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A LITERATURE REVIEW ON THE PERFORMANCE ANALYSIS OF 4 STROKE DIESEL ENGINES WITH CERAMIC COATING MATERIAL

A. I. PANDEY[1]

[1]*Lecturer In Mechanical Engineering Department, R.C.Technical Institute Sola Ahmedabad, pandeyatul2001@Gmail.Com*

Abstract : *Today's the use of diesel fuel is increase in the world. People do not use diesel only for transportation but also for agriculture and as we know that the lots of heat loss without any use of it. The efficiency of IC Engine is reduced and fuel consumption is increased. The Lots of research works are carried out to increase the efficiency of IC Engine and reduce fuel consumption such as Laser Surface Textured (LST) method, Thermal Barrier Coating (TBC) method. Piston is the one of the main part of IC engine. The function of piston is transfer the pressure to the crank through the onnecting rod. Generally piston is made by cast iron and aluminum alloy. As we know that by using of ceramic material coating on piston, the performance of IC Engine can be increased.*

Keywords: *Thermal Barrier Coating (TBC), Laser Surface Textured (LST), Ceramic materials*

I. INTRODUCTION TO PISTON OF C.I. ENGINE

As we know that the piston is heart of the C.I. engine. The function of piston is to compress the air during compression stroke and transmit the gas force to the crank through connecting rod during expansion stroke. The piston of C.I. engines are generally made of cast iron, cast steel and aluminum alloy. The thermal expansion coefficient of piston made from aluminum alloy material is greater than the thermal expansion coefficient of cast iron. When combustion of fuel takes place inside the cylinder into C.I. engine, high heat is generated. 30% of the heat supplied is lost through the coolant and 30% is wasted against friction and other losses, thus remaining 30% of heat can be utilize for working purpose.[16] It leads to reduce thermal efficiency and increase the fuel consumptions of C.I. engine. In now days the demand of diesel engines are increases, people use it for transportation and also in agriculture therefore the environment becomes more polluted. The automobile industries are facing a serious challenge to increase the fuel efficiency and do hard work to reduce the emission. So many research works are continue on alternate fuel of diesel engine or efficient use of diesel fuel into diesel engine .There are so many methods are used to improve the efficiency of diesel engine and reduced fuel consumption. For this purpose one of the technologies is used that is ceramic coated IC engine .It is also known as Thermal barrier coating (TBC) or low heat rejection engine (LHRE).

Finite element method (FEM) is widely used in almost all fields of engineering such as thermal, temperature, fluid flows, structural, pipe and channel flow, dynamics analysis etc. Finite element analysis is used for the thermal analysis of ceramic coated and uncoated piston.

List of methods of coating:

There are different methods of coating. Those are following:

- Thermal spray coating: Plasma spray, wire flame spray and powder flame spray, electrical arc spray, detonation gun technique and high speed oxy fuel system
- Chemical ceramic coating: Sole-gel, slurry, chemical vapour sedimentation, physical vapour sedimentation, hard coating.
- Laser coating
- Arc spark alloying
- Ion enrichment method

Types of Ceramic material:

- Yittria Stabilized Zirconia (YSZ)
- Partially Stabilized Zirconia (PSZ)
- Garnets
- Spinel
- Mullite
- Alumina

Advantage of Ceramic Coated piston

The basic intent of ceramic coated is to be considerably enhancing the performance of C.I.Engine. When performance of C.I. engine takes place with ceramic coated piston by experiment and finite element analysis, it offers the following advantages:

- Reduction in friction
- Low cetane fuels can be burnt.
- Improvements occur at emissions.
- Waste exhaust gases are used to produce useful shaft work,
- Increased effective efficiency,
- Increased thermal efficiency,
- Using lower-quality fuels within a wider distillation range,
- The ignition delay of the fuel is considerably reduced,
- The faster vaporization and the better mixing of the fuel,
- Reduced specific fuel consumption,
- Multi-Fuel capability,
- Improved reliability,
- Smaller size,
- Lighter weight,
- Decreased the heat removed by the cooling system,
- The first start of engine on cold days will be easier,
- Decreasing knocking and noise caused by combustion
- Increase the life of component[18]

Application of ceramic coated piston

- IC Engine
- Reciprocating air compressor

II. LITERATURE SURVEY

[1] Muhammet Cerit' Mehmet Coban "Temperature and thermal stress analyses of a ceramic-coated aluminum alloy piston used in a diesel engine" International Journal of Thermal Sciences , Volume 77, March 2014

The goal of this paper is to determine both temperature and thermal stress distributions in a plasma-sprayed magnesia-stabilized zirconia coating on an aluminum piston crown to improve the performance of a diesel engine. Effects of the coating thickness on temperature and thermal stress distributions are investigated, including comparisons with results from an uncoated piston by means of the finite element method. Temperature and thermal stress analyses are performed for various coating thicknesses from 0.2 to 1.6 mm excluding the bond coat layer. Temperature at the coated surface is significantly higher than that of the uncoated piston. It is observed that the coating surface temperature increases with coating thickness by decreasing rate. Increase in the maximum temperature according to the uncoated piston is 64.3% for 1.0 mm thick coating. The higher combustion chamber temperature provided by means of coating results in the better thermal efficiency of the engine

[2] Helmisyah Ahmad Jalaludin , Shahrir Abdullah, Mariyam Jameelah Ghazali, Bulan Abdullah, Nik Rosli Abdullah "Experimental Study of Ceramic Coated Piston Crown for Compressed Natural Gas Direct Injection Engines" INTERNATIONAL TRIBOLOGY CONFERENCE MALAYSIA 2013 Volume 68, 2013

In this paper it is observed that the YPSZ(Yttria Partially Stabilized Zirconia)/NiCrAl coated CNGDI piston crown experienced the least heat fluxes than the uncoated piston crowns and the coated CamPro piston crown, giving extra protection during combustion operation.

[3] Muhammet Cerit "Thermo mechanical analysis of a partially ceramic coated piston used in an SI engine" Surface and Coatings Technology Volume 205, Issue 11, 25 February 2011

It is observed that the coating surface temperature increase with increasing the thickness in a decreasing rate. Surface temperature of the piston with 0.4 mm coating thickness was increased up to 82 °C. The normal stress on the coated surface decreases with coating thickness, up to approximately 1 mm for which the value of stress is the minimum. However, it rises when coating thickness exceeds 1 mm. As for bond coat surface, increasing coating thickness, the normal stress decreases steadily and the maximum shear stress rises in a decreasing rate. The optimum coating thickness was found to be near 1 mm under the given conditions.

[4] O.P. Singh , Yogesh Umbarkar, T. Sreenivasulu, E. Vetrivendan, M. Kannan, Y.R. Babu "Piston seizure

investigation: Experiments, modeling and future challenges" Engineering Failure Analysis Volume 28, March 2013

This paper presents, the results suggest that high operating temperatures and significant reduction in thin film lubrication clearances accelerate the seizure failures. Further tests were conducted with coated piston to mitigate the high temperature effects. Future directions and challenges in terms modeling such complicated physics have been discussed. The authors believe that there exists a theoretical gap in modeling the seizure physics and hence, advanced theories should be developed to enhance the understanding of this complex seizure mechanism.

[5] M. Cerit, V. Ayhan, A. Parlak, H. Yasar "Thermal analysis of a partially ceramic coated piston: Effect on cold start HC emission in a spark ignition engine" Applied Thermal Engineering Volume 31, Issues 2–3, February 2011

This paper shows that the Effect of partially thermal barrier coating on piston temperature distribution and cold start HC emissions of a spark ignition (SI) engine are investigated numerically and experimentally. A Thermal analysis was performed for both standard and coated pistons by using a commercial code, namely ANSYS. The engine tests were conducted on a single cylinder, water cooled SI engine for both standard and coated cases. Analysis results show that the surface temperature of the coated piston part was increased up to 100 °C, which leads to an increase in air–fuel mixture temperature in the crevice and wall quenching regions. Thus, cold start HC emissions considerably decrease compared to the standard engine without any degradation in engine performance. Maximum decrease in HC emissions was 43.2% compared to the standard engine.

[6] Ekrem Buyukkaya, Muhammet Cerit "Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method" Surface and Coatings Technology Volume 202, Issue 2, 25 November 2007
The study of this paper, it is find that firstly thermal analyses are investigated on a conventional (uncoated) diesel piston, made of aluminum silicon alloy and steel. Secondly, thermal analyses are performed on pistons, coated with MgO–ZrO2 material by means of using a commercial code, namely ANSYS. Finally, the results of four different pistons are compared with each other. The effects of coatings on the thermal behaviors of the pistons are investigated. It has been shown that the maximum surface temperature of the coated piston with material which has low thermal conductivity is improved approximately 48% for the AlSi alloy and 35% for the steel.

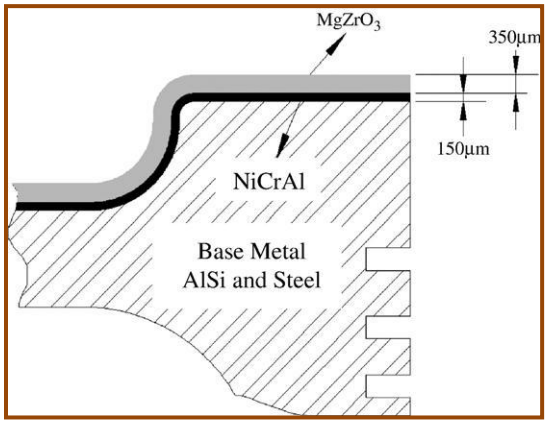

Fig 1Thermal barrier coating thickness.

The zirconia-based ceramic coatings are used as thermal barrier coatings owing to their low conductivity and their relatively high coefficients of thermal expansion, which reduce the detrimental interfacial stresses. Material properties of the MgZrO3, NiCrAl and piston material made of AlSi alloy. Piston is coated with a 350 µm thickness of MgZrO3 over a 150 µm thickness of NiCrAl bond coat (Fig. 1).

[7] Hanbey Hazar "Characterization of MoN coatings for pistons in a diesel engine" Materials & Design Volume 31, Issue 1, January 2010

In this study, the surface of a piston in a diesel engine was coated with molybdenum nitride (MoN) by using the arc PVD method, and its surface behavior was subsequently analyzed. Analyses of micro hardness, SEM, X-ray and surface roughness were carried out in order to examine surface characteristics of pistons. It is found that the hardness of coated piston is 2000 ± 400 HV while hardness uncoated piston 123 HV. The results show less deformation and fewer scratches due to wear on the MoN-coated piston as compared to uncoated one.

[8] Ekrem Buyukkaya "Thermal analysis of functionally graded coating AlSi alloy and steel pistons" Volume 202, Issue 16 15 May 2008

Functionally graded coatings are coating systems used to increase performances of high temperature components in diesel engines. These coatings consist of a transition from the metallic bond layer to cermet and from cermet to the ceramic layer. In this study, thermal behavior of functional graded coatings on AlSi and steel piston materials was investigated by means of using a commercial code, namely ANSYS. Thermal analyses were employed to deposit metallic, cermet and ceramic powders such as NiCrAl, NiCrAl + MgZrO3 and MgZrO3 on the substrate. The numerical results of AlSi and steel pistons are compared with each other. It was shown that the maximum surface temperature of the functional graded coating AlSi alloy and steel pistons was increased by 28% and 17%, respectively.

[9] Ravindra Prasad, N.K. Samria "Transient heat transfer analysis in an internal combustion engine piston" Computers & Structures Volume 34, Issue 5, 1990

In this paper, the isothermic distribution in the piston body and heat flow rates to cooling water and air below the piston at four different engine loads are depicted for cases both with and without insulation coating. The results indicate a 6% reduction in heat loss through the piston with the use of an insulation coating on the cylinder wall.

[10] Selman Aydın , Cenk Sayın " Impact of thermal barrier coating application on the combustion, performance and emissions of a diesel engine fueled with waste cooking oil biodiesel–diesel blends" Fuel Volume 136, 15 November 2014

Finally, the same engine out parameters were obtained and compared with those of uncoated engine parameters in order to find out how this modification would change the combustion, performance and emission parameters. Results showed that the modification of the engine with coating process resulted in better performance, especially in considerably lower brake specific fuel consumption (Bsfc) values. Besides, emissions of the engine were lowered both through coating process and biodiesel usage excluding the nitrogen oxides (NO*x*) emission. In addition, the results of the coated engine are better than the uncoated one in terms of cylinder gas pressure, heat release rate (HRR) and heat release (HR).

[11] I. Taymaz, , K. Çakır, A. Mimaroglu "Experimental study of effective efficiency in a ceramic coated diesel engine" Surface and Coatings Technology Volume 200, Issues 1–4, 1 October 2005

The combustion chamber surfaces (cylinder head, valves and piston crown faces were coated with ceramic materials. Ceramic layers were made of CaZrO3 and MgZrO3, by using plasma-coating method onto the base of the NiCrAl bond coat. The ceramic-coated research engine was tested at the same conditions as the standard (without coating) engine. The results showed a reduction in heat loss to the coolant and an increase in effective efficiency.

[12] Mesut Durat, Murat Kapsiz, Ergun Nart , Ferit Ficici, Adnan Parlak "The effects of coating materials in spark ignition engine design" Materials & Design Volume 36, April 2012

Ceramic coatings provide good thermal barrier properties for designers. In the design of adiabatic engines, reducing in-cylinder heat rejection requires very special thermal barrier coatings on the engine combustion chamber. Partially, thermal barrier coating (TBC) on the top surface of the piston in the annulus form is considered as a solution for unburned HC emission produced by incomplete combustion with respect to crevice volume after SI engines start (the three-way catalytic converter is not yet activated in the period of first 120 s). Because TBC on the top piston surface decreases the thermal conductivity and increases the unburned charge oxidation by increasing the temperature in the flame quenching area near the entrance of the crevice volume between the piston and liner during the compression and the early part of the expansion strokes.

In this study, a steady-state thermal analysis was performed to evaluate the temperature gradients in the standard and two different partially stabilized ceramic coated pistons by using Abaqus finite element (FE) software. A sharp increase in the temperature of the coated area of the piston was observed as a result of FE simulations. It is concluded that the annulus Y-PSZ coating may contribute better, as compared to Mg-PSZ, to decrease the cold start and steady state HC emissions without auto ignition, since the temperature in the area shows a local sharp increase.

[13] Ekrem Büyükkaya, Tahsin Engin, Muhammet Cerit "Effects of thermal barrier coating on gas emissions and performance of a LHR engine with different injection timings and valve adjustments" Energy Conversion and

Management Volume 47, Issues 9–10, June 2006, Pages 1298–1310

The results showed that 1–8% reduction in brake specific fuel consumption could be achieved by the combined effect of the thermal barrier coating (TBC) and injection timing.

[14] X.Q.Cao, R. Vassen, D. Stoever "Ceramic materials for thermal barrier coatings" Journal of the European Ceramic Society 24(2004) 1-10

The main objective of this paper is to study about ceramic materials. Ceramics, in contrast to metals, are often more resistance to oxidation, corrosion and wear, as well as being better thermal insulators. Except yttria stabilized zirconia, other materials such as lanthanum zirconate and rare earth oxides are also promising materials for thermal barrier coatings.

[15] Ilker Turgut Yilmaz, Metin Gumus, Mehmet Akçay "THERMAL BARRIER COATINGS FOR DIESEL ENGINES" INTERNATIONAL SCIENTIFIC CONFERENCE 19 – 20 November 2010, GABROVO

It is known that the efficiency of internal combustion diesel engines changes %38-42. It is about %60 of the fuel energy dismissed from combustion chamber. To save energy, combustion chamber component are coated with low thermal conduction materials. In this paper, give an eye to thermal barrier coating and ceramic materials which are used for making low heat released engines.

[16] Aravinth P1, Subramanian S P1, Sri Vishnu G2 and Vignesh P3 "COMPARISON OF VARIOUS THERMAL BARRIER COATINGS ALONG WITH THEIR EFFECTS ON EFFICIENCIES AND FUEL CONSUMPTION BASED ON THE RESULTS OF EXPERIMENTAL LITERATURES" International Journal of Mechanical Engineering and Robotics Research India , Vol. 1, No. 3, October 2012

It is well known fact that about 30% of the energy supplied is lost through the coolant and the 30% is wasted through friction and other losses, thus leaving only 30% of energy utilization for useful purposes. There have been numerous research papers in recent years describing the theoretical benefits obtained from the use of ceramic components in reciprocating engines, but that describes practical results is very limited.

Thermal Barrier Coatings (TBC) in internal combustion engine have advantages such as improved thermal efficiency and combustion, reduction in weight by eliminating cooling systems, etc. however, practical problems are faced in implementing these coatings in internal combustion engines. The problem presently faced in implementing of TBC as engine cylinder is thermal mismatch which mainly occurs due to improper adhesion and difference in thermal expansion coefficient between bond coat and cylinder materials.TBC must also withstand wear and tear. The disadvantage of the TBC method is that NOxemission is increased.

[17] Vikram A. Mistry, Dipak C. Gosai, Dr. H.J. Nagarsheth " Temperature Distribution Analysis of MgZrO3 Coated and Conventional IC Engine Components using FEM" IJEDR | Volume 2, Issue 2 | ISSN: 2321-9939 | 2014

This paper deals with temperature distribution analysis of the conventional (uncoated) and ceramic material coated IC engine combustion chamber components. In this study, firstly, thermal analyses are investigated on a conventional (uncoated) diesel piston and cylinder head, made of aluminum silicon alloy and cast iron respectively. Secondly, thermal analyses are performed on pistons and cylinder head, coated with ceramic material MgZrO3 by means of using a commercial code, namely ANSYS. After that, the results of ceramic coated components are compared with conventional one. The effects of coating on thermal behaviors of components are investigated. In which noted that the maximum surface temperature of the coated piston and cylinder head is increased about 479.4 0C and 108.6 0C respectively.

[18] Ravikumar T, Kiran K, Ravichandra V Koti, Chetan Appasab Chougale "Alternative Thermal Barrier Coatings for CI Engines -A Research Review" International Journal of Research in Advent Technology, Vol.2, No.5, May 2014
E-ISSN: 2321-9637

The depletion of supply of fossil fuels and their increased cost has driven the attention towards energy security. The energy security can be partially achieved by improving the efficiency of energy producing equipment's. Diesel fuels can be used more efficiently in low heat rejection engines (LHR), in which the temperature of combustion chamber is

increased by creating thin layer of ceramics, a thermal barrier. Also the use of thermal barrier coatings (TBCs) to increase the combustion temperature in diesel engines has been pursued for over 20 years. Increased combustion temperature can increase the efficiency of the engine, decrease the CO and unburnt Hydrocarbons (UBHC). TBCs have not yet met with wide success in diesel engine applications. To reach the desirable temperature of 850-900°C in the combustion chamber from the current temperature of 350-400°C, a coating with a thickness of order 1mm is required.

Objective of literature review paper

The objectives of literature review paper are:

- Increase the thermal efficiency
- Increase the mechanical efficiency
- Decrease the fuel consumption
- Reduction in emission

III. CONCLUSION

By this literature review, it is conclude that by using of thermal barrier coating method the efficiency of diesel engine can be increased, fuel consumption can be reduced, friction losses can be reduced and emission can be reduced except NOx.

IV. FUTURE SCOPE

The efficiency of diesel engine can be increased by using of TBC method but it is difficult to perform it experimentally. When ceramic coating is used in IC engine, the different types of practical problems are occur such as thermal mismatch due to improper adhesion and difference in thermal expansion coefficient between bond coat and piston materials and it has to withstand with wear and tear. In future try to develop new material or select proper material to avoid the above problem and reduce NOx emission also.

REFERENCES

[1] Muhammet Cerit, Mehmet Coban "Temperature and thermal stress analyses of a ceramic-coated aluminum alloy piston used in a diesel engine" International Journal of Thermal Sciences , Volume 77, March 2014
[2] Helmisyah Ahmad Jalaludin , Shahrir Abdullah, Mariyam Jameelah Ghazali, Bulan Abdullah, Nik Rosli Abdullah "Experimental Study of Ceramic Coated Piston Crown for Compressed Natural Gas Direct Injection Engines" INTERNATIONAL TRIBOLOGY CONFERENCE MALAYSIA 2013 Volume 68, 2013
[3] Muhammet Cerit "Thermo mechanical analysis of a partially ceramic coated piston used in an SI engine" Surface and Coatings Technology Volume 205, Issue 11, 25 February 2011
[4] O.P. Singh , Yogesh Umbarkar, T. Sreenivasulu, E. Vetrivendan, M. Kannan, Y.R. Babu "Piston seizure investigation: Experiments, modeling and future challenges" Engineering Failure Analysis Volume 28, March 2013
[5] M. Cerit, V. Ayhan, A. Parlak, H. Yasar "Thermal analysis of a partially ceramic coated piston: Effect on cold start HC emission in a spark ignition engine" Applied Thermal Engineering Volume 31, Issues 2–3, February 2011
[6] Ekrem Buyukkaya, Muhammet Cerit "Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method" Surface and Coatings Technology Volume 202, Issue 2, 25 November 2007
[7] Hanbey Hazar "Characterization of MoN coatings for pistons in a diesel engine" Materials & Design Volume 31, Issue 1, January 2010
[8] Ekrem Buyukkaya "Thermal analysis of functionally graded coating AlSi alloy and steel pistons" Volume 202, Issue 16 15 May 2008
[9] Ravindra Prasad, N.K. Samria "Transient heat transfer analysis in an internal combustion engine piston" Computers & Structures Volume 34, Issue 5, 1990
[10] Selman Aydın , Cenk Sayın " Impact of thermal barrier coating application on the combustion, performance and emissions of a diesel engine fueled with waste cooking oil biodiesel–diesel blends" Fuel Volume 136, 15 November 2014
[11] I. Taymaz, , K. Çakır, A. Mimaroglu "Experimental study of effective efficiency in a ceramic coated diesel engine" Surface and Coatings Technology Volume 200, Issues 1–4, 1 October 2005
[12] Mesut Durat, Murat Kapsiz, Ergun Nart , Ferit Ficici, Adnan Parlak "The effects of coating materials in spark ignition engine design" Materials & Design Volume 36, April 2012
[13] Ekrem Büyükkaya, Tahsin Engin, Muhammet Cerit "Effects of thermal barrier coating on gas emissions and performance of a LHR engine with different injection timings and valve adjustments" Energy Conversion and Management Volume 47, Issues 9–10, June 2006, Pages 1298–1310
[14] X.Q.Cao, R. Vassen, D. Stoever "Ceramic materials for thermal barrier coatings" Journal of the European Ceramic Society 24(2004) 1-10
[15] Ilker Turgut Yilmaz, Metin Gumus, Mehmet Akçay "Thermal Barrier Coatings for Diesel Engines" International Scientific Conference 19 – 20 November 2010, Gabrovo
[16] Aravinth P1, Subramanian S P1, Sri Vishnu G2 and Vignesh P3 "Comparison Of various Thermal Barrier Coatings along with their effects on Efficiencies and Fuel Consumption based on the results of experimental literatures" International Journal of Mechanical Engineering and Robotics Research India , Vol. 1, No. 3, October 2012

[17] Vikram A. Mistry, Dipak C. Gosai, Dr. H.J. Nagarsheth " Temperature Distribution Analysis of MgZrO3 Coated and Conventional IC Engine Components using FEM" IJEDR | Volume 2, Issue 2 | ISSN: 2321-9939 | 2014

[18] Ravikumar T, Kiran K, Ravichandra V Koti, Chetan Appasab Chougale "Alternative Thermal Barrier Coatings for CI Engines -A Research Review" International Journal of Research in Advent Technology, Vol.2, No.5, May 2014 E-ISSN: 2321-9637

[19] Murat Ciniviz, Mustafa Sahir Salman, Eyüb Canl, Hüseyin Köse and Özgür Solmaz "Ceramic Coating Applications and Research Fields for Internal Combustion Engines"

