Experimental Investigation of Performance and Emission On Thermal Barrier Coated Diesel Engine

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ABSTRACT

The purpose of this experimental work is to investigate the impact of a thermal barrier coating (TBC) on a Plam seeds biodiesel-fuel engine. NiCrAl was used as a bond coat, and three layers of plasma spray were used to cover the piston head and valves. Al_2O_3 and TiO_2 mixed together was chosen as the second layer, while Yattria Stabilized Zirconia (YSZ) was chosen as the third layer. During the transesterification procedure, Plam squamosa seed oil was transformed into Plam methyl ester. A Kirloskar TV1 model with an extremely accurate eddy current dynamometer was used to test a direct injection single-cylinder diesel engine. The brake thermal efficiency is increased by 5.59% in terms of performance parameters, and the specific fuel consumption(sfc) and emission characteristics are reduced.

Keywords: Diesel engine; Thermal barrier coated diesel; Coating material; efficiency; Emissions; TBC

1. INTRODUCTION

Internal combustion engines must continually adapt to changing performance parameter requirements, such as those for emission control, fuel efficiency, performance improvement, and power enhancement. In addition, it is anticipated that the IC engines would see several, previously unheard-of design alterations in order to best utilize the available fuel supplies. From the standpoint of IC engines, many developments over the last few decades are apparent. A systematic expectation for improvements in engine efficiency and fuel economy is without a doubt the first notable trend that has come to light. Minimizing Greenhouse Gas (GHG) emissions and reducing reliance on foreign and imported petroleum sources follow in due course. The reductions in hazardous emissions (NO_x, CO, UHC, and PM) must be regulated and controlled by the Environmental Protection Agency as a follow-up measure to the fuel economy and GHG rules enacted in the US (EPA, 2012a). The promotion of the desired IC engine characteristics, such as cutting-edge combustion and engine design, is greatly aided by these requirements. Due to the existence of the catalytic reactors employed to minimize the 2 pollutants, the exhaust particles prove to be a significant concern for current engines in terms of the complexity and expense of the exhaust After Treatment System (ATS). It would be incorrect to treat the ATS and the combustion system separately. A high level of integration is necessary to maximize their effectiveness The temperature of the exhaust gas leaving the cylinder can be changed by making adjustments inside the engine to the thermal management of the ATS. In some circumstances, the engine's fuel injectors can provide the extra fuel needed by the ATS (for example, for thermal management). It is crucial to understand that engine optimization does not aim to optimize the reduction of pollutants in the ATS or decrease their emissions from the combustion system. Instead, achieving a target level of emissions across the board is the goal. The objective is often low enough compared to the legal limit to accommodate manufacturing variation. If the ATS performance is good enough to still allow the design target to be met, doing so might necessitate an increase in the emission of some pollutants from the combustion system. It is found that the engine already exists with a well-established and easily adaptable design, despite the present expectations on the CI engine, which are made worse primarily by the fuel economy and pollution standards. The constant adaptation and subsequent development of this design are unavoidable. The CI engine design needs to be enhanced for the adoption and acceptance of the complex combustion operations, notwithstanding the adjustments that have already been made to use other fuels. Also, the proper integration of alternative powertrain technologies with hybrid systems is required, which puts additional pressure on the promotion of design changes in CI engines. The ceramic coatings have a remarkable capacity to operate the engines at notable timings when gaseous fuel is used in CI engines. This is a really good fit and environment for the 3 to realize higher power levels. A CI engine design can accommodate a wide range of fuel compositions and fluctuations in ambient air temperature because to the ceramic coating induction. Without making any concessions regarding the adverse effects of the precombustion phenomenon, this induction is properly carried out. Regular suitable testing is performed.

2. LITERATURE REVIEW

Recent studies have shown that Thermal Barrier Coatings (TBC) are a useful material coating system that may be used on metallic surfaces, such as those of gas turbine or aero-engine parts, which are unquestionably operated at high temperatures. The TBCs are regarded as an efficient system for managing exhaust heat. The 100 m to 2 mm coatings offer excellent heat load insulation against high and sustained heat loads. The TBCs' capacity to withstand the temperature difference between the load-bearing components and the coated surface allows them to attain these superior insulating properties. These coatings have the capacity to restrict the thermal exposure of structural components while still enabling the coated components to operate at greater operating temperatures. By reducing oxidation and thermal fatigue, they also increase component life. The TBCs allow some turbine applications to operate at fluid temperatures over the melting point of the metal air foil in addition to active film cooling. The TBCs are determined to meet these requirements by effectively assisting in the reduction of the unwanted weights in the rotating and sliding components of engines. This is due to the growing demand for factors such as higher engine operation (efficiency increases at higher temperatures), better durability/lifetime, and other similar factors.

For improved dependability and longevity, engine performance, and efficiency, ceramic thermal barrier engine coatings may be used. This is due to the coated engines' combustion chamber temperatures being higher than those of the uncoated engines. This also allows for the use of low-quality fuels, such as pure palm oil, and fuels with broad distillation ranges. Around 30% of the total heat energy in a typical diesel engine is lost to the coolant. So, taking into account the widespread use of engine coatings could be a viable answer. The plasma spray method is typically used to apply TBCs to the cylinder head, piston, and valves. Ceramic coating on these components removes the unwanted effects of wear, friction,corrosion, oxidation, and heating. It was effectively demonstrated in a fictitious diesel cycle study that heat transfer is proportional to energy loss, which further increased the increase in work output and thermal efficiency.

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3. THERMAL BARRIER COATING (TBC):

Many research projects have been carried out in the automotive sector in recent decades with the express goal of reducing engine fuel consumption and environmental pollutants. Due to the significant rise in fuel prices, the decline in fuel production, quality compromises, and environmental restrictions, CI engines with lower heat rejection that fully utilize TBCs are becoming more popular. In diesel engines, the coolant fluid is typically responsible for roughly 19–20% of the fuel energy being deemed superfluous [Debasish Das et al., 2013]. Using the TBC is intended to lessen this unnecessary heat loss, which supports improved thermal efficiency. Moreover, the robustness of the engine parts might be increased as a result of the consistent TBC usage. Hence, The use of appropriate TBCs in the engine combustion chamber and exhaust system results in the desired improvement in combustion characteristics, as well as decreased pollution levels, improved thermal efficiency, and unparalleled fatigue lifetimes. Ingenious work consistently done by Kamo and Bryzik between the years of 1978 and 1989 has resulted in a substantial advancement in diesel engine technology. They are credited with being the first to apply TBC to CI engines, according to their work. The effort involved insulating the various combustion chamber surfaces with thermal insulating materials, including silicon nitride. Several 4 researchers have looked into every potential route for the CI engine architecture from the TBC standpoint, particularly when using TBC to achieve Reduced Heat Rejection (LHR). Due to many unresolved parameters in the current combustion chamber design, the amount of energy obtained from the diesel is not at an expected level. The design of the combustion chamber itself, a lack of adequate turbulence there, a lack of oxygen at the intermediate level, a lower combustion temperature, the compression ratio, and the advancement of injection timing are a few of the important inhibitory parameters. Of the aforementioned parameters, it is likely that the combustion temperature is one of the most important ones. During the combustion process, the full interaction of the hydrocarbons with the oxygen is not possible. Hence, the components of the combustion chamber's coating Using materials with lower thermal conductivity is a major area of research to address this shortcoming. Based on the aforementioned facts, the current research investigation is solely focused on the ceramic material coating of combustion chamber components employing various approaches.

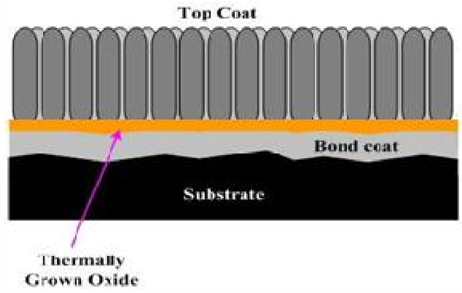


Fig. 1. *Thermal barrier coating*

TABLE I.Properties of Thermal Barrier Coating Materials

materials	Thermal Conductivity (W/ mk)	Thermal Expansion 10(1/k)	Melting point (oC)
YSZ (88% of mole of yatria remaining of zr02)	1	10.9	2980
AL203(60%)	30	12	3135
TI02(8%)	3.3	9.4	2123
NiCrA1(bond coat)	15	19	1673

A. BIODIESEL AS A FUEL IN DIESEL ENGINE :

Early in the 1890s, Rudolf Diesel patented the CI engine. For the engine's operation, the most popular peanut oil—obtained from common groundnuts—was employed. Typically, B100 diesel was used to power the CI engine. When compared to petrochemical diesel, this had a lower sulphur content, which encouraged better lubricating properties and a higher cetane number. The major use for biodiesel is as a viable substitute for regular diesel. The biodiesel can also be blended properly with regular diesel in a variety of ratios. However, biodiesel poses serious difficulties due to biodiesel production restrictions when blended with neat diesel at lower amounts. There is little doubt that the world's biodiesel producing facilities as a whole are not sufficient to satisfy the overall fuel requirements at this time. Biodiesel has a lot of environmental benefits. According to the current scenario, a diesel vehicle emits 3.3 tones of carbon dioxide in a single year. Hence, switching to biofuel will eliminate about 3 tones of extraneous carbon dioxide emissions per year. Since Malaysia will produce between 700,000 and 800,000 tones of palm biofuel year, switching to biofuel will unquestionably reduce the undesirable emissions of about 100,000 automobiles [MPOB, 2007]. It has been determined that using biodiesel regularly can reduce extremely dangerous acid rain by about 550 parts per million. Moreover, it reduces sulphur emissions by about 3,50,00 tones annually [Magin Lapuerta, 2008]. Biodiesel is a determined to burn more thoroughly while producing less smoke and soot than straight diesel. Particularly in urban areas, this significantly improves the air quality. Strictly speaking, biodiesel is said to have better qualities than regular diesel fuel. It offers improved lubricating properties, which implies fewer engine component wear and tear. A diesel fuel with a lower sulphur content, like Euro 5, will have a certain amount of lubricity, which implies significantly improvise from mixing. Since it contains more oxygen than regular diesel, biodiesel burns more consistently. 6 It makes sense, in the sense of a conclusion, that biodiesel is judged to be a clean, renewable fuel that can be used efficiently in all CI engines. In the long term, the biodiesel completely eliminated all concerns with pollution and unnecessary emissions. Also, it is planned to offer the engine better protection. The methodical practice of using biodiesel, a sustainable fuel, will lower carbon emissions and is very beneficial to the environment.

4. SELECTION OF SUITABLE THERMAL BARRIER COATING MATERIAL

Based on the material's physical and chemical characteristics, the TBC materials, which also include Yttria Stabilized Zirconia (YSZ), Titanium oxide (TiO_2), an alloy of Al_2O_3 and TiO_2, and YSZ, were selected. The chosen materials' wear resistance, bonding ability, and coating material deposition on the base metal were all examined in this chapter. SEM and EDX tests were carried out to determine the chemical makeup of the coating material as well as the deposition of the coating material on the base metal. The "peel off" adhesive test, which is used to identify good bonding strength of the coating material, was utilized to examine the bonding strength of coating materials. The chosen materials' wear rate and coefficient of friction were used the "Pin on Disc" test method for analysis. The next sections discuss the specified tests' methodology as well as their outcomes. This led to the selection of an appropriate material. Finite element analysis was used to compare the temperature distribution and heat transfer rate of the chosen material in order to determine the ideal coating thickness. The coating thickness was estimated to be 0.250 mm on the piston head, 0.250 mm on the cylinder liner, and 0.250 mm overall. In order to further investigate the study work, the high insulation temperature and low heat transfer rate 71 for the chosen thickness of the TBC material were studied.

A. COATING MATERIALS

According to the literature review, the following three materials were chosen because they have good TBC properties in terms of thermal fatigue strength, oxidation characteristics, physical properties, and chemical properties. In this section, the specific characteristics, benefits, and drawbacks resulting from the choice of the three coating materials are covered.

- YTTRIA STABILIZED ZIRCONIA(YSZ)
- ALUMINA OXIDE(Al2O3)
- TITANIUM DI OXDE(TiO2)

1) Yttria Stabilized Zirconia (YSZ)

The composition of YSZ is frequently chosen as the TBC layer material for a variety of CI engine applications due to its high thermal expansion coefficient, low thermal conductivity, and strong thermal shock resistance. When used on metals with a high thermal expansion coefficient, the YSZ can lower the thermal expansion variance. Since the engine gases contain high-velocity particles, YSZ serves as a good erosion resistance material and can survive these particles. Because the O2- vacancies were efficient phonon scattering sites, the thermal conductivity dropped as yttria content in the bulk YSZ increased. The increase in porosity levels caused the thermal conductivity to decrease, which enhanced in-plane compliance.

Fig. 2. *YSZ*

2) Aluminium Oxide (Al2O3)

High hardness and chemical inertness are two properties of aluminium oxide, often known as alumina (Al2O3). When compared to the YSZ, it is found that the Alumina has a comparatively high thermal conductivity and a moderate thermal expansion coefficient. The TBC material cannot be made only of alumina. Nevertheless, YSZ can be added to coatings to increase their hardness and to enhance the substrate's resistance to oxidation. In other words, the inclusion of silicon carbide fibres can enhance the alumina's inherent qualities. Hence, the coating's hardness can be increased by spraying alumina onto the yttria stabilized zirconia. The primary disadvantage of alumina is the comparatively high heat conductivity.When compared to YSZ, conductivity and low thermal expansion coefficient are present. When compared to an 8YSZ coating, an 8YSZ-Al2O3 gradient coating has a significantly longer thermal cycle life.

3) Titanium dioxide (TiO2)

Black hexagonal crystals are the most common type of titanium oxide nanoparticles. When compared to the materials indicated in appendix 2 (alumina and YSZ), it has a modest thermal conductivity. The primary benefit of titanium oxide is its capacity to function as a photocatalyst, which is utilized to break water down into hydrogen and oxygen molecules in order to minimize the polluting gases CO and HC. Moreover, the TiO2 can be doped with alumina to improve its characteristics, making it appropriate as an excellent TBC layer for the combustion chamber components in the CI engine.

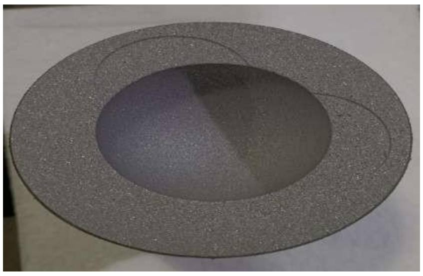


Fig. 3. AL2O3+TIO2

B. BOND COATING

NiCrAl as bond coating material

Plasma spraying is used to apply a nickel aluminum layer. The coating's most frequent use is as a bond coat between the metal substrate and a top coating. The nickel alloys with the aluminum during the spraying process to produce a nickel

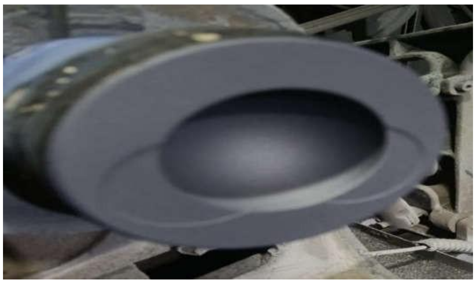


Fig. 4. Bond coat

aluminide. This alloying procedure is exothermic, which means that heat is produced. In the plasma flame, the material's individual particles melt, and as they move to the part, they employ exothermic heat to get hotter. When some of the particles actually diffuse into the substrate, creating microscopic spot welds, the individual particles subsequently adhere to the substrate. High structural integrity and strong bonding to a wide range of part base materials are characteristics of the nickel aluminum coating. Thickness with 0.75mm of coating.

Fig. 5. *Coated piston and Un coated piston*

C. SEM/EDX OF SELECTED MATERIAL

JSM 6700F scanning electron microscope was used to examine the characteristics of the pore morphology and the coating structure (SEM). It utilized cutting-edge digital imaging technology, ran under extremely high vacuum, and had a cold cathode field emission cannon. This microscope had a very high resolution of 1.0 nm at 15 kV and 2.2 nm at 1 kV and operated at accelerating voltages that ranged from 0.5 to 30 kV. The secondary electron imaging (SEI) capacity of the microscope made use of the through lens, in-chamber secondary electrondetectors, and backscattered electron imaging (BEI), with both compositional and topographical imaging contrasts. Also, it has the capacity to analyse material composition using an energy-dispersive X-ray spectroscopy (EDXS) detector, which was utilized to identify the crystalline structure of the phases present as well as the texture seen in the coating. The data were displayed on energy dispersive X-ray spectroscopy plots with X-ray wavelength on the X-axis and intensity on the Y-axis, each labelled with the respective element. By comparing the peak values on the x axis with the known wavelengths for each element, the elemental makeup of the sample may be determined.

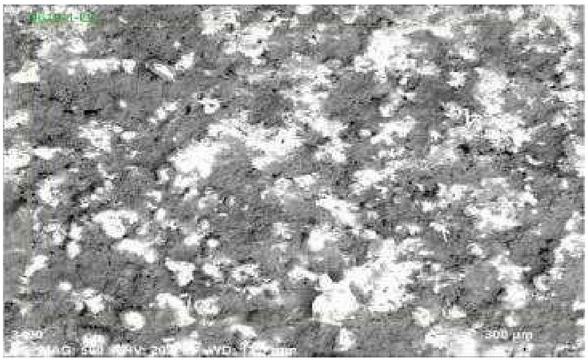


Fig.6.Sem of ysz

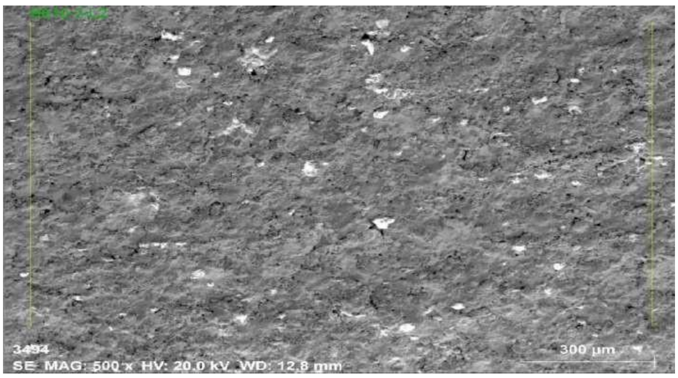


Fig.7. Sem of AL2O3+TIO2

D. TEST FUEL

The combination of Palm Biodiesel (BD 60, BD 80, and BD 100) and clean Petroleum-Based Diesel Fuel were the two fuels employed in the experimental inquiry (PBDF). The characteristics of diesel fuel and neat palm biodiesel were extensively examined.

E. Palm Oil

It is undeniably true that palm oil is the most productive oil produced globally per unit of land. Due to the minimal engine modification needed, palm oil mixed diesel has become a viable alternative fuel for internal combustion engines. This provides an extended engine life and lowers the dangers that could endanger human health and the environment during the stages of production, shipping, storage, and use.

Methyl alcohol was employed as a reactant and sodium hydroxide (NaOH) as a catalyst in the transesterification process to turn palm biodiesel into palm oil methyl ester (POME) (Gnaprakasam et al. 2013). The local market was used to acquire palm oil and diesel. For the study, analytical grade methanol, potassium hydroxide, and acetic acid were bought from a chemical supplier. The solid phase of the palm oil was first turned into liquid form by heating it. There was a transesterification reaction in a sphere-shaped glass reactor with a stirrer, a reflux condenser, and a thermometer. 1 liter of palm oil, 200 ml of methyl alcohol, and 12.5 g of potassium hydroxide were added to the reaction, and the mixture was heated at 65 °C for 1.5 hours. Following the reaction time, the liquid was left in the separation funnel for 8 hours to allow the methyl ester and crude glycerin to separate. The crude methyl ester was then dried for an hour at 105 degrees Celsius after being washed twice with water and 5% acetic acid until the water was clear. After transesterification, cleaned and dried methyl ester was run through a filter to extract the 98% oil conversion.

Fig. 6. *Plam seeds* *and* *Plam kernel and mesocarp*

Fig. 7. *Transeterification process*

F. PLASMA SPRAY TECHNIQUE

There are several distinct types of thermal barrier coating processes, including physical vapour deposition, chemical deposition, atmospheric plasma spray, and plasma arc. The approach of spraying atmospheric plasma is the most appropriate for this experimental investigation. By spraying molten metal on a metal surface, the plasma spraying method coats the metal. The material is introduced into a high-temperature plasma flame in powder form, where it is heated extremely quickly. Plasma gas streams past the anode and around the cathode, which is shaped like a nozzle and contains helium, argon, hydrogen, and nitrogen A high voltage release that results in restricted ionization and creates a conductive path for a DC arc to frame between the cathode and anode initiates the plasma. An 80 kW atmospheric plasma spray apparatus initially applied a bond coat of 0.75 mm thick NiCrAl powder to a piston crown. Then, a 0.250 mm thin top coat of ceramic powder made up of 88% Yttria stabilized Zirconia, ND 60% A L2O3, and 4% TiO2 is applied to a piston crown. Table lists the spray parameters for both line coat and top coat. Fig. illustrates how plasma spray coating operates. The images of the uncoated piston and the coated YSZ and A L2O3-TiO2 combination .

Fig. 8. *PLASMA SPRAY TECHNIQUE*

TABLE II. Specifications of Plasma spray Coating

Coating parameters	Specifications
Plasma Gun	3 MB Plasma spray gun
Nozzle	GH Type nozzle
Organ Gas Pressure	100-120 PSI
Organ Gas Flow Rate	80-90 LPM
Hydrogen Gas Pressure	50 PSI
Hydrogen Gas Flow Rate	15-18 LPM
Feed Rate Of Power	40-45 g per minute
Distance Of Spraying	3-4 m

G. METHODOL0GY

Step 1: Using a plasma coating spray, titanium dioxide and yttria stabilized zirconia are applied to the piston.

Step 2:The engine's coated piston is replaced in step two.

Step 3: Non-edible bio diesel is used as fuel in this coated piston engine, which is then put through performance and emission testing.

Step 4: The biodiesel is put through its paces in a conventional engine under the same operating circumstances (no modified pistons).

Step 5: Results for coated and uncoated piston engines are contrasted.

H. EXPERIMENTAL SETUP

Table is a list of the experimental test rig's technical specifications. A variable compression ratio compression ignition engine, an eddy current dynamometer, a fuel supply system, a fuel delivery system, a lubrication system, and a computerized data collecting system make up the experimental test rig. Fig. depicts the conceptual layout of the experimental test setup. The experiment was carried out using an eddy current dynamometer under five distinct load settings, ranging from no load to full load. The emission parameters, including carbon dioxide (CO_2), carbon monoxide (CO), unburned hydro carbon (HC), and nitrogen oxide (NO_x), were analyzed using an AVL Five gas analyzer. With an ARAI-EDACS controller system, all performance and emission characteristics were eliminated. Test engine specifications are listed in Table.

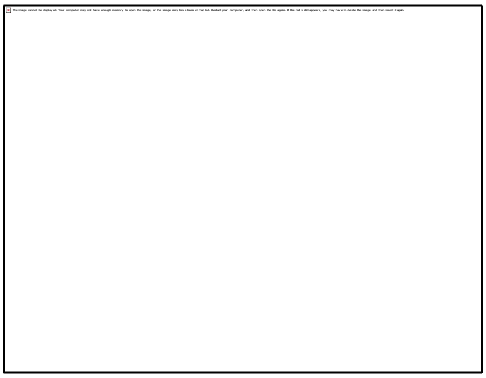


Fig. 9. *Expermental setup*

TABLE III. TECHNICAL SPECIFICATION OF ENGINE

SERIAL NUMBER	PARAMETERS	VALUES
1	ENGINE MAKE	KIRLOSKR
2	MODEL	TV 1
3	NO OF CYLINDERS	1
4	NO..OF STROKES	4
5	FUEL	DIESEL
6	RATED POWER(KW)	5.2 KW @1500 RPM
7	CYLINDER DIAMETER(MM)	87.5 MM
8	STROKE LENGTH(MM)	110 MM
9	COMPRESSION RATIO	17.5:1
10	IGNITION TYPE	COMPRESSION IGNITION
11	COOLING	WATER COOLED
12	LOADING TYPE	EDDY CURRENT DYNAMOMETER

13	COMBUSTION CHAMBER INJECTOR NOZZLE	3 HOLES WITH 0.3 MM DIAMETER EACH
14	COMBUSTION CHAMBER SHAPE	HEMI SPHERICAL SHAPE
15	IGNITION TIMING(CAD)	23 CAD BTDC
16	INJECTION PRESSURE(BAR)	200 BAR

5. RESULTS AND DISCUSSION OF EFFECT OF TBC

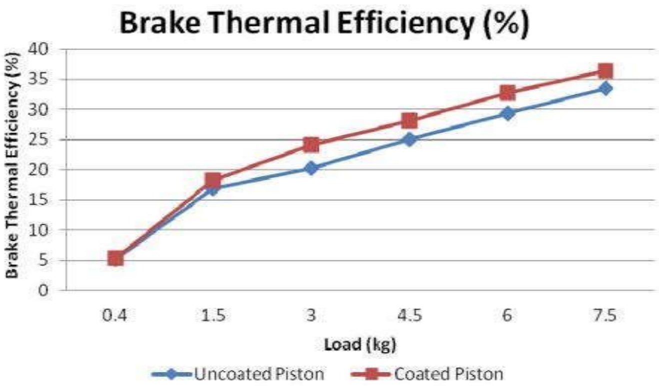
Under various load levels of 0%, 25%, 50%, and 100%, the performance and combustion parameters of the diesel-fueled TBC engine were compared. The phrase "base engine" refers to the "uncoated engine" in the statistics that follow. The TBC coatings that were put to the cylinder liner in the CI engine had corresponding thicknesses of 75micron, 250micron, and 250micron.

A. Specific Fuel Consumption (SFC)

The changes in the amount of fuel consumption in the base engine and the other coated piston head under various loads were clearly shown in Figure. When the results were compared to the base engine, the specific fuel consumption at 25% load condition reduced to 2%, 8%, and 12%, respectively, in the 70,250 and 250 micron coated cylinder liners. The SFC was found to decrease in the coated piston with the base engine by 5.714%, 5.714%, and 11.428% under a 50% load (part load) situation. The drop was seen as 3.333%, 10%, and 13.333%, respectively, under conditions of 75% load. When the results were examined under a 100% load (full load) situation, the SFC decreased by 3.571%, 7.142%, and 10.714% in the respective coated piston. The outcomes were evaluated against the base engine.

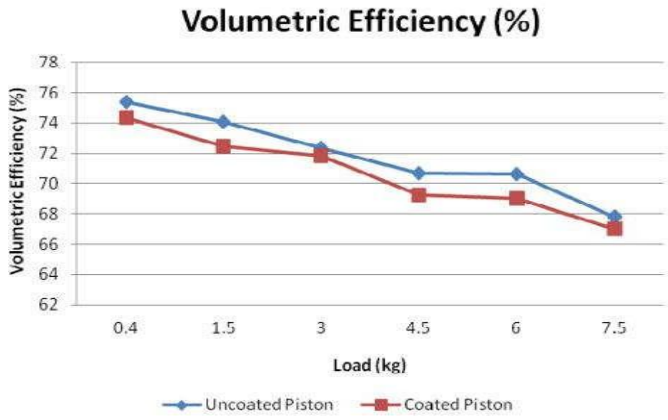
1) Brake Thermal Efficiency

According to Fig. the maximum braking thermal efficiency for the baseline engine and the TBC coated engine is 36.4% and 33.5%, respectively. When the engine is loaded at 75% of full load, the maximum development of 10% in brake thermal efficiency is shown. This is because the thermal barrier layer prevents heat energy from the piston crown from being transmitted through cooling water or any other medium to the atmosphere. As a result, the fuel consumption is reduced, increasing the thermal efficiency of the brakes.



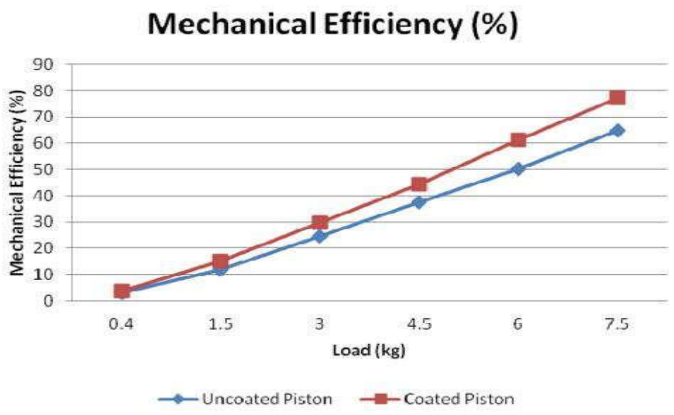
2) *Volumetric Efficiency:*

Figure shows the variations in volumetric efficiency of baseline and TBC-coated engines under various load circumstances. Based on the environment and the engine's operational circumstances, the engine's capacity for inhalation is referred to as volumetric efficiency. The LHR engine's ceramic coating lowers heat transfer, which raises the temperature of the combustion chamber walls. The TBC coated engine has a lower volumetric efficiency. This is because heated walls and outside gas cause the concentration of the infused air to drop.



3) *Mechanical Efficiency:*

The TBC coated engine exhibits higher mechanical efficiency than the uncoated engine at all loading circumstances, as shown in Fig. 8. The highest mechanical efficiency of the baseline engine and TBC coated engine, respectively, is 64.3% and 77.3%. Mechanical efficiency increases by 16.81% at fully loaded conditions. This is a direct effect of the energy expansion brought on by TBC. Due to a reduction in heat rejection to the engine cylinder walls, the energy available for work output will increase, increasing mechanical efficiency.



6. Emission Characteristics

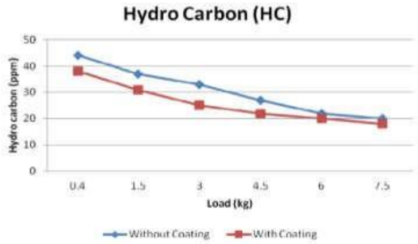
To characterize the emission parameters, the engine is put through testing using an AVL five gas analyzer. Figure 9 displays the weighted average of the experimental data's emissions of Nitrogen Oxide, Carbon Monoxide, Carbon Dioxide, and Hydrocarbons. When compared to the baseline engine, it has been found that the TBC coated engine has CO2 emissions that are up 39.28% and HC emissions that are down about 28.2% and 15.8%, respectively. The average value of each emission for each load state was computed for both the TBC coated engine and the baseline engine. This resulted in the weighted average of emissions such as CO, CO2, HC, and NOx. Plot the weighted average emission graph for the baseline engine and the TBC coated engine following that.

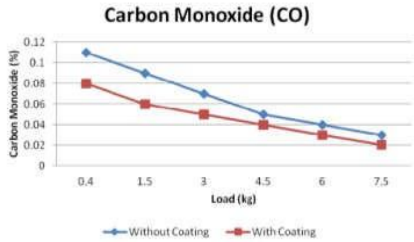
A. Hydrocarbon Emissions (HC)

As shown in Fig. the hydro carbon emissions of the TBC engine are reduced by roughly 15.8% when compared to the baseline standard engine. In general, incomplete combustion processes result in the production of hydro carbon, which is then found in exhaust gases. The experimental data makes it abundantly evident that the thermal barrier ceramic coating keeps local parameters like temperature, pressure, oxygen content, and mixture ratio constant and allows for continued combustion in diesel engines. The gradual increase in combustion temperature during the afterburning process and the subsequent reduction in heat loss are the primary causes of the thermal barrier coated engine's decreased hydro carbon emission. The TBC also aids in evaporation of the hydrocarbons due to the higher combustion temperature.

B. Carbon Monoxide Emission (CO)

The data obtained from the experiments of CO emissions for TBC and the baseline engines are shown Fig. The CO emission decreases with increase in load condition and also lesser CO emission is the outcome of the improved fuel combustion. It is experimentally calculated that TBC engine decreases about 28.2% of CO emission as compared to the baseline engine. Complete burning of the fuel is the major reason for decrease in CO emission in the case of TBC engine. In common, diesel hydrocarbons are considered by lengthy carbon string and mainly saturated link. Therefore, using of TBC reduces the heat transfer and breaking of lengthy carbon string into small carbon string to reduce CO emissions.



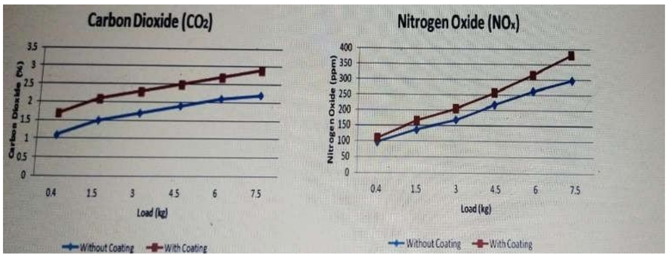


Carbon di-oxide emission (CO2)

With respect to varied load circumstances, Figure depicts CO2 changes. A piston crown's thermal barrier coating absorbed an increase in CO2 level. It is common knowledge that better fuel combustion increases the engine's oxygen intake, which raises CO2 emissions in TBC Engines. Experimental calculations show that the TBC engine increases CO2 emissions at all load levels, with a noticeable increase of 39.28% in comparison to the baseline engine.

Nitrogen Oxide Emission (NOX):

Figure demonstrates how the given load condition on the TBC and baseline engines causes an increase in NOx emissions. In general, the amount of oxygen in the engine's intake air and the combustion temperature have a major impact on NOx levels. The experimental data clearly show that the TBC engine's smoke level and NOx increase by 12% and 27%, respectively, as a result of the engine's high combustion temperature, which causes combustion to begin early and shift to its peak pressure and temperature. Researchers projected from a review of the literature that NOx emissions from LHR engines would generally be greater and that the amount of NOx emissions would also have increased due to an increase in post combustion temperature. The temperature during the combustion in the fuel is clearly higher than. According to experimental data, the TBC engine is good. The TBC engine's NOx emission level will increase in direct proportion to the afterburner's temperature.



7. CONCLUSION

The numerical and experimental research conducted led to the accurate establishment of the following findings. The heat flux rate distribution of mixed ceramic powder made of Yttria Stabilized Zirconia (YSZ) and Alumina (Al2O3). It was discovered that the piston head were kept at temperatures of 482.30 degrees Celsius and 680.50 degrees Celsius, respectively, by coatings of 0.575 millimeter thickness. When contrasted with the other coating thickness, this was unquestionably higher. When compared to the other coating thicknesses, the heat flow rate for the same thickness was measured to be 2.065*105 and 1.690*104W/m2, respectively. Hence, the increase in coating thickness was what caused the temperature distribution to increase the slowing down of heat flux. The 570 micron thickness coated piston head tested in the CI engine with neat diesel fuel produced extremely noteworthy results. On average, the SFC was decreased by 11.869%. When the results were compared to the uncoated engine, all pollutants except NOx were reduced in the 250 micron thickness coated piston used in CI engines. All of the polluting gases were greatly less. When the results were compared to the performance of an uncoated engine, the NOx was likewise reduced.The palm biodiesel was chosen as the best alternative fuel in order to combat issues including the depletion of fossil fuels, achieving EURO emission regulations, and the increased cost of petroleum fuel. The diesel fuel was blended with palm biodiesel blends of 60%, 80%, and 100% before being tested in the TBC engine in line with the standard engine. Poor performance metrics were created because of the high viscosity of palm biodiesel, including a 10.630% greater SFC.However, the pollutant gases except the NOx were drastically reduced when the neat palm biodiesel (BD100%)was used in the TBC engine. The best combinationof100% palm biodiesel, 570micronthickness coated piston head. the coded and actual factor Equation for the performance parameters of SFC and the pollution parameters of CO, HC, NOx, and smoke were successfully obtained. The optimum testconditionswereobtainedas250micronthicknessfor piston head,100%180blendofpalm biodiesel.The output findings under this combination were as follows: SFC = 0.217kg/kWh, CO = 0.033%, HC = 19.25ppm, NOx = 1915.38ppm, and smoke opacity = 7.862% combined with neat palm biodiesel in an LHR was used in the experimental examination on the 250 and 250micron thickness coated combustion chamber sections of the piston head .In the uncoated engine, the SFC was lowered on average to 0.29 kg/kWh, which was 0.103 kg/kWh lower under the use of pure palm biodiesel and 0.065 kg/kWh lower under the use of plain diesel. During full load conditions,the heat release rate of the combustion process. Under full load conditions, the heat release ratewere calculated to be 70.91bar and 43.82J/deg CA, respectively. The average lowered value of the polluting gases was 0.033% for CO, 18.6ppm for HC, 14.4% for smoke opacity, and 1027.2ppm for NOx. In the final test, the average brake-specific pollutant gas measurements showed that CO was 1.19 g/kWh, HC was 0.37 g/kWh, and NOx was 6.818 g/kWh. With the exception of NOx, the pollutant levels were found to be similar to the typical Euro IV emission requirements.

8. FUTURE SCOPE

The favourable performance parameters inclusive of reduced BSFC With a normal engine specification of 23 CAD BTDC fuel injection, 200 bar fuel injection pressure, and 17.7 CR, higher BTE and minimum CO, HC, and smoke emissions, with the exception of the NOx, were produced. If the aforementioned engine characteristics are greatly altered, these results will undoubtedly improve. With this research, the goals of increased thermal efficiency, significant fuel economy, and decreased emissions were unquestionably defined. To explore the full potential of using palm biodiesel in the TBC Engines, however, numerous investigations under appropriate operating limitations with improvised engine design are needed. The material to be utilized for the fuel distribution system for the continuous use of palm biodiesel in the CI Engine is one of the potential issues that has to be addressed for the possibility of commercialization. the capacity to maintain the lubricating oil's viscosity, which is susceptible to degradation at higher combustion chamber surface temperatures in the TBC Engine.

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