

A Review Study on Experimental Investigation on Improving Performance of I.C. Engine by Varying Advance Piston Coating Materials

Mahesh M. Chudasama¹ Prof. Y. D. Vora²

¹M.E. Student (IC & Auto) ²Associate Professor

^{1,2}Department of Mechanical Engineering

^{1,2}L D College of Engineering, Ahmedabad

Abstract— The consumption of hydrocarbon deposits at a faster rate in the present world the engine manufacturer as well as automobile industry is generating an essential demand for increase in efficiency of internal combustion engine. Advance technology demand for modifications of diesel engine more efficient with respect to fuel economy, power output, and reduce emissions. Engine life depends mainly on the part of the engine, service life increased by considering the part which dominates its major role in the working condition of the engine. higher temperatures demand for enhanced temperature resistant materials to be used. The use of Advance coating material in the automotive industry has been found to yield a significant effect on the efficiency of engines. An experimental investigation is carried out on a partially insulated single cylinder Diesel engine to study the performance and emission characteristics. The Piston Crown is coated with a ceramic material consisting of Zirconium dioxide (ZrO₂) with 8% by weight of Yttrium Oxide (Y₂O₃) by plasma spray method. It was also found that heat lost to coolant is reduced and there is increase in energy of exhaust gases for Low heat rejection (LHR) engine when compared with the conventional single cylinder diesel engine.

Key words: Thermal Barrier coating, piston crown, diesel engine

I. INTRODUCTION

Internal combustion engines are self propelled engine in which combustion of fuel takes place inside engine cylinder, high pressure combustion product would be expanded through the piston thus work produced. An Internal combustion engine parts are exposed to severe gas loads, high temperature, as well as corrosion and erosion media. Engine life depends mainly on the part of the engine service life increased by considering the part which dominates its major role in the working condition of the engine. The engine manufacturer as well as automobile industry is facing a serious challenge to improve engine efficiency and reduce emission. Reductions in fuel consumption can be achieved by a variety of measures, including improved aerodynamics, weight reductions and hybrid power trains. Since the early stages of modern engine construction, their producers have been applying protective coating systems in order to enhance their durability and to maximize the exploitation of the properties of the used materials

Modern engine constructions together with the technological advancement lead to the evolution of new coating types and to the improvement of the formerly used coatings. The presents applications of a variety of protective coatings for the piston crown of an I.C. Engine.

However, in the hot section of the engine, which includes piston, the combustion chamber area the thermal barrier coatings (TBCs) and high-temperature seal coatings are used. The hot operating temperature of the parts demands the application of Advance ceramic material.

The developmental tendencies in obtaining high performance of I.C. engine are chiefly connected with an increase in the engine's capacity, its efficiency, lifetime, reliability, reduce emission and a decrease in the fuel consumption. These may be achieved with the development of ceramic coating for thermal insulation system for minimal heat rejection of heat and metal protection of hot gases faced in cylinder component is continued with emphasis on plasma spray.

Those materials need to be resistant to the high temperature of the gas stream, which may have a strong oxidizing, corroding or eroding impact. The influence of the destructive environment might be incredibly complex, depending on the engine construction, its working cycle, the used fuel and its operation site.

A. Methods to Produce Thermal Barrier Coatings:

1) Thermal Barrier Coatings Can Be Produced In Industries By The Following Methods:

- Air Plasma Spray (APS)
- Electron Beam Physical Vapour Deposition (EBPVD)
- High Velocity Oxygen Fuel (HVOF)
- Electrostatic Spray Assisted Vapour Deposition (ESAVD) and
- Direct Vapour Deposition (DVD)

2) Advanced Technology Ceramics Consist Of Pure Oxides And Type Of Ceramic Material:

- Alumina (Al₂O₃),
- Zirconia (ZrO₂),
- Magnesia (MgO),
- Barilla (BeO),
- Yttria (Y₂O₃) and non oxide ones.
- Garnets
- Spinel
- Mullite

B. Benefits of Ceramic Coated Piston:

When performance of C.I. engine takes place with ceramic coated piston by experiment and fin ite 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,
- 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

C. Application of Ceramic Coated Piston:

- IC Engine
- Reciprocating compressor

II. EXISTING LITERATURE

Ashish jashvantlal Modi and dhiren patel[1] investigated the performance and emission characteristics of twin cylinder ceramic coated water cooled CI engine using blends of diesel and neem bio diesel. In this work they prepared bio-diesel in laboratory from non-edible vegetable oil (neem oil) by transesterification process with methanol, where potassium hydroxide (KOH) was used as a catalyst and Combustion chamber inner wall. Piston top surface (crown) and valve faces were coated with the Magnesium Zirconate (Ni₂ZrO₃). An experimental investigation was conducted at medium speed with varying load to obtain actual driving condition experienced in most urban areas and measurements like fuel flow; exhaust temperature and smoke test were carried out. The results indicate that brake thermal efficiency of the LHR engine is found to be higher by 11-13% than the standard base line engine. The brake specific fuel consumption (BSFC) was 7-12% lower in LHR engine than that of the base engine at high load condition. Biodiesel also increased efficiency in reducing particulate emissions. The use of neem biodiesel resulted in lower emissions of unburned hydrocarbons, carbon monoxide, with some increase in emissions of oxides of nitrogen.

Y. Sureshbabu, P. AshokaVarthanan[2] Presents on Study the emission characteristics of catalytic coated piston and combustion chamber of a four stroke spark ignition (SI) engine. In this research coating materials on the engine piston and their performances are studied and hence conclude that the catalyst coating on the piston, combustion chamber gives the maximum brake thermal efficiency. This study analyses the work of other researchers who used various catalyst as coating materials. This study also aims to identify the best coating material for spark ignition engine. Among the different catalysts investigated, copper is very effective in reducing HC and CO emissions for SI engines and hence proved that copper coating is most suitable for SI engines. In future copper coating thickness will be optimized for better results.

Parag C. Thanare, R. G. Telrandhe[3] Present on Design And Analysis Of Piston Head With Different Coat they investigate and analyze the thermal stress distribution of piston, piston rings at the real engine condition during combustion process head by using FEA Software. Focusing on the critical investigation of original piston of engine and its performance along with the different materials

coatings with different thickness, mesh optimization with using finite element analysis technique to predict the higher stress and critical region on the component. With using computer aided design, Pro/ENGINEER software the structural model of a piston will be developed. Furthermore, the finite element analysis performed with using software ANSYS With application of the thermal barrier coating on piston head the stress 10 -15% decreases because low thermal conductivity of coating material.

Vinay Kumar Domakonda and Ravi Kumar Puli [4] presents on Application of Thermal Barrier Coatings in Diesel Engines. A review of research on low heat rejection engines, to incorporate various systems of ceramic materials in intermittent combustion engines, and on the use of ceramics in these engines is presented. The reduction of heat loss from the combustion chamber of diesel engines improves fuel efficiency only by 3 or 4 per cent. Some other gains may be possible from a smaller cooling system, recovery of exhaust energy, and improvements in aerodynamics. The increase in the in-cylinder temperatures helped in better release of energy in the case of biodiesel fuels thereby reducing emissions at, almost the same performance as the diesel fuel. The purpose of this paper is to explain the effect of insulation on engine performance, heat transfer characteristics, and combustion and emission characteristics.

Helmisyah Ahmad Jalaludin, Shahrir Abdullah, Mariyam Jameelah Ghazali, Bulan Abdullah, Nik Rosli Abdullah[5] presents "Experimental study of ceramic coated piston crown for compressed natural gas direct injection engines In this work, bonding layer NiCrAl and ceramic based yttria partially stabilized zirconia (YPSZ) were plasma sprayed onto AC8A aluminum alloy CNGDI piston crowns and normal CamPro piston crowns in order to minimize thermal stresses. Several samples were deposited with NiCrAl bonding layers prior to coating of YPSZ for comparison purpose with the uncoated piston. The performance of the coating against high temperature was tested using a burner rig. The temperatures on the top of piston crown and piston underside were measured. Finally, the heat fluxes of all conditions of piston crown were calculated. In short, the YPSZ/ 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. From the experiment, the average heat flux of YPSZ/NiCrAl coated piston crown exhibited 98% lower than the uncoated piston crowns. This might be due to the existence of lower conductivity of the ceramic coating. Current result may lead to contribution for the betterment of heat protection to the piston in CNGDI engine.

Nagarjuna.Jana, K.Komali[6] presents on DESIGN AND ANALYSIS ON A CERAMIC COATED DIESEL ENGINE PISTON USING ANSYS Recently the performance of IC engines is enhanced by using various thermal barrier coatings. The importance of various coatings in IC engines is also presented. The finite element results show that steel piston is showing maximum surface temperature than AlSi alloy piston for selected boundary conditions and coatings. It is due to lower thermal conductivity of steel material than AlSi material. It is also observed from the results the surface temperature in uncoated piston is less than coated piston. The coatings act as thermal barrier on the

surface of piston which resulting in lesser heat loss to the piston and maintaining higher temperature on the top surface of the piston. From the selected coating types and compositions the functional graded coatings are giving better performance compared with other coatings like single layer, composite and multilayer coatings except single layer MgZrO₃. Practically it is not possible to coat single layer Zr based ceramic coatings on substrate due poor adhesion and high brittleness. The temperature value of FGM coating piston surface are lower than that of the single layer MgZrO₃ coating at the same coating thickness. This is because of the fact that the increase of the layer number reduces the thickness MgZrO₃ material on top surface of the coating and raises the thermal heat loss. Therefore, the heat insulation capability of the coating system gradually decreases.

G.Sivakumar, S. Senthil Kumar [7] investigate effect of Ytria Stabilized zirconia coated piston crown on performance and emission characteristics of a diesel Objective The aim of this paper is study of effect on performance and emissions results with yttria stabilized zirconia coated piston crow. Modification: Ytria stabilized zirconia coating on an aluminum piston

Conclusion& Result Thermal efficiency of the engine increases. BSFC is reduced by 3.38% and 28.59% at full load and 25% of the full load conditions respectively . Hydrocarbon emissions were reduced by 35.27% in the TBC coated engine, where Carbon monoxide emission is reduced by 2.7% and Carbon dioxide emission increased by 5.27%.

Sean D'silva, Sumit Jain, Mayur Ingale[8] Presents on "Design Analysis of a Circular and Square Shaped Piston Head Considering Mechanical Stresses .In this paper a circular piston is compared with a square shaped piston (piston with square-shaped crown). In this comparison they are focusing mainly on mechanical parameters like stress induced, strain induced and deformation of the piston and explains why square pistons cannot be used once the two are compared. The pistons have been designed using Autodesk INVENTOR and the analysis has been done using ANSYS static structural neglecting the frictional losses. It is observed that although fatigue is not responsible for the biggest slice of damaged pistons, but the stresses induced are the major factor for piston failure. From the analysis it can be seen that for some instances a square piston is better. This is seen in case of the total deformation, equivalent stress and maximum principle stress. All these results have been formulated without considering friction and other losses. Although it might seem better to use a square shaped piston head instead of a circular shaped one after looking at these results, but it will require extra cooling arrangements and more maintenance. Square shaped pistons may have applications in some machines, but cannot be used in the modern day practical automobiles, as the losses are more.

M. Azadi, M. Baloo [9] presents on A review of thermal barrier coating effects on diesel engine performance and components life time. This experiment was aimed to study effect on performance and emissions results of thermal barrier coating on diesel engine .Use of NiCrAl as bond coat with 150 microns thickness and another layer made of ZrO₂-8%Y₂O₃ with top coat 300 microns thickness by using the plasma thermal spray method. Hence they conclude that

thermal Efficiency increases & Emission result is also improved. BSFC decreased by 12%. Increase in Engine lifetime, Engine power, Valves lifetime compared with the uncoated piston is 20%, 10% and 300% respectively.

Nagarjuna Jana, K. Komali[10] presents on DESIGN AND ANALYSIS ON A CERAMIC COATED DIESEL ENGINE PISTON USING ANSYS In this paper single cylinder four stoke diesel engine piston was model using Pro/E for thermal analysis. Further 10 node solid 87 is selected for meshing,The finite element mesh of the piston model used ANSYS code.The finite element results show that steel piston is showing maximum surface temperature than AlSi alloy piston for selected boundary conditions and coatings. It is due to lower thermal conductivity of steel material than AlSi material. It is also observed from the results the surface temperature in uncoated piston is less than coated piston. The coatings act as thermal barrier on the surface of piston which resulting in lesser heat loss to the piston and maintaining higher temperature on the top surface of the piston. From the selected coating types and compositions the functional graded coatings are giving better performance compared with other coatings like single layer, composite and multilayer coatings except single layer MgZrO₃. Practically it is not possible to coat single layer Zr based ceramic coatings on substrate due poor adhesion and high brittleness. The temperature value of FGM coating piston surface are lower than that of the single layer MgZrO₃ coating at the same coating thickness. This is because of the fact that the increase of the layer number reduces the thickness MgZrO₃ material on top surface of the coating and raises the thermal heat loss. Therefore, the heat insulation capability of the coating system gradually decreases.

III. CONCLUSION

Research or innovation regarding any of the subject can be made possible only through the knowledge of past work related to the same field. So, work carried out by the eminent personalities will always be the stepping-stone for the future revelations. Required preparation before carrying research work can be made well by discussing the previous work carried out by the researchers in the various fields which are related to topic.

This chapter presents the detailed literature review on Piston Shaped Analysis with mechanical parameter and effect of piston crown coating on the performance of engine thus following conclusions have been made:

- Low thermal conductivity Coating materials such as copper, MgZrO₃, NiCrAl on the engine piston , combustion chamber gives the maximum thermal efficiency in Engine an decreases 10 -15% stress on piston head .
- Square pistons cannot be used in Modern engine compared to circular shaped since total deformation , von mises stress and maximum principle stress less in case of square shape loss are more.

There are some of the areas where more work can be done to improve the performance of an I.C. Engine by redesigning different Advance ceramic Coating materials and its composition for Piston ,Coating thickness variation for Piston Piston crown profile It can be seen that with maximum surface temperature of the ceramic coated piston is improved, thus thermal efficiency increase.

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