

Effect of Mahua Methyl Ester on Performance & Emission Characteristics on Di Diesel Engine with Mullite as a Thermal Barrier Coating (TBC)

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Abstract - In the Di engine heat losses to the cooling system and surrounding plays a important role in the power output & in term the thermal efficiency reduction in heat loss to the surrounding directly increases the desired work output also thermal energy carried away by the exhaust gas which must be utilized to produced some useful work for the desired results by thermally insulating engine components like piston head, cylinder head & valves with a 0.5mm thickness of mullite($3Al_2O_3 \cdot 2SiO_2$) as a thermal barrier coating over a $150\mu m$ thickness of NiCrALY. Application of TBC improve the bsfc 9.89% with MME when compared to diesel fuel with TBC, brake thermal efficiency (BTH) increases 1.92% by use of TBC with MME as compared to conventional DI diesel engine. Exhaust gas temperature of MME with TBC is increases by 26.7% when compared to diesel fuel with TBC and reduction of 27% & 47% in CO & HC emissions respectively were obtained in LHR engine when compared to standard diesel engine at full load.

Key Words: Mullite, Mahua Methyl Ester (MME), TBC- Thermal Barrier Coating, LHR-Low Heat Rejection, BTH- Brake Thermal Efficiency

1. INTRODUCTION

The desire to reach higher efficiencies, lower specific fuel consumptions, thermal Efficiency and reduce emissions in modern internal combustion engines has become the focus of engine researchers and manufacturers for the past three decades. Diesel engines generally rejecting each one third of fuel energy to coolant and exhaust. Thus only one third of fuel energy is utilized as work output. By the thermally insulating heat rejection to the coolant can be reduced. Pioneer work was done in diesel engine technology by David J. Duval & Subhash H. Risbud [5] and different surfaces of combustion chamber was thermally coated with material like silicon nitride. Thermal barrier. coatings are used to improve reliability and durability of hot section metal components and enhance engine performance and efficiency in internal combustion engine by Hejwowski T & Weroniski A [10], the material used were partially stabilized zirconia (PSZ) and ZrO_2 & the investigations leads to lowering of fuel consumption by 2 to 16% and increasing thermal efficiency in the range of 2 to 2.6% as compared to conventional diesel engine. Mullite is an important ceramic material because of its low density, high thermal stability, stability in severe chemical environments, low thermal conductivity and favorable strength and creep behavior. It is a compound of

SiO_2 and Al_2O_3 with composition $3Al_2O_3 \cdot 2SiO_2$ Compared with YSZ. David J. Duval & Subhash H [5] Mullite has a much lower thermal expansion coefficient and higher thermal conductivity, and is much more oxygen-resistant than YSZ. For the applications such as diesel engines where the surface temperatures are lower than those encountered in gas turbines and where the temperature variations across the coating are large, mullite is an excellent alternative to zirconia as a TBC material. Engine tests performed with both materials show that the life of the mullite coating in the engine is significantly longer than that of zirconia. Above 1273 K, the thermal cycling life of mullite coating is much shorter than that of YSZ. Mullite coating crystallizes at 1023–1273 K, accompanied by a volume contraction, causing cracking and de-bonding. Mullite is the most promising coating material for the SiC substrate because their thermal expansion coefficients are similar by Ilhan A. Aksay & Daniel M. Dabbs [11]

Table-1 Important properties of mullite as TBC

Properties	Melting point	Thermal conductivity (λ)	Young's modulus (E)	Thermal expansion coefficient (α)
Mullite	2123 K	3.3 W/mK (1400K)	30 Gpa (293 K)	5.3×10^{-6} (293-1273)

one of the most promising is mullite. Mullite is an important ceramic material because of its low density, high thermal stability, stability in severe chemical environments, low thermal conductivity and favorable strength and creep behavior. It is a compound of SiO_2 and Al_2O_3 with composition $3Al_2O_3 \cdot 2SiO_2$ Compared with YSZ, mullite has higher thermal conductivity.

the exhaust emissions are affected by the use of biodiesel. It is known that biodiesel generally causes as increase in NOx emission and decrease in HC and CO emissions relative to diesel fuel. The purity of biodiesel was 99%. Parker D & Bonar J found [7] that 100% biodiesel experienced lower CO, HC emissions, while slight increased is NOx emission is realized by the Sukumar Puhana & N Vedaraman [12]. The biodiesel from mahua oil is termed as mahua methyl ester. Finally exhaust gas emissions with biodiesel have been investigated and compared with those of neat diesel fuel.

Table No.-2: Properties of mahua methyl ester & diesel

Properties	MME	Diesel fuel
Density(15°C),kg/m ³	880	850
Specific gravity	0.916	0.85
Kinematic viscosity at 40°C, mm ² /s	5.8	3.05
Calorific Value (KJ/kg)	39400	42800
Flash Point °C.	129	56
Fire Point °C.	141	63
Cetane No.	50	50

Finally exhaust gas emissions with biodiesel have been investigated and compared with those of neat diesel fuel by Yoshiyuki K & Changlin Y[8].

2. EXPERIMENTAL SETUP

A single cylinder, four stroke, constant speed, water cooled, direct injection diesel engine is used for the experiments conducted. The technical specifications of the engine are as below.

Table-3 Engine specifications

Name of Engine	Kirloskar
Stroke	4
Stroke length	110mm
bore	80mm
No. of Cylinder	1
Comp. Ratio	16.5:1
R.P.M	1500
Vdisp	552.94cc
Rated output	3.68kw(5.0hp)
Injection advance	27° BTDC
Loading	Hydraulic

Crude oil extracted from Mahua oil was transesterification into MME with the best of 905 ml yield of net biodiesel per liter of raw oil. Diesel engine is investigated first with diesel fuel and then is converted to LHR DI diesel engine by installing mullite coated piston crown, cylinder head and valves. Experimental were carried out LHR engine at no load, 20%, 40%, 60% and 80% load, applied on the engine with the help of a hydraulic dynamometer and full load condition with & without using MME as a fuel and the results are compared with standard engine. Nitrous oxides (NO_x), carbon monoxide (CO), hydrocarbon (HC) were measured by NETEL gas analyzer.



Fig.-1 Netel exhaust gas analyser

The schematic diagram of experimental test ring is below

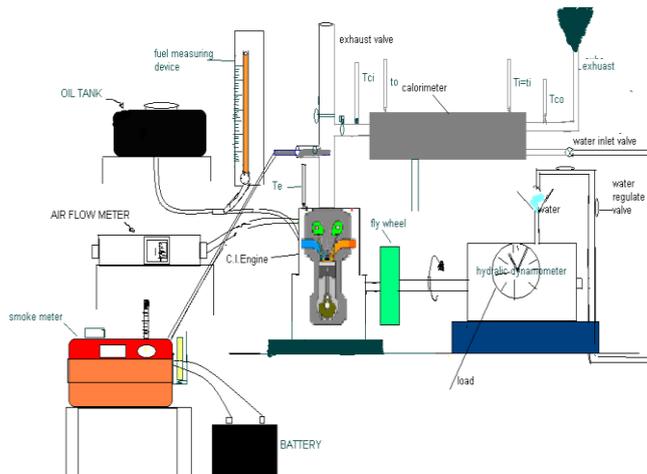


Fig.-1 Schematic diagram of experimental setup

2. RESULTS AND DISCUSSIONS

By the experimental investigations were carried out on DI diesel engine in which the LHR version i.e. with mullite as a TBC of the engine was fuelled with the well prepared MME & evaluation of BSFC, BTH, exhaust gas temperature and energy balance for LHR engine with and without MME fuel and is compared with that of LHR engine with diesel fuel. MME showed the reduction in CO and HC emissions, while NO_x emissions are increased and reduction in BTH is observed. Thus the final set up showed improved performance as well as exhaust emissions and not to be ignored heat loss to coolant is reduced with the effect of increase in thermal energy of exhaust gases.

2.1 Specific fuel consumptions

In the chart no-1 bsfc v/s load at 200 bar injection pressure with and without TBC. Here bsfc of diesel is less when compared to MME. bsfc of diesel without TBC is 10.6% less compared to that of MME without TBC at 80% load. bsfc of MME with TBC is increased by 9.89% when compared to diesel fuel with TBC.

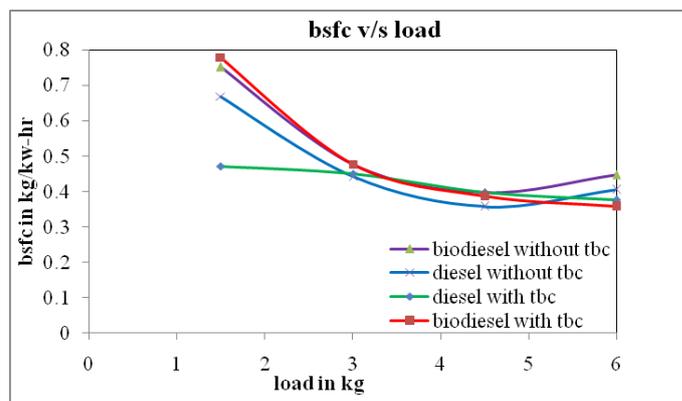


Chart-1: bsfc v/s load

2.2 Brake Thermal Efficiency

The brake thermal efficiency v/s load at 200 bar in the chart no. 2 injection pressure with and without TBC. brake thermal efficiency of MME without TBC is 1.07% less compared to that of diesel without TBC at 80% load. Brake thermal eff. of MME with TBC is reduced by 0.7 % when compared to diesel fuel with TBC, this decrement is very less as we are having remarkable improvement in emissions with MME as fuel. Application of TBC increases the brake thermal efficiency by 1.92% with MME as compared to conventional DI diesel engine.

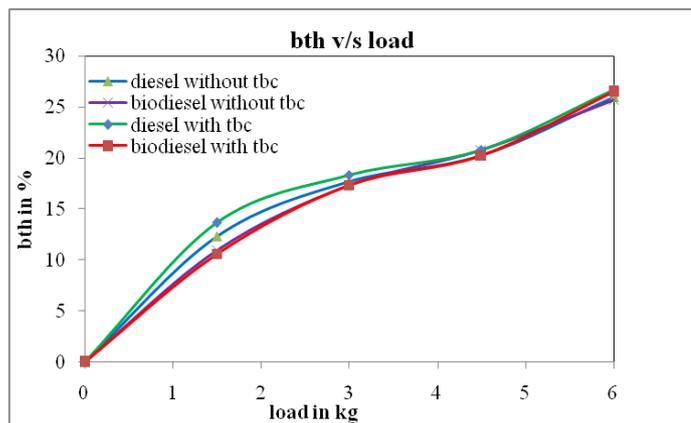


Chart-2: brake thermal eff. v/s load

2.3 Exhaust Gas Temperature

In Chart no.3 exhaust gas temp. v/s load at 200 bar injection pressure with and without TBC. Here exhaust gas temperature of diesel is less when compared to transesterified mahua oil. Exhaust gas temperature of diesel without TBC is 4% less as compared to that of mahua oil without TBC at 80% load. Exhaust gas temperature of MME with TBC is increased by 26.7 % when compared to diesel fuel with TBC.

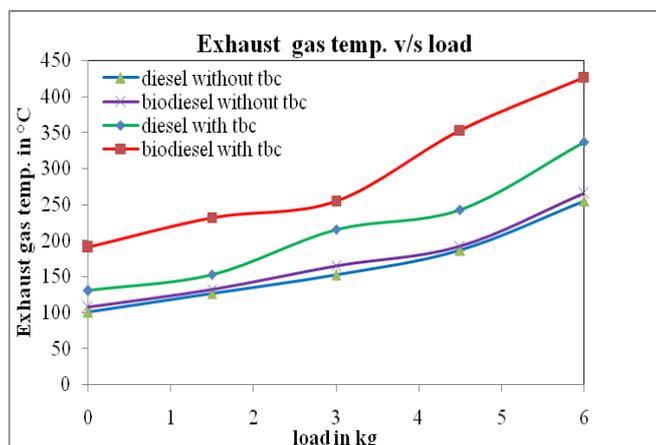


Chart-3: Exhaust gas temp. v/s load

2.4 CO Emissions

CO emissions of biodiesel are reduced by 27% when compared to diesel without TBC. CO emissions of biodiesel with TBC are also reduced by 34% as compared to that of diesel with TBC at 80% load show in the chart no. 4 The reason of less CO emissions is that biodiesel have extra oxygen molecule as compare to diesel.

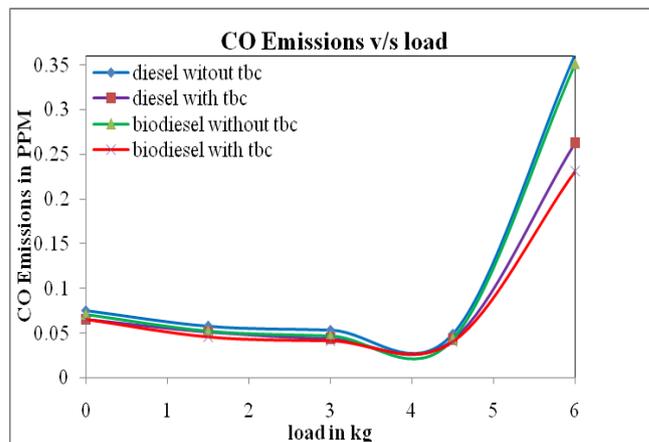


Chart-4: CO emissions v/s load

2.4 HC Emissions

In Chart no. 5 Comparison of HC emissions of diesel and biodiesel at 200 bar injection pressure are shown in figure. Here HC emissions of biodiesel are reduced by 47% when compared to diesel without TBC. HC emissions of biodiesel with TBC are also reduced 28% as compared to that of diesel with TBC at 80% load.

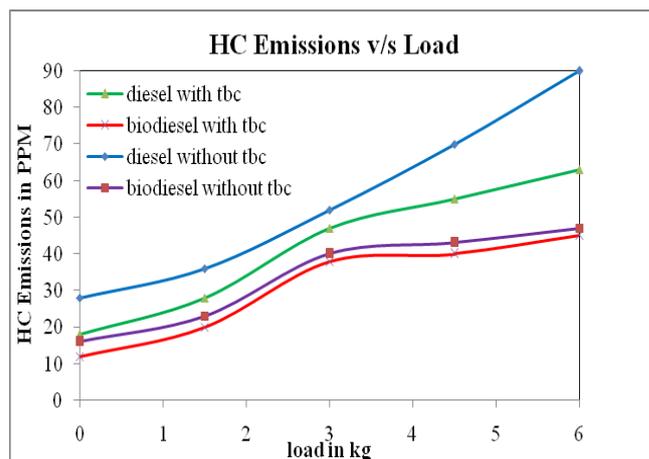


Chart-5: HC emissions v/s load

2.5 NOx Emissions

Comparison of HC emissions of diesel and biodiesel at 200 bar injection pressure are shown in figure. Here NOx emissions of biodiesel are increased by 31% when compared to diesel without TBC. NOx emissions of biodiesel with TBC are also increased by 32% as compared to that of diesel with

TBC at 80% load show in chart no. 6 Because the exhaust temperature higher when use coated piston.

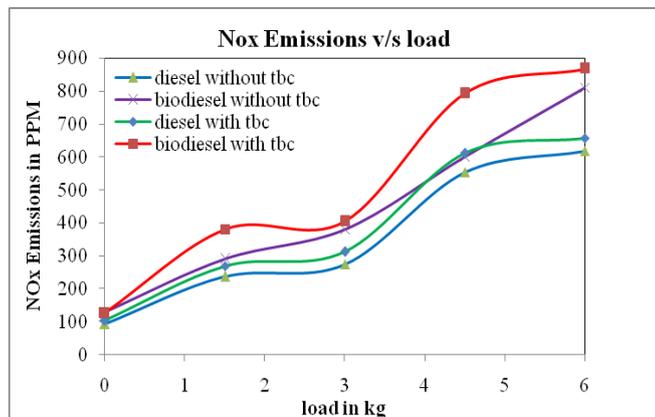


Chart-6: NOx emissions v/s load

2.6 Heat Balance Analysis

In fig.-2 and fig.-3 show the useful heat energy and heat lost through various means. With the application of thermal barrier coating on the piston crown, heat loss to the coolant water was reduced dramatically compared to standard diesel engine. It has been observed from the tests that the heat equivalent of brake power is higher to biodiesel compared to the diesel engine. This is due the complete combustion of the fuel and reduced frictional losses.

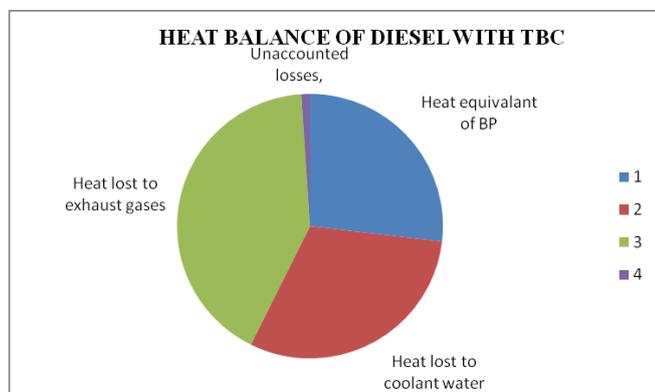


Fig.2:-Heat balance of diesel with TBC

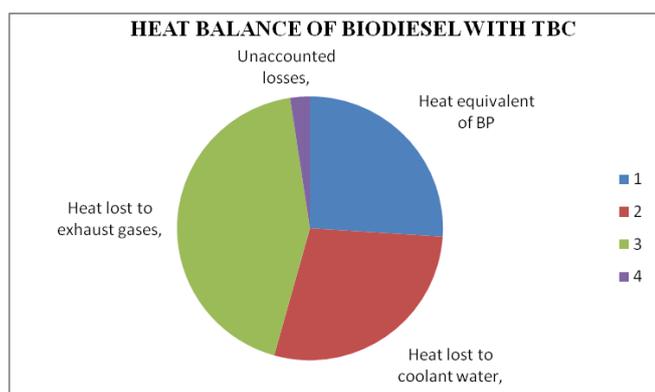


Fig.3:- Heat balance of biodiesel with TBC

3. CONCLUSIONS

When biodiesel was used as fuel, increments in the engine efficiency were mainly caused by the higher mixture heating value of the biodiesel. The application of the TBC, engine efficiency was increased mainly due to better combustion of fuel. Lower heating value of the biodiesel also reduced the exhaust gas temperature when biodiesel was used in standard diesel engine. With the application of the thermal barrier coating the exhaust gas temperature increases for both fuels in engine. CO, HC emissions and smoke density of biodiesel with TBC are also reduced by 34%, 28% & 26% as compared to that of diesel with TBC at 80% load. Application of the thermal barrier coating improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in LHR engine.

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