaZrO_3$. The pistons were coated with 0.35 mm of $MgZrO_3$ using plasma-spray technique. The engine was insulated and tested at baseline conditions to see the effect of insulated surfaces on engine heat losses. A specific computer program was developed to process the data. The ceramic-coated engine (LHRE) was compared to standard engine.

1.1 Zirconia (ceramic coating)

Materials Required: Piston (87.5 mm), Piston rings, lock rings, Head gasket, and general tools.

The following parameter with coated (zirconia) and non coated pistons were noted in the operations of a single cylinder four stroke diesel engine.

Parameters:

- Time for 10 ml fuel consumption
- Manometer difference (cm)
- Water inlet temperature to calorimeter (T1)
- Temperature of water outlet of engine jacket (T2).
- Temperature of water outlet of calorimeter (T3)
- Temperature of exhaust gas inlet to calorimeter (T4)
- Temperature of exhaust gas outlet to calorimeter (T5)
- Time for one liter calorimeter water flow (T6)

2. LITERATURE REVIEW

The performance and emission characteristics of thermal barrier coated diesel engine fuelled with biodiesel results in improved efficiency, fuel consumption and exhaust emission [2-5]. Dongming Zhu *et al*. used zirconate based material for insulating engine component and concluded that TBCs increase engine operating temperature with adequate back- side cooling, thus results in great emissions and high efficiency [6]. The effect of titanium oxide coating on the performance characteristics of biodiesel fueled engine is studied by Naveen *et al*. They concluded that after applying Alumina- Titanium oxide coating, there was reduction in specific fuel consumption and an improved brake thermal efficiency for LHR engine [7]. Madhu *et al*. in their work coated normal diesel with alumina-zirconia powder and observed that brake specific fuel consumption at lower load is higher for non coated piston using biodiesel and at higher load maximum BSFC is for engine using coated piston and biodiesel [8]. Thus by coating the component, different properties can be achieved viz. increase of working temperature, efficiency, reduced thermal loads, reduced heat transfer to the cooling system and increased exhaust gas temperature[9-11]. Kamo and Bryzik in their work used thermally insulating materials such as silicon nitride for insulating different components of combustion chamber and reported an improvement of 7% in performance [12].

3. PROBLEM DEFINITION

Problem faced in Standard compression ignition diesel engine fueled with diesel are:

- Diesel engine convert one third of the fuel energy into useful work and the remaining two third is lost as waste through coolant and exhaust.
- Specific fuel consumption is more in standard compression diesel engine using diesel as a fuel.
- Exhaust gas temperature is high in standard diesel engine.

  Thus there is need to modify diesel engine in order to ensure low heat rejection, low specific fuel consumption and higher efficiency.

4. METHODOLOGY

The blends of bio diesel are tested on engine to check the performance of engine.

Table 1 shows the specification of diesel engine. There is no engine modification when diesel and diesel blends are tested on it.

Table 1 Technical specifications of the diesel engine

Parameters	Details
BHP	5
Speed	1500 RPM
No. of cylinder	One
Compression ratio	16.5:1
Bore	80 mm
Stroke	110 mm
Orifice diameter	21mm
Type of ignition	Compression ignition
Method of loading	Rope brake
Method of starting	Crank Start
Method of cooling	Water cooling

4.1 Apparatus & instrumentation required:

Engine test rig Tachometer, Stop watch, Digital Temperature Indicator to measure different temperature sensed by respective thermocouples. Manometer to measure the quantity of air drawn into the engine cylinder. Burette to measure the rate of fuel consumed.

4.2 Loading system:

The setup consists of a four stroke, single cylinder diesel engine connected with brake rope dynamometer. The brake rope dynamometer is used for loading the engine. One end of the rope (Top end) is connected to a spring balance and the other end to a weighing platform. The load to the engine can be varied by adding slotted weights provided. The platform is above the base (hanging) while the engine is loaded, this can be achieved by using the hand wheel provided on loading frame.

$$H.P = \frac{2\pi N (W_1 - W_2) (D + 2d)/2}{4500}$$

gives the BHP

Where, W1 = Dead Weights in Kgs

W2 = Spring Balance reading in kgs

D = Diameter of Brake drum in m (0.3m)

d = Diameter of rope in m (0.015m)

N = Speed of the engine RPM

4.3 Fuel measurement:

The fuel is supplied from the main fuel tank through a measuring burette with 3 way manifold system. To measure the fuel consumption of the engine, fill the burette by opening the cock on the manifold block. When the burette is filled with fuel close the cock. By starting a stop clock measure the time taken to consume 25 cc of fuel.

$$\text{Weight of fuel} = \frac{2}{\text{Time}} \times \frac{\text{Density of fuel}}{1000} \times 3600 \text{kg/hr}$$

4.4 Air flow measurement:

An air drum is fitted on the panel frame and is connected to the engine through an air hose. The air drum facilitates an orifice manifold with orifice and pressure pickup point of the orifice. The pressure pickup point is connected to and {"U' tube manometer limb. The difference in manometer reading is taken at different loads and the air sucked by the engine is calculated by.

$$V = C_d A \, 2ghm \frac{\sqrt{\rho}\sqrt{w}}{Pa} \times 3600 \text{ m /hr}$$

C_d of orifice = 0.62

Dia. of orifice = 20 mm

5. Experimental procedure:

Engine jacket inlet is connected to a water source with a constant head of 5 m. Panel instrumentation is connected to a 230 V 50 Hz single phase power source. Fuel is filled into the fuel tank mounted on the panel frame. Engine is started and allowed to run and stabilize (approximately 1500 rpm). Engine is loaded by placing the necessary dead weights on the weighing hangers, to load the engine in steps of ¼, ½, ¾, full and 10% over load. Engine is allowed to stabilize on every load change.

Following parameters indicated on the panel instruments on each load step were noted.

a) Speed of the engine from RPM indicator.
b) Rate of fuel from burette
c) Quantity of air sucked into the engine cylinder from manometer.
d) Temperatures TC1 to TC6 from the temperature indicator by turning the selector switch to respective position.
e) Quantity of water flowing through engine head and calorimeter from respective rotameters.
f) Exact load in kg (W1) plus weight of pan in Kg (W2) minus spring balance reading in Kg (W3)

With the above parameters recorded at each step load, the values are calculated for obtaining the heat losses.

After taking these parameters, the necessary calculations for brake power were done and the observations were noted.

Given;

Brake drum diameter = 190 mm

Rope diameter = 10 mm

Specific gravity of diesel = 0.832

Calorific value of diesel = 44600 KJ/Kg

C_p for water= 4.2 KJ/Kg°K

Torque (T) = [Brake drum radius + rope radius] x g x load

Brake power= (2πNT/60000) KW (KJ/sec)

HEAT BALANCE SHEET

1. HEAT INPUT = H = WF x CV kcal/hr
   Where WF = weight of fuel consumed
   CV = calorific value of fuel in kcal/hr (diesel) 11000 kcal/kg

2. Heat equivalent to BHP= H1 = $\frac{\text{BHP x 46500 x 60}}{427}$ kcal/h

3. Heat carried away by engine jacket cooling water= H_2

   H_2= mass of water flowing through engine jacket (kg/hr) x specific heat x difference in temperature inlet to outlet

   $H_2 = m\,C_p\,(T_3-T_1)$

   Specific heat of water is 1

   T_3= engine water jacket outlet temperature

   T_1= engine water jacket inlet temperature.

4. Heat carried away by exhaust gas = h3

   Heat carried away by exhaust gas= exhaust gas inlet to calorimeter to exhaust gas outlet of calorimeter

   H3= (mass of fuel + mass of air) x specific heat of gas x differences in temperature

   $= (M_f + M_a)\,C_p \times (T_4 - T_1)$

   Where, C_p= specific heat of gas = 1.008 kJ/kg°K

   M_a =mass of air = volume of air x density of air

   M_f= mass of fuel

5. Heat losses= heat supplied-(H_1+ H_2 + H_3)

6. RESULT AND DISCUSSION

The load test results were processed to compare the heat losses of all the diesel blends considered in the study.

Fig. 1 shows the variation of heat losses of pure diesel, B10, B20, B30 with the load for coated piston.
It is evident from the figure 1 that at lower load (5 kg), heat loss is minimum forB30 blend and maximum for normal diesel. At higher load (20 kg) heat loss is minimum for B30 blend and maximum for normal diesel.

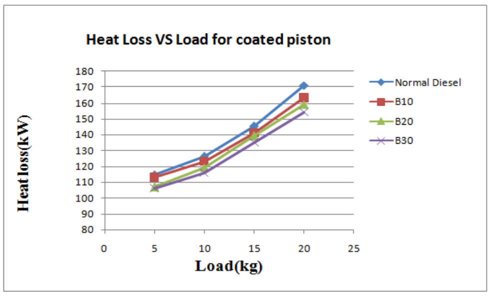

Fig 1: Heat loss VS Load for coated piston

Figure 2 shows the variation of heat losses of pure diesel, B10, B20, B30 with load for un - coated piston. It is evident from figure 2 that at lower load (5 kg), heat loss is minimum for B30 blend and maximum for normal diesel. At higher load (20 kg), heat loss is minimum for B30 blend and maximum for normal diesel.

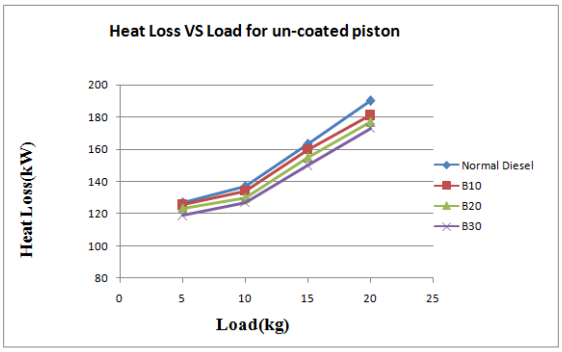

Fig 2: Heat loss VS Load for un-coated piston

Figure 3 shows the variation of heat loss with load for engine using normal diesel and coated piston and for engine using normal diesel and uncoated piston. It was found that for lower load that is 5 kg, heat loss is minimum for engine using coated piston and at higher load that is 20 kg, heat loss is higher for engine using unc

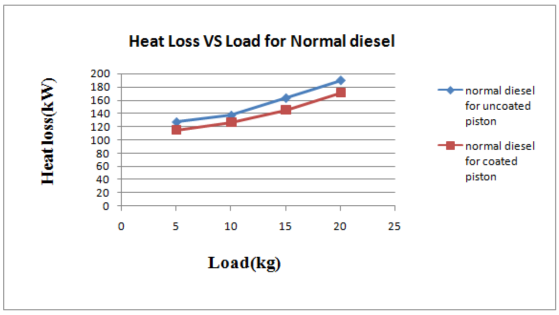

Fig 3: Heat loss VS load for Normal diesel

Figure 4 shows the variation of heat loss with increasing load for diesel engine using B10 for both coated and uncoated piston. It is evident from the figure that for uncoated piston heat loss is higher than that for coated piston at lower load. At 20 kg load, coated piston has lower heat loss as compared to uncoated piston.

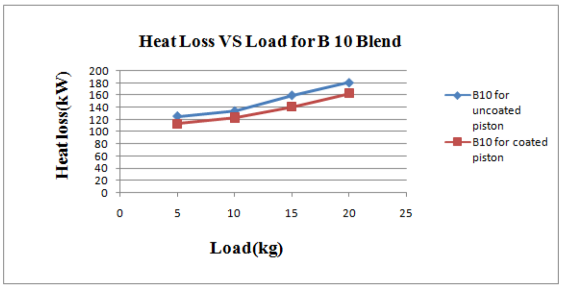

Fig 4: Heat VS Load for B10 blend

Figure 5 shows the variation of heat loss and load for B20 blend. It was found that at 10 kg load there is a little difference between heat loss for coated piston and uncoated piston. At 5 kg load, heat loss is higher for engine using uncoated piston. At higher load, coated piston has less heat loss.

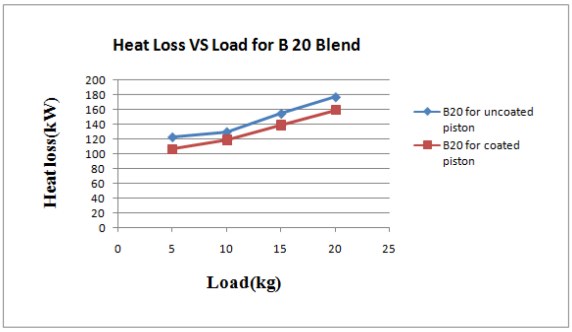

Fig 5: Heat loss VS load for B20 blend

Figure 6 shows the variation of heat loss VS load for B30 blend. It is evident from the figure that at higher load difference between heat loss for coated piston and uncoated piston is more in comparison to heat loss difference at 5 kg load. Also heat loss is higher for uncoated piston than that of coated piston for both lower and higher loads.

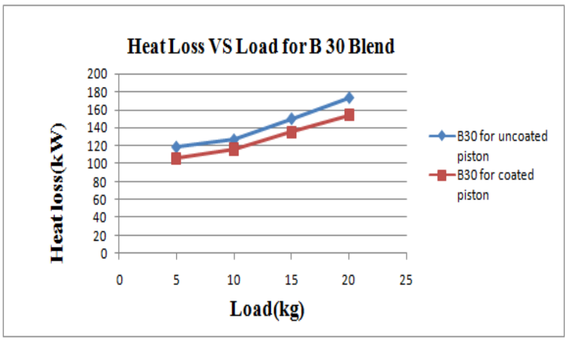

Fig 6: Heat loss VS load for B30 Blend

7. CONCLUSION

In this work, Conventional diesel engine is converted to Low Heat Rejection engine by coating engine components with thermal barrier coatings. The following conclusions can be drawn:

i. Due to reduced heat rejection, thermal efficiency of diesel engine is improved.
ii. Reduction in heat transfer to the coolant resulted in improved power output along with increase in exhaust energy.
iii. Thermal barrier coating resulted in low emission due to increase in engine operating temperature.
iv. Blending with petroleum based diesel had also added lubricity, a desirable feature, decreased when sulphur is removed.

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