Experimental Investigation on IC Engine Aluminum Piston With Zirconium Coating To Enhance Its Mechanical Properties

Prof Kalyan Kumar M[1], Pradeep G[2], R Vinay[3], Murthy BN[4], Nikhil S[5]
[1] asst prof
[1, 2, 3, 4, 5] REVA UNIVERSITY

Abstract- *As we all know that piston works at 1100˚ C and usually pistons are made up of aluminium material it generally has melting point of 660 ˚C, so in order to increase the resistive temperature we implemented coating on piston material. Ceramics coatings are widely used in industry for providing valuable improvements against wear, corrosion, and erosion. Zirconium dioxide is one of the most studied ceramic materials. Owing to following reasons, zirconium coating has been done on the aluminium piston consisting of 320 micrometre of zirconium and 80 micro metre of Nickel-Chromium as bond material. This coated piston was then tested and compared with uncoated piston of same composition.*

Keywords- Aluminum piston, Zirconium coating, Wear test, Hardness test, Corrosion test

I. INTRODUCTION

In industries, ceramic coatings are widely used to reduce wear, erosion, corrosion and to improve the hardness of the material. High pressurized oxygen and fuel gas are made to flow with internal combustion to produce very high particle velocities with relatively low temperatures compared with other thermal spray processes such as air or plasma spraying process. HVOF spraying has been implemented to produce low porosity, metallic, ceramic and carbide protective coatings, which are typically 200 mm thick. It is applicable to resistance coating of corrosion. There is also a need for coatings that have the properties of high hardness and wear resistance with the ability to resist.

Electrodeposited hard chrome coatings is replaced by corrosion which is easily done in industries Owing Zirconium's properties such as erosion, oxidation resistance, corrosion, high hardness, chemical and thermal stability at high and cryogenic temperatures, they are widely used in the industries for different applications. These properties make them useful for many applications. Including thermal barrier coatings on metallic substrates used at high temperatures in the areas of aircraft and aerospace, especially for thermal protection of components in gas turbines and IC diesel engines. A lot of experimental study has been done to utilize these Zirconium oxide properties to improve thermal efficiency by reducing heat losses, and to improve output mechanical efficiency by eliminating cooling systems.

II. PROBLEM IDENTIFICATION

Since Aluminum pistons are most used in internal combustion (IC) engine pistons which have a thermal expansion coefficient 80% higher than the cylinder bore material made of cast iron.

The melting point temperature of the Aluminum piston is 660˚C.This temperature can be increased by implementing Zirconium coating.

A cursory look at the internal combustion engine heat balance indicates that the input energy is divided into roughly three equal parts: energy converted into useful work, energy transferred to coolant and energy lost to exhaust as a waste heat. The 20% of energy is lost to due to heat, 30% of energy is transferred to coolant and remaining 50% of energy is only converted to useful work. The energy lost can be recovered by ceramic coating. (Crown of the piston, side of the cylinder liner, cylinder head).

III. LITERATURE SURVEY

In this study, 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.

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.

High velocity oxy-fuel (HVOF) spray coating of micron (m) and nano (n) WC–Co powders has been studied for the improvement of durability of sliding machine components (SMC). In this work, optimal coating process (OCP) is obtained from the best surface properties of coating prepared by the Taguchi program. Hardness of coating is strongly dependent on powder size and spray parameters (SP) because of their strong influence on in-flight parameters.

IV. NEED OF COATING

Ceramics coatings are widely used in industry for providing valuable improvements against wear, corrosion, and erosion.

Coatings must maintain intended performance during their life cycles.

Theoretically if the heat rejection could be reduced, then the thermal efficiency would be improved.

Low Heat Rejection(LHR) engines aim to do this by reducing the heat loss to the coolant.

Coating of Al piston with Zirconium i.e., ceramic material using plasma spray coating process.

Conducting various mechanical tests like wear, hardness, and corrosion test for both uncoated and coated specimen.

Comparing the results of both the specimens and concluding the advantages of coated material.

Specimen without coating (Sample 2)

Specimen with coating (Sample 1)

V. CONCLUSION

RESULTS:

Wear Test:

Load: 20N
Speed: 1000rpm
Time: 40 min

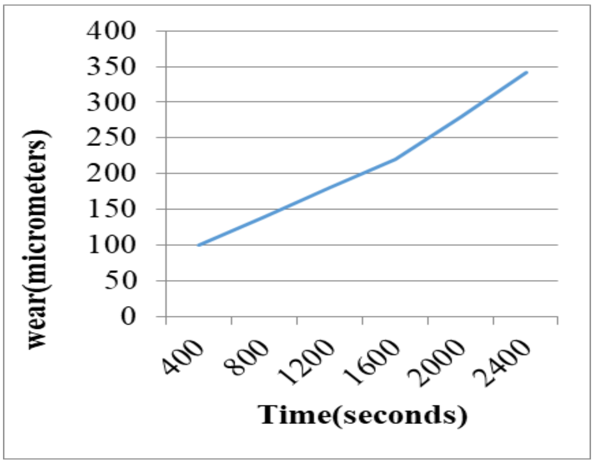
Sample	Wear (μ)	Frictional force (N)	COF
1	343	6.78	0.339
2	407	5.54	0.277

It is evident from the above results that wear rate of the Zirconium coated specimen is lesser than that of uncoated specimen.

Hence, we conclude that wear resistance increases of coated specimen. Life of the Al piston increases on coating.

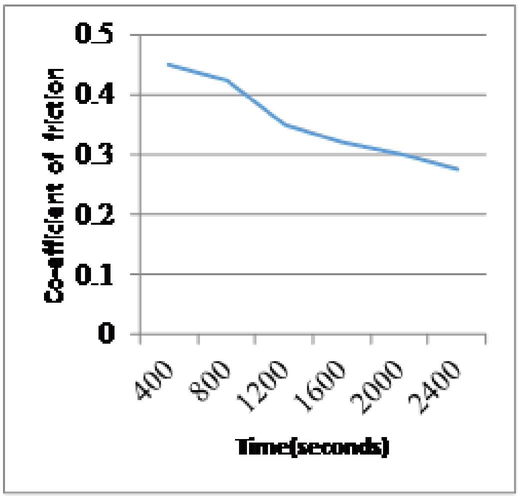
The weight loss of coated piston is less than that of uncoated piston which means longer duration of life of reciprocating IC engine coated piston.

SPECIMEN WITH COATING



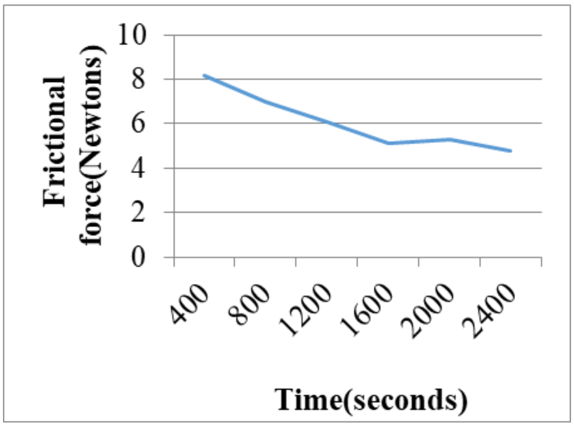
Description: It can be clearly observed that, the wear rate increases as time increases and this in turn indicates that as time and speed of the engine increases there will be increase in temperature also since the melting point temperature of zirconium is high this temp won't affect the piston.

SPECIMEN WITH COATING



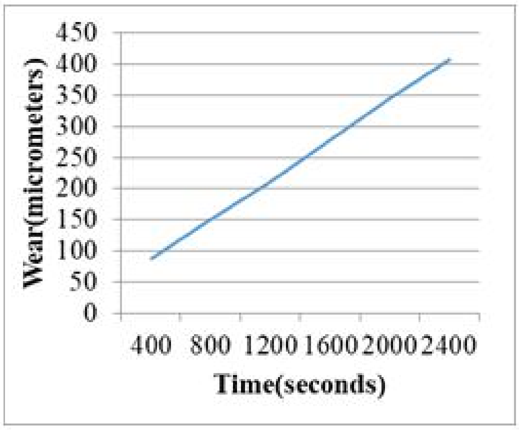
Description: It is evident from the graph co-efficient of friction is max at 400 seconds and co-efficient of Friction is continuously decreasing with respective time it is found that at around 2000 seconds co-efficient of friction value is minimum. Since the piston is coated with Zr the heat generation is gradually reducing compared to uncoated.

SPECIMEN WITH COATING



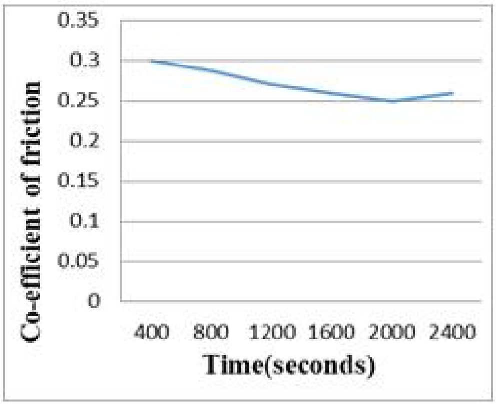
Description: The increase in frictional force is marginal and it can be easily neglected because the resistive temperature is more compared to Al based piston. Therefore its impact on performance on IC engine can be easily neglected.

SPECIMEN WITHOUT COATING



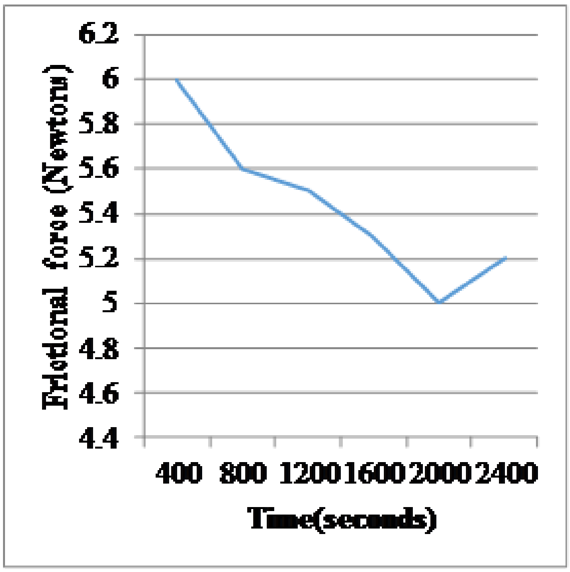
Description: It can be clearly observed that, the wear rate increases as time increases and this in turn indicates that as speed of the engine increases there will be increase in temperature also since the aluminum piston has very moderate melting point temperature the wear rate of the piston increases and piston life will be reduced.

SPECIMEN WITHOUT COATING



Description: It is evident from the graph co-efficient of friction is max at 400 seconds and co-efficientof friction is continuously decreasing with respective time it is found that at around 2000 seconds co-efficient of friction value is minimum. Since by comparing Al piston to coated piston the heat generation will be more.

SPECIMEN WITHOUT COATING



Description:Here frictional force is more and increase temperature will also be more since here piston is not coated and Al has low melting point when compared to Zr coated Al piston. Therefore, here wear rate, corrosion and hardness will be reduced.

Hardness test:

Sample	Equipment used	Hardness number (HV)
1	Micro hardness	193HV0.1
2	Micro hardness	120HV0.5

By this we conclude that the hardness of the Zirconium coated Aluminium piston is more when compared to uncoated Aluminium piston.

Above results also shows that, the Zirconium coated Aluminium piston will tend to carry more external load and high performance than that of uncoated Aluminium piston. This shows that Zirconium has superior mechanical properties because of its phase transformation toughening mechanism that prevented crack propagation in the material.

Corrosion Test:

Parameters	Sample 01	Sample 02
Concentration of salt solution	5%NaCl	5%NaCl
Test temperature in °C	35±1	35±1
Volume of test solution collected ml/hr/80cm²(1.0-2.0ml)	1.85	1.85
PH of the collected solution (6.5-7.2)	6.72	6.72
Cleaning procedure: After the test	Washed with running tap and distilled water	Washed with running tap and distilled water

Since the results of the both coated and uncoated Al piston are same. Hence the corrosive resistance doesn't change.

This means that the rusting, reduction of oxidation does not happen with the Zirconium coated piston.

It well known for years, Zinc Phosphate has been the best surface treatment to maximize your coatings durability.

Zirconium is great for aluminium and that show that Zirconium obtains results almost as good as a well-tuned Zinc Phosphate surface preparation.

VI. CONCLUSION

The overall output efficiency and performance of the Zirconium coated Aluminum piston is improved.

The life and hardness of the coated piston is increased.

Thermal stability also increased on coating the Al piston.

VII. ACKNOWLEDGMENT

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REFERENCE

[1] N.F. Aka, , C. Tekmena, I. Ozdemira, H.S. Soykanb, E. Celika (2003) "NiCr coatings on stainless steel by HVOF technique" Surface and Coatings Technology 173 –174 (2003) 1070–1073

[2] Ekrem Buyukkaya , Tahsin Engin, Muhammet Cerit (2006) "Effects of thermal barrier coating on gas emissions and performance of an LHR engine with different injection timings and valve adjustments" Energy Conversion and Management 47 (2006) 1298–1310 [3] K...

[3] Ekrem Buyukkaya , Muhammet Cerit (2007) "Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method" Surface & Coatings Technology 202 (2007) 398–402

[4] Ekrem Buyukkaya (2008) "Thermal analysis of functionally graded Nalloy and steel pistons" Surface & Coatings Technology 202 (2008) 3856–3865

[5] T.Y. Cho a, J.H. Yoon a, K.S. Kim a, K.O. Song a, Y.K. Joo a, W. Fanga, S.H. Zhang a, S.J. Youn b, H.G. Chun c, S.Y. Hwang (2008) "A study on HVOF coatings of micron and nano WC–Co powders" Surface & Coatings Technology