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Study on Effect of Biodiesel and Thermal Barrier Coating in Diesel Engine - A Review

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***Abstract*: This paper is an overview of past research papers which implies how to improve the performance and emission characteristics of a CI engine using different ceramic coatings and biodiesel as a blend. In CI engine the heat produced during the combustion is not utilized completely. The unutilized heat is lost by conduction of cylinder wall and through exhaust gas. The exhaust gas contains hydrocarbon, carbon monoxide due to incomplete combustion of fuel. These can be overcome by using the thermal barrier coating coated over the engine components such as cylinder head, piston head, and inlet and exhaust valve. The thermal barrier coating having a lower thermal conductivity value will use the maximum amount of heat and reduce the exhaust gas emissions. The vegetable oil extracted from the seeds of atrophy, cotton seed and so on is Trans esterified to get biodiesel. The biodiesel extracted is blended with the diesel. The use of biodiesel will replace the part of diesel fuel, reduce the hydrocarbon emissions and improve the performance and emission characteristics of a CI engine.**

***Keywords*: Thermal Barrier Coating, Brake specific fuel consumption, Biodiesel, Emission.**

1. Introduction

Piston generally made up of cast iron, aluminium is used in IC Engine to compress the air or air-fuel mixture during the compression stroke and to transmit the power to crankshaft with the use of connecting rod in the expansion stroke. Piston made up of aluminium alloy will have higher value of thermal expansion coefficient than that of piston made up of cast iron. The heat is produced during the combustion of fuel inside the combustion chamber. 30% of the heat produced during the combustion process is carried away by the coolant used. Another 30% of heat generated is lost through friction developed between the moving components. Remaining amount of heat available is only utilized for producing the power. This results in the increase in fuel consumption and also the thermal efficiency of an IC Engine is reduced. In the populated world, the demand of fuel is increasing day by day. Due to its continuous usage the atmosphere gets polluted. Increasing the fuel efficiency and reducing the emission are the big challenges for the automobile industries. Researchers works continuously to find the alternative fuel for diesel engine. Diesel engine. Different methods are available for increasing the thermal efficiency and reducing the fuel consumption of a diesel engine. From the available methods, one such method is coating the piston with ceramic material. This is known as Thermal Barrier Coating (TBC).

A. *Coating methodologies*

- Physical Vapor Decomposition (PVD)
- Chemical Vapor Decomposition (CVD)
- Splash Coating
- Electron Beam Evaporation Coating
- Flame Spray (FS)
- Plasma Spray (PS)

From these methods, one such method which is widely used for coating is plasma spray coating.

B. *Equations*

1) *Plasma Spray Coating*

Plasma spray coating is a technique where the material is melted and sprayed over a surface of the base material. The heating of coating material is done by electrical or chemical means. Based on the process, the thickness of 20µm to some millimeters is achieved by thermal spraying. Deposition rate of coating material for a larger area is higher in this coating process compared to other process. Initially the coating material is available in the form of wire or powder. Then it is converted into a molten orsemi-molten state by heating. It is then forced towards the substrate where the size of coating material is in the range of micrometers. The source for thermal spraying in plasma spray coating process is combustion or electrical arc discharge. By measuring the porosity, oxide content, macro and micro-hardness, bond strength and surface roughness, the quality of coating is determined. Particles with high velocities results in the good quality of coating.

2) *Thermal barrier coating materials*

The coating material should be selected which poses the basic requirements. The thermal barrier coating material should poses the higher melting point and it should not change its phase between the room temperature and operating temperature. The value of thermal conductivity for the coating material should be low. Adding to the above properties, it should also poses the chemical inertness, good adherence to the substrate and low porosity. The thermal barrier coating materials were found few in numbers. Some of the ceramic materials used as the thermal barrier coating material are explained following.

3) *Zirconates*

This material poses the higher value of thermal expansion

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coefficient, lower value of thermal conductivity. Adding to above properties, it also poses the good thermal cycling resistance. The delamination is caused due to high thermal expansion coefficient which results in the presence of thermal stress on the piston surface.

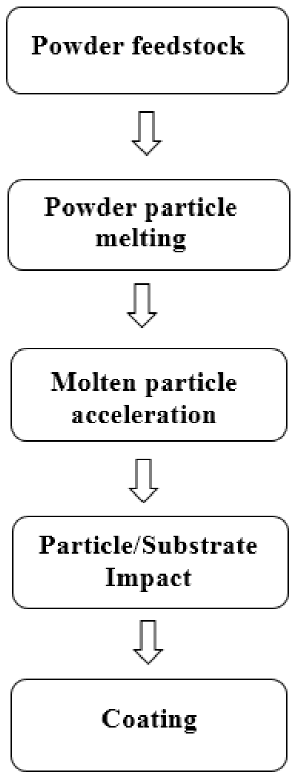

Fig. 2. Plasma spray coating

4) Yttria stabilized zirconia

The advantage of Yittria stabilized zirconia is that it poses the higher value of thermal expansion coefficient, lower value of thermal conductivity, and good shock resistance. Sintering the zirconia is done above 1470 K but at 1443 K the zirconia starts to change its phase.

5) Mullite

The density of mullite is low, it poses the higher thermal stability, chemical inertness, the lower value of thermal conductivity. Adding to above properties it also poses oxygen resistant than yittria stabilized zirconia. The value of thermal expansion coefficient of mullite is low than yttria stabilized zirconia in high thermal gradients and under thermal shock conditions. At 1023-1273K the mullite tends to crystallize

6) Alumina

It poses the higher hardness value and chemical inertness. The value of thermal conductivity of Alumina is higher than yittria stabilized zirconia. Due to this reason, it cannot be used directly as a thermal barrier coating material. It is used is used along with the yttria stabilized zirconia which increases the hardness of coating and reduce the oxidation on the coated surface.

C. Benefits of ceramic coated piston

- Resistant to high temperatures
- High chemical stability
- High hardness values
- Low densities
- Resistant to wear
- Low heat conduction coefficient
- High compression strength
- Reduction in friction
- Improvements occur at emissions.
- Increased effective efficiency,
- Increased thermal efficiency
- Reduced specific fuel consumption,
- Improved reliability,
- Smaller size,
- Lighter weight,
- Reduce the heat removed by the cooling system
- Reduction knocking and noise caused by combustion
- Increase the life of component.

D. Application of ceramic coated piston

- IC Engine
- Reciprocating compressor
- Turbocharger
- Missile Rockets
- Nozzle
- Turbine blade
- Surgical Equipment's.

E. Most commonly used biodiesel blend jatropha

Seeds of jatropha is crushed which results in the formation of jatropha oil. The oil is then processed to use it as a biofuel in a diesel engine.

1) Uses

Jatropha is a household plant. The seeds from jatropha crushed produces the oil in which the residues left are treated as feedstock for fish or animal.

2) Neem

Seeds of neem are crushed and oil is extracted from it. It is observed that the neem seed consists of 30-40% of oil. The chemical name of neem oil is mono alkyl ester produced by the process called transesterification.

3) Uses

Neem oil has a high medicinal value. It is used as an alternative fuel for diesel engine after transesterification process. It also cures the skin disease

4) Cotton Seed

Cotton seed is crushed and the oil is extracted from it. Refining of extracted oil is done to remove the impurities and free fatty acids. It is then blended with diesel and used as a biofuel.

5) Uses

The residual left out after the oil is extracted is used as a feedstock for the animal.

F. Benefits of bio diesel blends

- Ease to use.
- Power performance and economy.
- Emission and green house reduction.
- Energy balance security.
- Economic development.
- Renewablefuel.
- Less toxic in nature.
- Bio spills can be avoided as it decomposes easily than any other fuels.
- Carbon monoxide and hydrocarbon emissions are less.
- Health risk is less when compared to diesel fuel emissions.
- Emission does not contain SO_2 (Sulfur dioxide).
- Flash point is high compared to diesel fuel (100ºC minimum).

G. Draw backs of biodiesel blends

- Fuel consumption is slightly higher for biodiesel when compared with the standard diesel.
- Nitrous oxide emission is high due to increase in exhaust gas temperature.
- Freezing point of biodiesel is high in comparison with standard diesel fuel.
- Stability of biodiesel is less when compared with the diesel fuel and therefore it cannot be used for running

H. Esterification process

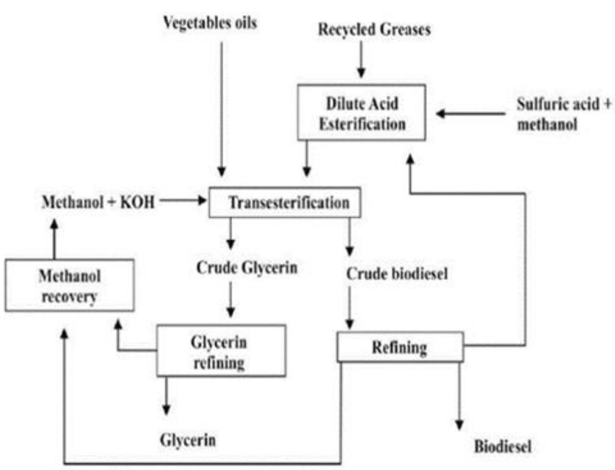

Fig. 2. Esterification process of vegetable oil

It is a process of producing the biodiesel. Animal and plant fats and oils are typically made of triglycerides which are esters of free fatty acids with the tri hybrid alcohol, glycerol. The stronger nucleophile is made by deprotonating the alcohol with base in Trans esterification process. Ethanol and methanol are alcoholic compounds used commonly. This reaction takes place slowly or does not happen, to increase the speed of a reaction, catalyst is used. Base or acids used in the trans esterification process is only the catalysts. Base-catalyzation is used to extract the biodiesel from vegetable oils which are virgin. The above process is most economical which requires only low pressure and temperature. Biodiesel can be produced in another way which is done by acid catalysis consumes more time than former.

2. Review of literature

(2014) In [1], Selman Aydin, Cenk Sayin introduced anImpact of thermal barrier coating application on the combustion, performance and emissions of a diesel engine fuelled with waste cooking oil biodiesel–diesel blends. The goal of this paper was to make an experimental investigation of effect of using the thermal barrier coating in diesel engine components such as piston, cylinder head and valves. To maintain the same compression ratio, the piston surface was grinded to 500µm and later the coating process was carried out. ZrO2 of 88%, MgO of 4% and 8% of Al2O3 were used for coating the surface. NiCrAl was initially coated as a lining layer of 100 µm and later 400 µm of ZrO2 of 88%, MgO of 4% and 8% of Al2O3 were coated. Dynamometer of BT-140 model was used to carry out the entire test. Exhaust gas analyzer of CAPELEC CAP 3200 model was used for measuring the emissions from the exhaust gas. Power values for B20 and B50 were increased by 2.05% and decreased by 0.03% respectively. Heat transfer is reduced due to the insulation of inside cylinder, therefore the temperature in the cylinder. Increases which in turn increases the cylinder pressure resulting in the higher power values. The average brake specific fuel consumption was decreased in coated engine when compared with uncoated engine. The brake thermal efficiency was increased in coated engine when compared with uncoated engine. Emission characteristics were improved by the usage of biodiesel. (2010) In [2], Hanbey Hazar, Ugur Ozturk introduced the effects of Al2O3eTiO2 coating in a diesel engine on performance and emission of corn oil methyl ester. The main focus of this paper was the effects of using corn methyl ester, and its mixtures as an alternative fuel in a diesel engine that has had its combustion chamber elements parts coated with ceramic, to determine any significant effects on performance and exhaust gas emissions. Madur GA-21 Plus gas analyzer is used to measure the NOx and CO emissions. Cylinder components are coated with Al2O3-TiO2 of 250µm with a bond coat of NiAl. It is found that brake thermal efficiency was increased to 5% in coated engine compared with standard engine. CO and HC were found to decrease in coated engine compared with standard engine. (2013) In [3], S. Vedharaj, R. Vallinayagam, W.M. Yang , S.K. Chou, K.J.E. Chua, P.S. Lee introduced the Experimental and finite element analysis of a coated diesel engine fuelled by cashew nut shell liquid biodiesel. The aim of this paper was to use cashew nut shell liquid as a biodiesel. 450µm of Partially Stabilized Zirconia was used as a thermal barrier coating. Plasma Spray technique was employed to coat the engine components. The effluents such as HC, CO, CO2, NOx were measured using the non- dispersive gas analyser (AVL 444 di-gas analyser) was used. CO emission is 22.7% lower in coated engine in comparison to the uncoated engine. HC emission was 7% lower in coated engine when compared with the uncoated engine. NOx emission was higher in coated engine due to the increase in combustion chamber temperature. Brake thermal efficiency was increased to 6% in coated engine when compared with uncoated engine. (2014) In [4], S. Vedharaj, R. Vallinayagam, W.M. Yang, C.G. Saravanan, S.K. Chou, K.J.E. Chua, P.S. Lee introduced Reduction of harmful emissions from a diesel engine fuelled by kapok methyl ester using combined coating and SNCR technology. The author's intention in this paper was to reduce the effect of NOx in the atmosphere. Partially stabilized Zirconia of 450µm was coated by plasma spray technique. Kapok Methyl Ester (KME) was used as a bio-diesel extracted from kapok tree seed by transesterification process. AVL 444 di- gas analyser was used to measure the emissions. Urea based SNCR system reduced the NOx emission. Brake thermal efficiency was increased (2015) In[5], Selman Aydin, Cenk Sayin, Hüseyin Aydin introduced an Investigation of the usability of biodiesel obtained from residual frying oil in a diesel engine with thermal barrier coating. Partially stabilized zirconia of 400µm was coated on the engine components. Brake specific fuel consumption was found to decreased in the range of 3.12% in coated engine compared with the uncoated engine. CO and HC emission was decreased simultaneously with the increase of NOx and CO2. Brake thermal efficiency was increased. (2015) In [6], Bahattin_ISintroduced an Application of ceramic coating for improving the usage of cottonseed oil in a diesel engineto the Engine Performance and Emission. The piston surface and valves of the test engine were covered with zirconium oxide (ZrO2) ceramic coating material. At that point waste cottonseed oil was volumetrically mixed with oil based diesel fuel by 15% cottonseed oil 85% petroleum diesel (CO15), 35% cottonseed oil 65% petroleum diesel (CO35) and 65% cottonseed oil 35% oil diesel (CO65). These mix energizes were then tried in the coated engine. Results were contrasted and the aftereffects of introductory test in uncoated engine task. The examination of all the test outcomes demonstrated that the covering procedure impressively enhanced the execution of the test engine for all the test fuels. The fuel utilization of the motor with running on diesel fuel was diminished by coating process. CO, HC and smoke discharges were diminished for all the test powers with coating the cylinder and valves of the test motor. Plus, CO, HC and smoke outflows of the mix powers of cottonseed oil and standard diesel fuel were lower than those for diesel fuel both in coated and uncoated engine. Be that as it may, NOx outflows were expanded when engine was coated. Likewise NOx outflows were expanded when utilizing cottonseed oil diesel mixes. (2016) In [7], Basavaraj M, Shrigiri, Omprakash. D, Hebbal. K, Hemachandra Reddy presented a Performance, emanation and ignition qualities of a semi-adiabatic diesel engine utilizing cotton seed and neem piece oil methyl esters. The execution, discharge and burning qualities of a diesel engine are explored utilizing two methyl esters: One got from cotton seed oil and other from neem kernel oil. These two oils are trans esterified utilizing methanol and alkaline catalyst to deliver the cotton seed oil methyl ester (CSOME) and neem kernel oil methyl ester (NKOME) separately. Test examinations are led with CSOME and NKOME in a four stroke, direct injection LHR engine. The LHR motor utilizing CSOME and NKOME is dissected and contrasted and that of diesel fuel in typical motor (uncoated). Contrasted and cotton seed oil methyl ester (CSOME) activity, neem kernel oil methyl ester (NKOME) brought about better execution attributes in LHR motor. At rated load, the brake specific fuel utilization estimations of CSOME and NKOME in LHR motor are higher contrasted with that of fuel in customary engine by 28.57% and 10.71%. At peak load, the unburned hydrocarbon emanations for CSOME and NKOME in LHR motor are 88.67 ppm and 87.72 ppm separately against 85.65 ppm of diesel in ordinary engine, which are 3.52% and 2.41% higher than that of diesel in typical engine. Further, CO outflows for CSOME and NKOME in LHR engine are higher by 26.92% and 39.53% contrasted with that of diesel in ordinary engine. The oxides of nitrogen level for CSOME and NKOME in LHR engine are 21.67% and 11.69%, which are higher than that of diesel fuel in normal engine. (2017) In [8], M. Mohamed Musthafa introduced a Development of performance and emission characteristics on coated diesel engine fueled by biodiesel with Cetane number enhancing additive. This study shows the performance and emission characteristics on partially stabilized zirconia (PSZ) coated diesel engine with biodiesel and cetane number enhancing additive of Di-tertiary-butyl peroxide (DTBP). Additive was mixed with biodiesel in 1% volume.The biodiesel was set up from palm oil utilizing basic base transesterification process. The experiment was conducted on a single cylinder, four stroke, water cooled and direct injection coated engine and to determine the performance and emission characteristics of engine running on the test fuels. There was a huge change on performance and emission on coated engine fuelled by expansion of cetane improver di-tert-butyl-peroxide to biodiesel. Anyway a similar fuel demonstrated negative impact in uncoated engine. The rate increment in proficiency at most extreme load for biodiesel with added substance was found by 5.67% and 11.23% contrasted with the diesel fuel in coated motor and uncoated motor individually. The brake fuel utilization additionally diminished fundamentally by 8.1% and 19.6% at greatest load contrasted with diesel fuel in coated and uncoated engine individually. The expansion of cetane improver has a critical impact in decrease of HC, CO and NOx emanations. It was discovered that HC diminished to 5.8% and 15.6%; CO decreased to 20% and 42.8% and NOx was lessened to 8.69% and 3.92% at pinnacle stack contrasted with diesel fuel in coated motor and uncoated engine individually. Smoke emanations from biodiesel mixes with DTBP added substance

Table 1
Methodology comparison

S. No.	Title	Authors	Merits	Demerits	Cited
1	Impact of thermal barrier coating application on the combustion, performance and emissions of a diesel engine fueled with waste cooking oil biodiesel–diesel blends	Selman Aydın , Cenk Sayın	coated engine showed the increase in break thermal efficiency and decrease in CO &HC emissions	Higher heat rejection (HR) values in coated engine than that of uncoated engine	28
2	The effects of Al_2O_3&TiO_2 coating in a diesel engine on performance and emission of corn oil methyl ester	Hanbey Hazar, Ugur Ozturk	Brake specific fuel consumption (BSFC) is less in coated engine and also there was a decrease in HC emissions due to biodiesel	NOx emission was higher due to the higher temperature in exhaust gas.	43
3	Experimental and finite element analysis of a coated diesel engine fueled by cashew nut shell liquid biodiesel	S.Vedharaj,R. Vallinayagam, W.M. Yang, S.K. Chou, K.J.E. Chua, P.S. Lee	Reduction in average temperature, thermal stress and heat flux for coated piston than that of uncoated piston	Coated engine resulted in the increase in Nox emission	36
4	Reduction of harmful emissions from a diesel engine fueled by kapok methyl ester using combined coating and SNCR technology	S. Vedharaj , R. Vallinayagam , W.M. Yang , C.G. Saravanan , S.K. Chou , K.J.E. Chua , P.S. Lee	9% increase in BTE for B50 in coated engine than uncoated engine at full load condition and also the major emissions from the coated engine such as HC, CO and smoke for B50 were found to be reduced by 35.3%, 40% and 21.4%, respectively, than uncoated engine	NOx emission was found to be increased without the urea-SNCR	31
5	Investigation of the usability of biodiesel obtained from residual frying oil in a diesel engine with thermal barrier coating	Selman Aydin a, Cenk Sayin b, Hüseyin Aydin c	The decreases in the engine noise were observed with ceramic coating that can be explained by shortening of the ignition delay, due to reduction of the heat transfer from the insulated combustion chamber.	Cylinder gas pressure values obtained from the engine coated with thermal barrier were almost higherthan the cylinder gas pressure values attained from uncoated engine.	19
6	Application of ceramic coating for improving the usage of cottonseed oil in a diesel engine	Bahattin_IS	The power output and torque values of the test engine increased with coating process when using vegetable oil diesel blends	NOx emissions were increased when using cottonseed oil diesel blends.	13
7	Performance, emission and combustion characteristics of a semi-adiabatic diesel engine using cotton seed and neem kernel oil methyl esters	Basavaraj M. Shrigiri, Omprakash.D, Hebbal.K,Hemachandra Reddy	The brake specific fuel consumption values in LHR engine are higher compared to that of fuel in conventional engine by 28.57% and 10.71%.	The oxides of nitrogen level in LHR engine are 21.67% and 11.69%, which are higher than that of diesel fuel in normal engine	12
8	Development of performance and emission characteristics on coated diesel engine fuelled by biodiesel with Cetane number enhancing additive	M.Mohamed Musthafa	The brake fuel consumption also decreased significantly by 8.1% and 19.6% at maximum load compared to diesel fuel in coated and uncoated engine respectively	B50 resulted in the increase of NOx emissions	2
9	Effects of thermal barrier coating on the performance and combustion characteristics of a diesel engine fueled with biodiesel produced from waste frying cottonseed oil and ultra-low sulfur diesel	Selman Aydın, Cenk Sayın, Şehmus Altun & Hüseyin Aydın	Engine noise values were decreased when the test engine was coated	The cylinder pressure values of coated engine operation are slightly higher than the values of uncoated engine operation for almost all the test fuels	4
10	Impact of partially stabilized zirconia on single cylinder diesel engine using orange oil methyl ester biodiesel	V. Karthickeyan	In coated engine, B1 showed higher brake thermal efficiency than diesel.	NOx emission was higher in coated engine.	6

in both covered and uncoated task were lower than those of neat diesel. (2016) In [9], Selman Aydın, Cenk Sayın, Şehmus Altun & Hüseyin Aydınintroduced an Effects of thermal barrier coating on the performance and combustion characteristics of a diesel engine fueled with biodiesel produced from waste frying cottonseed oil and ultra-low sulfur diesel. The top surfaces of cylinder and valves of a four-strokes and direct-infusion diesel motor have been covered with no adjustment in the pressure proportion with a 100 µm of NiCrAl lining layer by means of plasma splash technique and this layer has later been covered with fundamental covering material with a blend of 88% of ZrO2, 4% of MgO and 8% of Al2O3 (400 µm). After the motor covering process, ultra-low sulfur diesel as base energizes and its mix with utilized searing cottonseed oil inferred biodiesel in extent of 20%, volumetrically, have been tried in the coated engine and information of ignition and execution qualities on full load and at various velocities have been noted. The outcomes, which were contrasted and those gotten by uncoated-engine task. Engine noise were diminished when the test motor was covered. The cylinder pressure estimations of coated engine task are marginally higher than the estimations of uncoated engine activity for all the test energizes. The brake thermal efficiency estimations of the completely stacked engine task for coated engine is higher when contrasted with the uncoated engine. NOx emanations expanded while HC discharges stayed comparable with a little diminish in CO outflows with coating process. (2017) In [10], V. Karthickeyan introduced an Impact of partially stabilised zirconia on a single-cylinder diesel engine's performance, using orange oil methyl ester biodiesel. Partially stabilised zirconia was used as a thermal barrier coating (TBC) for the combustion chamber components using plasma spray technique. The study focused on the impact of TBC on performance and emission characteristics of a diesel engine with (20% orange oil methyl ester with 80% diesel) sample and diesel. Increased brake thermal efficiency and reduced brake-specific fuel consumption are observed for the TBC engine. The (20% of prepared orange oil methyl ester was mixed with 80% of diesel fuel) showed

3. Methodology comparison

This area gives a diagram about the advantages and disadvantages that are happened in the examine procedures whose useful situations are talked about top to bottom in the past segment. From the Table 1, it very well may be anticipated a superior methodology that gives extensive change in the proposed situation.

4. Conclusion

By the literature review, we presume that by the utilization of various ceramic thermal barrier coating and biodiesel blend to enhance the execution qualities of the IC engine. Research or advancement with respect to any of the subjects can be made conceivable just through the learning of past research related to a similar field. Required planning before conveying research work can be made well by talking about the past work did by the scientists in the different fields which are identified with the theme. In this writing talked about the detailed coating materials and impact of cylinder crown covering in the performance of an engine. Following conclusions are made, such as low thermal conductivity coating materials are yttria, MgO, AL Sic, ZnO, Al2O3, ZrO2 this material coating gives maximum thermal efficiency. Biodiesel blends are ethanol, jatropha, and neem. It leads to improve the specific fuel consumption and improve the emission characteristics.

5. Future scope

Ceramic coating in IC engine causes the practical problems like thermal mismatch on account of thermal expansion coefficient value difference between bond coat and piston materials, improper adhesion. To avoid the above problems in future, a new material should be selected to reduce the NOx emission.

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