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A Technical Investigation of Coating Material on Internal Combustion Engine's Piston

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Abstract- **Achieving higher efficiency in IC engines is where a lot of research went into for the past one century and even with the effort of all the research the nominal efficiency is 31 percentages.The remaining energy is rejected in the form of heat and friction in the engine.The diesel engine usually offers better efficiency than petrol engine. Even the diesel engine loses about two thirds of the heat energy produced from the fuel, one-third to the coolant, and one third to the exhaust, leaving only about one-third as useful power output. Theoretically we can improve the thermal efficiency of the engine by decreasing the energy loss unless the second law of thermodynamics is not violated.In order to improve the thermal efficiency of the Internal Combustion Engines the heat energy rejected to the coolant is reduced by coating the pistons with a Thermal Barrier Coating (TBC). The main function of the TBC is to reduce the heat energy transferred through the piston body. The types and effects of different types of TBC are discussed here.**

Index Terms- emission control, un-burnt hydrocarbon, copper coating.

I. INTRODUCTION

In Internal Combustion Engine most of the heat energy produced during combustion process is absorbed by piston. This directly reduces the efficiency of the Internal Combustion Engine. Coating the piston crown with TBC directly reduces the heat lost due to transfer of heat energy to the piston. This heat energy can be used to burn the un-burnt gases there by reducing the pollutants in the exhaust gas and also increasing the power output per each power stroke of the piston. The combined effect of reduction in loss of heat energy through piston and efficient burning of fuel air mixture results in a net increase in thermal efficiency of the Internal Combustion Engine. Thermal barrier coatings are usually of stabilized Zirconias such as Yttria-Stabilized Zirconia (YSZ), but other ceramics like Silicon Nitride (SN) have been used. Thermalconductivities (k) have ranged from less than 0.5 W/mK to 10 W/mKand thicknesses have ranged from 0.1 mm to 4.5 mm. Ceramic coatings can be applied by a variety of methods, although thermal spraying techniques such as plasma spray are the most common.

Figure 1.Piston without TBC

Figure 2.Piston without TBC

II. CERAMIC POWDER SELECTION

The key to the success of this coating is the selection of the powder composition. Typically, ceramic powders used for piston rings are hard. In the past, Cr_2O_3 was used, which was expensive, yet yielded excellent tribological properties. Today, we incorporate two iron based powders (Fe_2TiO_5 and

Fe_2O_3) to achieve superior tribological properties for application to piston rings. The coating displays the potential to be applied near net shape and may not even require expensive grinding and polishing. An patented organometallic phosphate binder that has a maximum use temperature of 600ºC bonds the coating to the substrate [3]. As the phosphate generates a glass phase once bonded, it is relatively inert.

III. COMPARISON TO OTHER PISTON RING COATINGS

Coatings and surface treatments to piston ring substrates are compared to the new ceramic coating for both commercial and military applications. Our work has investigated vapor deposited "films" that work well, yet are so thin they do not last over a practical life cycle. We also compare the new ceramic to thermal sprayed ring and plating materials. The mating wear surface is hardened 4140H alloy steel. This was chosen as a possible candidate for future cylinder bores, and proves to be very a challenging wear surface. The ceramic piston ring coating provides a good friction and wear surface as well as a cost effective means of producing it.

This new coating has been compared to others we have worked with such as the following:

1. Chemical (CVD) and Physical (PVD) Vapor Deposited Diamond Like Carbon (DLC) films
2. Plasma Sprayed Nickel Cobalt Chrome Moly Alloyed Coatings, and traditional Plasma Sprayed Molybdenum piston ring coating.
3. Plating material such as Hard Chrome Plate

IV. EXPERIMENTAL SETUP

Determining ceramic coating effects on performance and exhaust emissions of turbocharger diesel engine requires standard values for performance indicators. For this purpose, test engine was operated without ceramic coatings according to 1231 numbered Turkish Standards (TS) experimental essentials and results were recorded. Ceramic coatings were applied after those standard tests. Cylinder heads, piston tops and intake exhaust valves were machined at 0.5 mm depth. Machining was done for achieving same compression rate with conventional combustion chamber after ceramic coating. Ceramic coating was applied by plasma spray coating system in Metal & Seramik Kaplama Ltd. Sti. in Turkey.

The most critical coated engine part is pistons due to its thermal expansion rate which is very different from selected ceramic material. In literature, ZrO_2 stabilized with Y_2O_3 and Si_3N_4 ceramic coating materials are told as positive result giving materials. At cylinder heads and intake exhaust valves, ZrO_2 stabilized with MgO can be utilized safely. Another important point in ceramic coatings is the binding layer composition. Coating durability is increased when NiCrAlY is used as binding layer.

Surfaces to be coated were cleaned from lubricants and other unwanted dirt after machining before roughed by sandblasting and prepared for ceramic coating. When surface preparation was done, surface was first coated with binding layer at 0.15mm thickness and then coated with 0.35 mm thick ceramic material layer. Reduction of thermal instability (high heat conduction difference) between coating layer and target surface is aimed by this way.

V. EXPERIMENTAL RESULTS

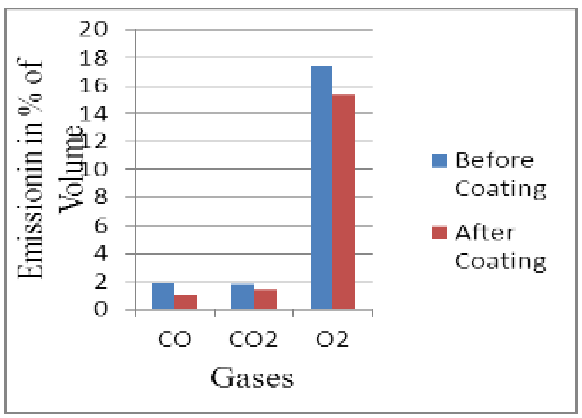

Fig 3. CO, CO_2,O_2 analysis of standard vs coated engine

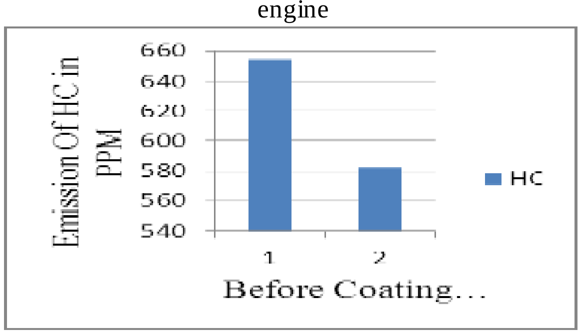

Fig 4. HC analysis of standard vs coated engine

From the experimental investigation of coated engine the following conclusion could be arrived.

From the experimental results at idle speed the HC emissions is for standard engine is 654ppm, whereas HC emission is for coated engine is 582ppm. (i.e.) 11% emission is reduced for coated engine compared to standard engine. It is represented in graph.

From Figure 3 CO emission standard engine is 1.92 % of volume where as coated engine gives 1.02% of volume. From the results is 46.7 % of emission is reduced in coated engine at idle speed condition.

From the Figure 3 CO_2 emission standard engine is 1.82 % of volume where as copper coated engine gives 1.42% of volume. From the results is 21.9 % of emission is reduced in coated engine at idle speed condition

VI. CONCLUSION

Thus the emission of the exhaust gases namely HC, CO, CO_2 and O_2 have been reduced to 582 ppm, 1.02 %, 1.42 % and 15.37% respectively using Automotive Emission Gas Analyzer. This can be further reduced by implementing further additional technologies.

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