"TO IMPROVE THE THERMAL PROPERTIES OF PISTON BY THERMAL BARRIER COATING"

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ABSTRACT

The aim of this work is to determine the temperature of the ceramic coated aluminum piston crown used in spark ignition engine. The ceramic coating used in this experiment is yttria stabilized zirconia which is known as thermal barrier coating material. A bond layer of thickness 300 micron is laid on the piston .The temperature on the piston crown with ceramic coatings is investigated and compared with uncoated piston by experimental method. By using the ceramic coating as a thermal barrier coating on the piston the piston body temperature is get reduced with increase the thickness of coating. Also hardness of top surface of the piston and wear rate between piston skirt and wall of cylinder is reduced.

Keywords: *Thermal barrier coating, Piston, plasma spray process, TBC material.*

1. INTRODUCTION

An Internal Combustion Engine is that kind of prime mover that converts chemical energy to mechanical energy. In I.C Engine, engine can be called the heart of a vehicle and the piston may be considered the most important part of an engine. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod. Piston in an IC engine must possess the Strength to resist gas pressure, Must have sufficient bearing area to prevent wear, Must seal the gas from top and oil from the bottom, Must disperse the heat generated during combustion, Must have good resistance to distortion under heat forces and heavy temperature. The major promises of thermal barrier coated engines were increased thermal efficiency and elimination of the cooling system. A simple first law of thermodynamics analysis of the energy conversion process within a diesel engine would indicate that if heat rejection to the coolant was eliminated, the thermal efficiency of the engine could be increased. Thermal barrier coatings were used to not only for reduced in-cylinder heat rejection and thermal fatigue protection of underlying Metallic surfaces, but also for possible reduction of engine emissions. Thermal insulation brings, according to the second law of thermodynamics, to engine heat efficiency improvement and fuel consumption reduction. Exhaust energy rise can be effectively used in turbocharged engines. Higher temperatures in the combustion chamber can also have a positive effect in diesel engines, due to the ignition delay drop and hardness of engine operation.

Thermal barrier coating

The most common coatings currently used in high temperature engine applications are Yttria stabilized zirconia due to their very low thermal conductivity and a coefficient of thermal expansion which is higher than the vast majority of insulating ceramics. Coating thicknesses used in engine applications have varied from 0.1mm to 4.5mm, with thicker coatings theoretically providing greater resistance to heat flux. The most common way of applying these coatings has been through plasma spraying which has been used to apply coatings both selectively to specific engine components (i.e. valves, cylinder head, and piston crown) and to the entire combustion chamber. The primary challenges posed by thermal barrier coatings within engine environments stem from their durability. Due to their low coefficients of thermal expansion (CTE) in comparison to the metallic substrates upon which they are applied, ceramic TBCs are prone to cracking, spalling and eventual failure resulting from the cyclic thermal stresses created by the temperature differential between the coating and the substrate. In an attempt to alleviate these problems, new Nano-structured ceramic and metal-based TBCs with CTEs more comparable to typical metallic substrates have been studied, with some promising results. Typical material properties of yttria-stabilized zirconium (YSZ), metallic TBCs and a typical aluminum piston material are shown in table. The increased surface temperatures in a TBC-coated combustion chamber may also result in the degradation of engine lubricants, while decreasing the volumetric efficiency of the engine due to heating of the intake charge. As will be discussed, the higher temperatures may also have significant effects on combustion and thus engine emissions. Though not currently used in production engines, a great deal of research has been conducted studying the use of TBCs in both compression and spark ignition engines as a means of managing heat losses. In the following, a brief overview of the available work in the two research areas is given.

2. LITERATURE REVIEW

A. Dr. Raghu1, Girishkumar , K Chandrasekhar , In this paper he explained that Experimental Study of the Effect of Thermal Barrier Coating on Diesel Engine Performance , International Research Journal of Engineering and Technology (IRJET). In this paper explained about the depletion of fossil fuel resources at a faster rate in the present world is demand for searching alternative fuels and the innovative methods to increase in efficiency of internal combustion engines. In this regard the use of thermal barrier coating materials in the automotive industry has been found to yield a significant effect on the efficiency of engines. Higher the operating temperature more will be the efficiency of the system. However, such higher temperatures demand for enhanced temperature resistant materials to be used. Yattria Stabilized Zirconia material is used as coating for the engine piston crown and cylinder liner by Plasma Spraying technique.

B. Balbheem Kamanna , This paper is explained about Thermal barrier coating on IC Engine Piston to improve Engine efficiency, International Journal of Scientific & Engineering Research. In this paper explained that piston is considered as most important part of I.C engine. High temperature produced in an I.C engine may contribute to high thermal stresses. Without appropriate heat transfer mechanism, the piston crown would operate ineffectively which reduce life cycle of piston and hence mechanical efficiency of engine. The literature survey shows that ideal piston consumes heat produced by burnt gases resulting in decrease of Engine overall Efficiency. In this project work an attempt is made to redesign piston crown using TBC on piston surface and to study its Performance.

C. Dr.shashank , In this paper he explained that the Design and optimization of coating structure for the thermal barrier coatings fabricated by atmospheric plasma spraying via finite element method has presented fabricating the thermal barrier coatings (TBCs) with excellent performance is to find an optimized coating structure with high thermal insulation effect and low residual stress. This paper discusses the design and optimization of a suitable coating structure for the TBCs prepared by atmospheric plasma spraying (APS) using the finite element method. The design and optimization processes comply with the rules step by step, as the structure develops from a simple to a complex one. The research results indicate that the suitable thicknesses of the bond-coating and top-coating are 60–120 μm and300–420 μm, respectively, for the single ceramic.

D. D. Freiburg , Development and Analysis of Microstructures for the Transplantation of Thermally Sprayed Coatings has presented thermally sprayed coatings and tribological surfaces are a point of interest in many industrial sectors. They are used for better wear resistance of lightweight materials or for oil retention on surfaces. Lightweight materials are often used in the automotive industry as a weight-saving solution in the production of engine blocks. It is necessary to coat the cylinder liners to ensure wear resistance. In most cases, the coating is sprayed directly onto

the surface. Previous research has shown that it is possible to transfer these coatings inversely onto other surfaces. This was achieved with plasma sprayed coatings which were transplanted onto pressure-casted surfaces.

E. K. Thiruselvam, Thermal Barrier Coatings In Internal Combustion Engine , National Conference On Recent Trends And Developments In Sustainable Green Technologies . The depletion of fossil fuel resources at a faster rate in the present world of economic competitiveness is generating an essential demand for increase in efficiency of internal combustion engines. The use of coating in the automotive industry has been found to yield a significant effect on the efficiency of engines. Higher the operating temperature more will be the efficiency of the system. However, such higher temperatures demand for enhanced temperature resistant materials to be used. This paper presents a review on the various aspect and usage of thermal insulating materials (commonly known as thermal barrier coatings.

F. S Pal, A Deore, A Choudhary, V Madhwani and D Vijapuri , In this paper he explained that the Analysis and experimental investigation of ceramic powder coating on aluminum piston , : Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines. The diesel engine generally offers better fuel economy than its counterpart petrol engine. Even the diesel engine rejects about two thirds of the heat energy of the fuel, one-third to the coolant, and one third to the exhaust, leaving only about one-third as useful power output. Theoretically if the heat rejected could be reduced, then the thermal efficiency would be improved, at least up to the limit set by the second law of thermodynamics. Low Heat Rejection engines aim to do this by reducing the heat lost to the coolant. Thermal Barrier Coatings (TBCs) in diesel engines lead to advantages including higher power density, fuel efficiency, and multifuel capacity due to higher combustion chamber temperature. Using TBC can increase engine power by 8%, decrease the specific fuel consumption by 15-20% and increase the exhaust gas temperature by 200K. Although several systems have been used as TBC for different purposes, yttria stabilized zirconia with 7-8 wt. % yttria has received the most attention. Several factors playing important role in TBC life include thermal conductivity, thermo chemical stability at the service temperature, high thermo mechanical stability to the maximum service temperature and thermal expansion coefficient (TEC).

G. Mr.Bhavin D. Pate, This paper gives the information about Review of Literature Survey on Effect of Thermal Coating on Cylinder and Piston Crown. The desire to reach higher efficiencies, lower specific fuel consumptions and reduce emissions in modern internal combustion (IC) engines has become the focus of engine researchers and manufacturers for the past three decades. The global concern over the decreasing supply of fossil fuels and the more stringent emissions regulations has placed the onus on the engine industry to produce practical, economical and environmentally conscious solutions to power our vehicles.

3. OBJECTIVES

•To determine the heat transfer rate between the top of the piston head and bottom of the piston head with comparing the ceramic coated piston and uncoated ceramic piston.

•To determine the hardness of the top of the piston with comparing the ceramic coated piston and uncoated ceramic piston.

•To minimize the friction between the piston skirt and cylinder wall by applying the thermal barrier coating

4. METHODOLOGY

1. Feasibility study
2. Literature survey and its reviews
3. Study of different materials and specifications of piston
4. Selection of material and piston
5. Preparation of specimen
6. Thermal spray process
7. Coating of piston crown and piston skirt
8. Performance testing of specimen with coated and without coating
9. Performance comparison with and without coated piston

5. STUDY OF THERMAL BARREIER COATING MATERIALS

ALLUMINIA-

It has very high hardness. Alumina has relatively high thermal conductivity compared with yttria stabilized zirconia. Even though alumina alone is not a good thermal barrier coating, its addition to yttria stabilized zirconia can increase the hardness of the coating and improve the oxidation resistance of the substrate.

YATTRIA STABILIZED ZIRCONIA-

7-8% yttria stabilized zirconia has high thermal expansion coefficient, low thermal conductivity and high thermal shock resistance.

MULLITE-

The large mismatch in thermal expansion coefficient with metallic substrate leads to poor adhesion.

ZIRCONATES-

High thermal expansion coefficient which results in residual stress in the coating, and this can cause coating delamination.

5.1 Thermal Barrier Coating

MATERIAL: YTTRIA STABILIZED ZIRCONIA

Over the course of development, 6-8% yttria partially stabilized zirconia (YSZ) has become the material of choice for this application. The reason for the choice has been its combination of properties. This material is used due to its relatively high coefficient of thermal expansion and very low thermal conductivity of around 2.25 W/mk in bulk form and the region of 1 W m-1 K-1 for a standard TBC coating.

Properties Of Coating Material:

1. Low thermal conductivity
2. High coefficient of thermal expansion which allows reducing thermal stresses at the boundary with the metallic substrate.
3. Relatively high fracture toughness
4. High thermal shock resistance

Technical Specifications And Properties Of Piston

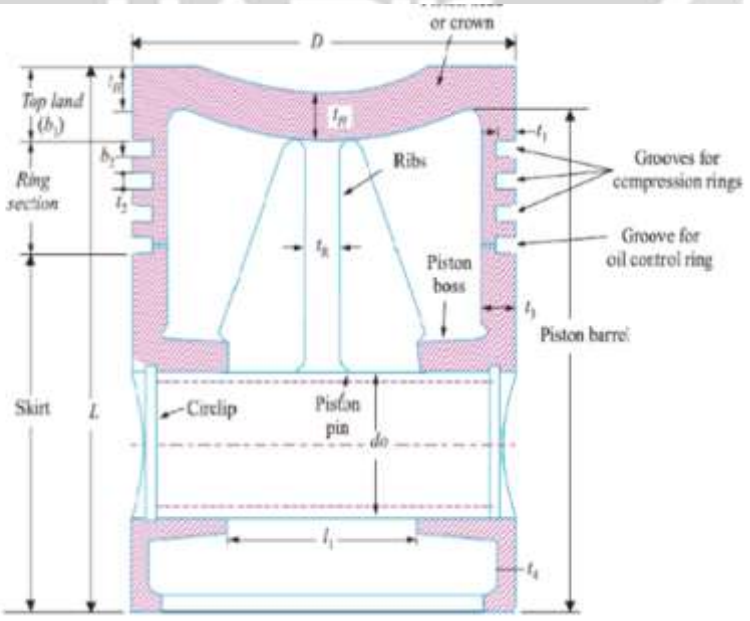

Fig 1 : piston terminolog

Material for Pistons:

The most commonly used materials for pistons of I.C. engines are cast iron, cast aluminum, forged aluminum, cast steel and forged steel. The cast iron pistons are used for moderately rated engines with piston speeds below 6 m / s and aluminum alloy pistons are used for highly rated engines running at higher piston speeds. It may be noted

1. Since the coefficient of thermal expansion for aluminum is about 2.5 times that of cast iron, therefore, a greater clearance must be provided between the piston and the cylinder wall in order to prevent seizing of the piston when engine runs continuously under heavy loads. But if excessive clearance is allowed, then the piston will develop 'piston slap' while it is cold and this tendency increases with wear. The less clearance between the piston and the cylinder wall will lead to seizing of piston.

2. Since the aluminum alloys used for pistons have high heat conductivity (nearly four times that of cast iron), therefore, these pistons ensure high rate of heat transfer and thus keeps down the maximum temperature difference between the center and edges of the piston head or crown. 3. Since the aluminum alloys are about three times lighter than cast iron.

Specifications (Splendor-Pro) Of Piston

Engine Type	Air Cooled Four Stroke Single Cylinder OHC
Displacement	97.2cc
Max Torque	5.66kw ,@500rpm
Compression Ratio	9.9:1
Starting	Kick Start / Self Start
Ignition	Dc Digital CDI
Bore	50mm
Stroke	49mm
Thickness of piston head	th = 4.01mm

Chart 1: specification of piston

Method of Depositing Thermal Barrier Coatings: Air Plasma Spraying (APS)

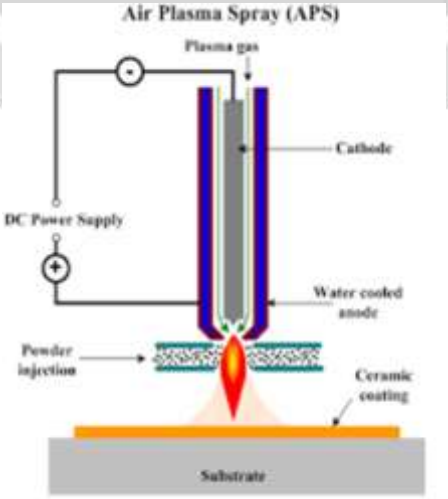

Fig 2 : air plasma spray

Thermal Spraying technique consists of different types such as Chemical deposition method (CVD), plasma arc method, Physical vapour deposition method (PVD), and Plasma spray method. From the above four methods, plasma spray method is adopted in our experimental study. The main objective in plasma spraying was to constitute a thin layer that has high protection value over other exposed surfaces. YSZ is sprayed in powder form molten in ionized gas rapidly on the piston crown surface to form a 100 micron thin TBC coating. A typical Plasma spray coating system is shown in Figure. The system primarily consists of power unit, powder supply unit, gas supply unit, cooling system, spraying gun and control unit. The coating material is Nickel Chromium and Ceramic. The plasma generator consists of a circular anode, usually of copper, and a cathode of tungsten. The cathode is made of graphite in a water stabilized torch. A strong electric arc is generated between anode and cathode. This ionizes the flowing process gasses into the plasma state. Now, powdered feedstock material is injected into the plasma jet. Plasma jet will melt the material and propel it onto the work piece surface. Atmospheric plasma spraying is carried out using a Sulzer Metco gun operating at power levels up to 50 kW. A gas mixture of hydrogen and argon is used as a plasma gas. The argon gas is also considered as a carrier gas for the feedstock.

Coating Thickness

Engine piston is a very sensitive component. The dimensions of the components are very critical as the injection timing, fuel consumption, spark timing mapping, and overall Engine Control Unit (ECU) mapping is done for those particular dimensions. From literature review the decided coating thickness was 300 microns and hence the plasma spray parameters were decided to get the coating of 0.3 mm.

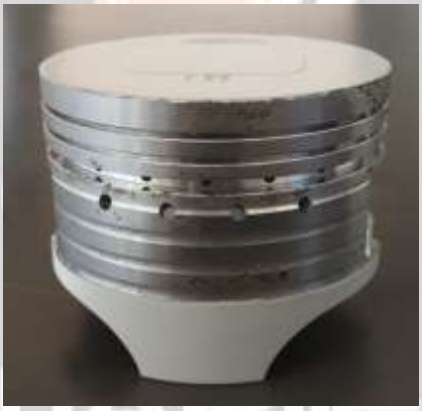

Fig 3: Ceramic coated piston

6. CONCLUSION

1. Due to thermal barrier coating on top of the piston the thermal stresses get reduced, thermal conductivity between top to bottom surface minimize.

2. TBC coating increases the hardness of the piston

3. Life of the piston increases.

REFERENCES

1. An Experimental Investigation of Piston Coating on Internal Combustion Engine
Prof. Pervez F. Agwanprof. Swapnil.A.Pande- International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 National Conference on Emerging Research Trends in Engineering and Technology (NCERT- 02nd & 03rd November 2015)

2.Thermal Barrier Coating on IC Engine Piston To Improve Engine Efficiency

Balbheem Kamanna, CAE Analyst, Matrix Cad Academy, Navi Mumbai- Journal Of Scientific & Engineering Research, Volume 8, Issue 3, March-2017 ISSN 2229-5518.

3.Experimental Study of the Effect of Thermal Barrier Coating on Diesel Engine Performance Raghu1, Girishkumar G S2, K Chandrashekara3- International Research Journal of Engineering and Technology (IRJET).

4.Review Of Literature Survey On Effect Of Thermal Coating On Cylinder And Piston Crown Mr.Bhavin D. Pate, Prof.Ramesh N. Mevada, Prof. Dhaval P. Patel- International Journal Of Engineering Research And General Science Volume 2, Issue 6, October-November, 2014.

5.Thermal Barrier Coatings in Internal Combustion Engine K. Thiruselvam-National Conference on Recent Trends and Developments in Sustainable Green Technologies.

6. Bhagat A R and Jibhakate Y M 2012 Thermal Analysis and Optimization of IC Engine Piston using finite element method International Journal of Modern Engineering Research 2919-21.

7. Singh P and Pramanik D 2015 Structural and thermal analysis of a C. I. engine piston of different materials using FEM technique MR International Journal of Engineering and Technology 7(1) 41-48.

8. Wang Y X, Liu Y Q and Shi H Y 2010 Finite Element Static and Dynamic Analysis for a Piston Advanced Materials Research 97-101 3323-3326

9. Kaiser M S and Dutta S 2014 Corrosion Behaviour of Aluminium Engine Block in 3.5% NaCl Solution Journal of Materials Science and Chemical Engineering 2 52-58

10. Analysis and experimental investigation of ceramic powder coating on aluminum piston
S Pal, A Deore, A Choudhary, V Madhwani and D Vijapuri.