Effect on Performance & Emission Characteristics on Di Diesel Engine using biodiesel as Pongamia Methyl Ester (PME) with Mullite as a Thermal Barrier Coating (TBC)

Amit Kumar , Sandeep Kumar, Dr. A. Veeresh Babu

[1] *Asst. Prof. Mechanical Deptt. Subharti University Meerut (U.P.),*
[2] *Asst. Prof. Mechanical Deptt. Subharti University Meerut (U.P.),*
[3] *Associate Prof. Mechanical Deptt. Natioanal Institute of Technology Warangal (A.P.)*

---***---

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(3A2O3.2SiO2)as a thermal barrier coating over a 150µm thickness of NiCrALY. Application of TBC improve the bsfc 9.90% with PME when compared to diesel fuel with TBC, brake thermal efficiency (BTH) increases 1.92% by use of TBC with PME as compared to conventional DI diesel engine. Exhaust gas temperature of PME 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. PME-Pongamia Mehtyl Ester, TBC-Thermal Barrier Coating, BTH-Brake Thermal Efficiency & 3A2O3.2SiO2-Alumina Silicate.*

Key Words: **Mullite, Pongamia Methyl Ester (PME), TBC-Thermal Barrier Coating, BTH-Break Thermal Efficiency, LHR-Low Heat Rejection.**

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 or minimize. 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 & Weronski A [10], the material used were partially stabilized zirconia (PSZ) and ZrO2 & 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 SiO2 and Al2O3 with composition 3Al2O3.2SiO2 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 1275 K, the thermal cycling life of mullite coating is much shorter than that of YSZ. Mullite coating crystallizes at 1023–1275 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 llhan A. Aksay & Daniel M. Dabbs [11].

Table -1:

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 SiO2 and Al2O3 with composition 3Al2O3.2SiO2 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 Puhan & N Vedaraman [12]. The biodiesel from Pongamia oil is termed as Pongamia methyl ester. Finally exhaust gas emissions with biodiesel have been investigated and compared with those of neat diesel fuel.

Table -2:

Properties	PME	Diesel fuel
Density(22°C), kg/m3	850	847
Kinematic viscosity at 40⁰C, mm²/s	4.86	3.05
Calorific Value (MJ/kg)	39.40	43.66
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].

1.1 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:

Name of Engine	Kirloskar
Stroke	4
Stroke length	110 mm
bore	80 mm
No. of Cylinder	1
Comp. Ratio	16.5:1
R.P.M	1500
Vdisp	552.94cc
Rated output	3.68kw(5.0hp)
Injection advance	23° BTDC
Loading	Hydraulic

Crude oil extracted from Pongamia oil was transesterification into PME 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 PME as a fuel and the results are.

Compared with standard engine. Nitrous oxides (NOx), carbon monoxide (CO), hydrocarbon (HC) were measured by NETEL gas analyzer.

2. RESULTS & 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 PME & evaluation of BSFC, BTH, exhaust gas temperature and energy balance for LHR engine with and without PME fuel and is compared with that of LHR engine with diesel fuel. PME showed the reduction in CO and HC emissions, while NOx 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 PME. bsfc of diesel without TBC is 10.6% less compared to that of PME without TBC at 80% load. bsfc of PME with TBC is increased by 9.9% when compared to diesel fuel with TBC.

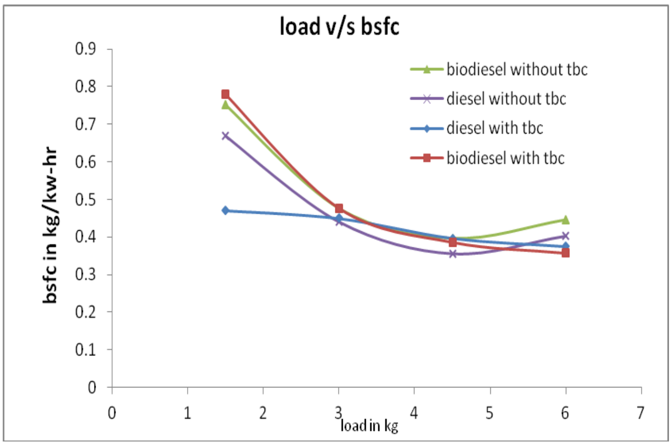

Chart -1: bsfc v/s load

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 PME without TBC is 1.08% less compared to that of diesel without TBC at 80% load. Brake thermal eff. of PME with TBC is reduced by 0.8 % when compared to diesel fuel with TBC, this decrement is very less as we are having remarkable improvement in emissions with PME as fuel Application of TBC increases the brake thermal efficiency by 1.92% with PME as compared to conventional DI diesel engine.

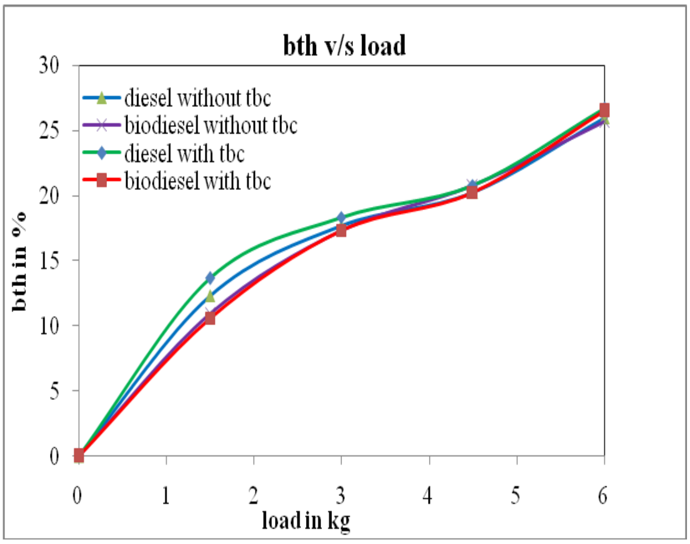

Chart -2: brake thermal eff. v/s load

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 Pongamia oil. Exhaust gas temperature of diesel without TBC is 4% less as compared to that of Pongamia oil without TBC at 80% load. Exhaust gas temperature of PME with TBC is increased by 26.8 % when compared to diesel fuel with TBC.

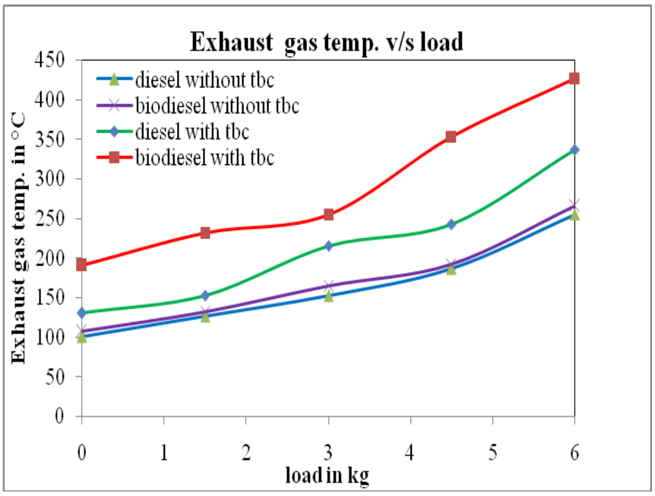

Chart -3: Exhaust gas temp. v/s load

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 reducedby 34% as compared to that of diesel with TBC at 80% load show in the chart no. 6. The reason of less CO emissions is that biodiesel have extra oxygen molecule as compare to diesel.

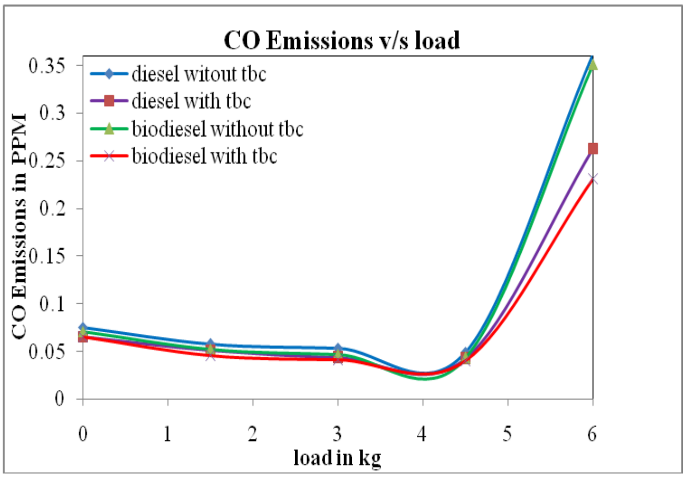

Chart-4: CO emissions v/s load

2.5 HC EMISSIONS

In chart no. 5 Comparison of HC emissions of diesel and biodiesel at 200 bar injection pressure are shown in chart. Here HC emissions of biodiesel are reduced by 48% when compared to diesel without TBC. HC emissions of biodiesel with TBC are also reduced 29% as compared to that of diesel with TBC at 80% load.

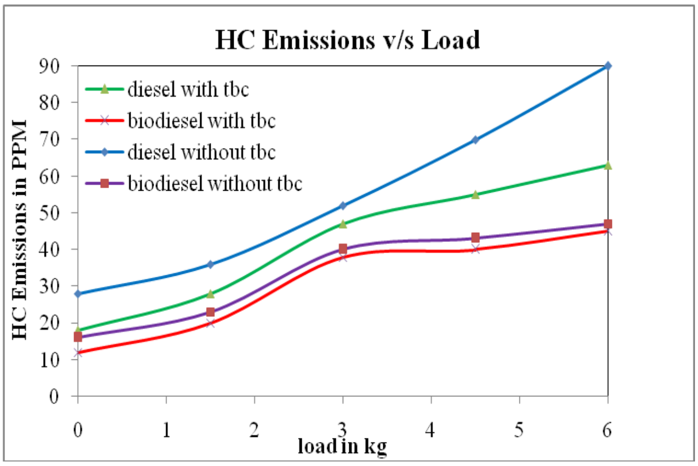

Chart -5: HC emissions v/s load

2.6 NOx EMISSIONS

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

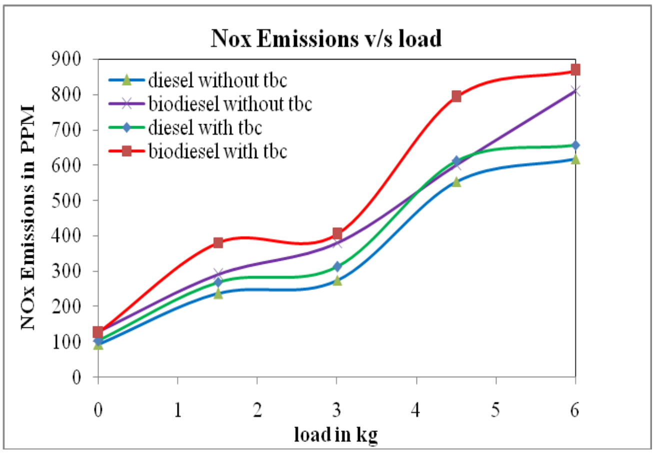

Chart -6: NOx emissions v/s load

2.7 Heat Balance Analysis

In Chart no. 7 and 8 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.

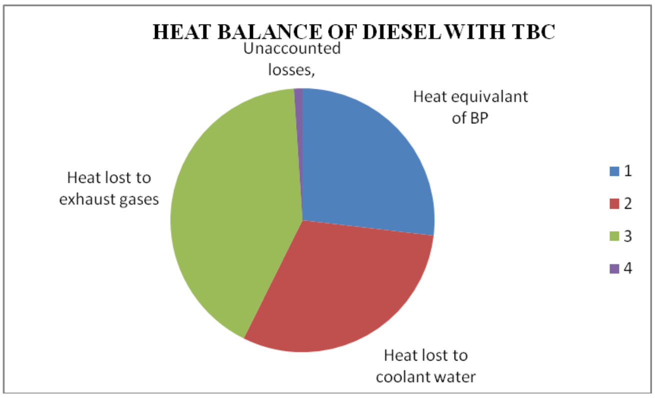

Chart -7: Heat balance of diesel with TBC

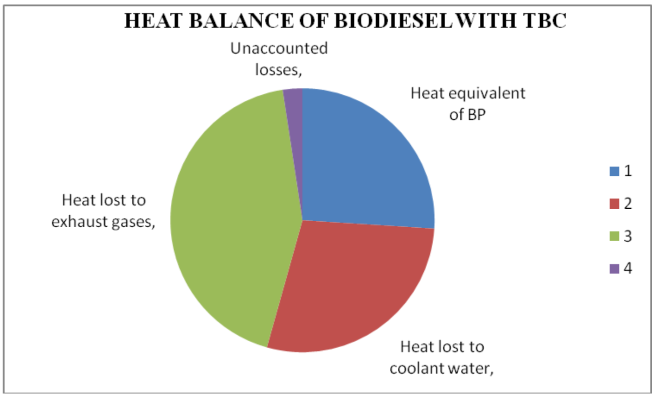

Chart -8: Heat balance of biodiesel with TBC

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 Thermal barrier coatting, 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 35%, 29% & 27% 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.

ACKNOWLEDGEMENT

We extend our sincere gratitude to l.j. technology private limited hydrabad (a.p.) for providing ceramic mullite to carry on our research work

REFERENCES

[1]. T.Morel, R.Keribar, P.N.Blumberg and E.F.Fort, “Examination of Key Issues in Low Heat Rejection Engines”, SAE Paper No.860316

[2]. Prasad CMV, Krishna MVSM, Reddy CP, Mohan KR. Performance evaluation of non-edible vegetable oils as substitute fuels in low heat rejection diesel engines. Proc Instrum Mech Eng 2000; 214 (D):181–7.

[3]. Kawamura H, Higashino A, Sekiyama S. Combustion and combustion chamber for a low heat rejection engine. SAE paper no. 960506, 1996.

[4]. T.Morel, R.Keribar, P.N.Blumberg and E.F.Fort, “Methods for Heat Transfer and Thermal Analysis of Insulated Diesels,” proceedings of the 23rd

[5]. David J. Duval, Subhash H. Risbud, Ceramic and Glass Materials: 27 (2009).

[6]. Brindley WJ et al., editors. Thermal Barrier Coating Workshop. Proceedings of a Conference, NASA Lewis Research Center, Cleveland, OH, March 27-29, 1995.

[7]. Parlak A, Yas-ar H, S-ahin B. Performance and exhaust emission characteristic of a lower compression ratio LHR diesel engine. Energy Convers Manage 2003;44(1):163–75.

[8]. Yoshiyuki K, Changlin Y, Kei M. Effects of fuel properties on combustion and Emission haracteristics of a Direct injection Diesel Engine, Society of Automotive Engineers paper No. 2000-01-1831, 2000.

[9]. Transactions of Nonferrous Metals Society of China, Volume 21, Issue 7, July 2011, Pages 1574-1579 Lan JIANG, Xiao-yan CHEN, Guo-ming HAN, Yu MEN.

[10]. Hejwowski T, Weronski A. The effect of thermal barrier coatings ondiesel engine performance. Vacuum 2002;65:427–32.

[11]. Mullite for Structural, Electronic, and Optical Applications “llhan A. Aksay,Daniel M. Dabbs? and Mehmet Sarikaya” 2343-58 -1991.

[12]. Performance and emission study of Pongamia ethyl ester in a 4-stroke natural aspirated direct injection diesel engine, Sukumar Puhana, N Vedaramana, G. Sankaranarayanana, b, Boppana V. Bharat Rama R.H.Thring, “Low Heat Rejection Engines”, SAEPaper No.860314

BIOGRAPHIES

Amit Kumar, (Asst. Prof)
Mechanical Department , Swami Vivekanand Subharti University-Meerut.
M.Tech (A.E.)-NIT Warangal (A.P.)

Sandeep Kumar, (Asst. Prof.)
Mechanical Department , Swami Vivekanand Subharti University-Meerut.
M.Tech (Production Engr).

Dr. A. Veeresh Babu (Asso. Prof.)
Mechanical Engineering Deptt. ,
National Institute of Technology,
Warangal (A.P.)