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Finite Element Thermal Analysis of Ceramic Coated Aluminium Silicon Alloy on Piston

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Abstract: the last few years the usage is increase in the utilisation of aluminium-silicon alloys, especially in the automobile industries, due to their high strength to weight ratio, wear resistance, low density, low coefficient of thermal expansion. In this paper investigation, aluminium based alloys containing 8%, 10% and 12% weight of silicon were synthesized using casting method. Compositional analysis and tensile investigation of different samples of same composition have showed near uniform distribution of si in the prepared alloys. Study of microstructure has showed the presence of primary silicon. Tensile tests were carried out with universal testing machine. The yield strength and ultimate tensile strength has developed to increase in silicon percentage. Wear behaviour was analyse and studied by using computerized pin on disc wear testing machine system. Resistance to wear has increased with increase same level in silicon amount. The worn surfaces is analysed using scanning electron microscope.
Keywords: ansys, hard chrome, thermal boundary

I. INTRODUCTION

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. Fast years, a different techniques have been taken to attain develop to improve in efficiency and reduce emissions in existing engine designs. The demonstration of new technique has played a role in making advancements to this old technology. Light and strong materials, modern manufacturing processes, improved combustion chamber designs, advanced exhaust after-treatment technologies, and new computation means for designing, analyzing and optimizing the internal combustion engine are just a few of the advantages i have made to achieve significant improvements in efficiency, performance and emissions.

II. THERMAL ANALYSIS OF PISTON

In the present numerical simulation work Pro-E, a modeling tool has been employed for modeling the piston. The developed model of the piston is saved in IGES format and imported in ANSYS for conducting the finite element analysis. The aim of the paper is to investigate the Al Si alloy piston temperature distribution by using different coating materials to achieve higher engine performance. Analyses have been performed for uncoated piston crown and ceramic-coated piston crown with a coat thickness of 0.3mm. The coating consists of 0.1mm bond coat (Ni Cr Al) and the ceramics YSZ and $MgZrO_3$ deposited onto the piston crown. Some of the properties of the ceramic coat, interlayer metallic bond coat, rings and piston are listed in the Table 1 are obtained from the literatures6,7. The bond coat layer is an inter-metallic alloy used between the thermal barrier coating and the metal substrate provides oxidation resistance and the internal stress resistance at higher temperatures helps in the bonding of the TBC layer to the substrate material8.

III. THERMAL BOUNDARY CONDITIONS

The heat transfer phenomena are complex in the heat engine piston. It is assumed that, the heat diffusion between gas and the piston surface is the convection in the temperature analyses8,9. A traditional heat load includes the radiation effects on the to p surface of the piston. The heat conduction model is performed in the zone of piston ring land and piston skirt with the following presumptions: (a)the influence of piston displacement on

Material	Density (kg/m^3)	Thermal Conductivity (W/m K)	Thermal coefficient of Expansion (10^{-6} K^{-1})	Young's Modulus (G pa)
Piston (aaluminum alloy)	2700	155	21	70
Bond coat (Ni Cr Al)	7870	16.1	12	90
Ceramic coating ($MgZrO_3$)	5600	0.8	8	46
Ceramic coating (YSZ)	5650	1.40	10.9	11.25
Oil rings	7200	25	10	135
Compression rings	7300	46	10	110

Table 1. Material properties of piston, piston rings and ceramics

the heat transmission is neglected. (b) There is no ring deformation (ring twist) has been permitted during piston motion. (c) Heat transfer due to convection in oil film is neglected. Symmetrical constraints are provided in the axially symmetrical axis and there is no radial displacement6. It is pretended that the inner temperature of the gas was taken as the mean temperature results on suction, compression, and combustion and gas explusion temperature in the course of engine operation. Hence, the inside temperature was 1100C with heat transfer coefficient of 1500 W/ m2 0 C and other boundary conditions are also taken from literature8. Piston lateral surface temperature was 2250C with a convective heat transfer coefficient of 500 W/m2 C. The piston ring temperatures are 2000C, 1800C, 1600C for compression rings and 1400C for oil rings. Piston skirt temperature was 1100C and heat transfer coefficient of 1500W/m2 0C.

IV. SELECTION OF CERAMIC COATING MATERIALS

After the feasibility study is made, proper selection of material is done. As already quoted the material selection is made from literature survey and suggestions made by the experts.

A. Materials those are Suitable as Thermal Barrier Ceramic Coatings are,

1) Zirconium
2) Hard Chrome
3) Aluminum Titanate
4) Silicon Nitride
5) Aluminum Magnesium Silicate
6) Yttria Partially Stabilised Zirconia
7) Yttrium Barium Copper Oxide
8) Aluminium silicon

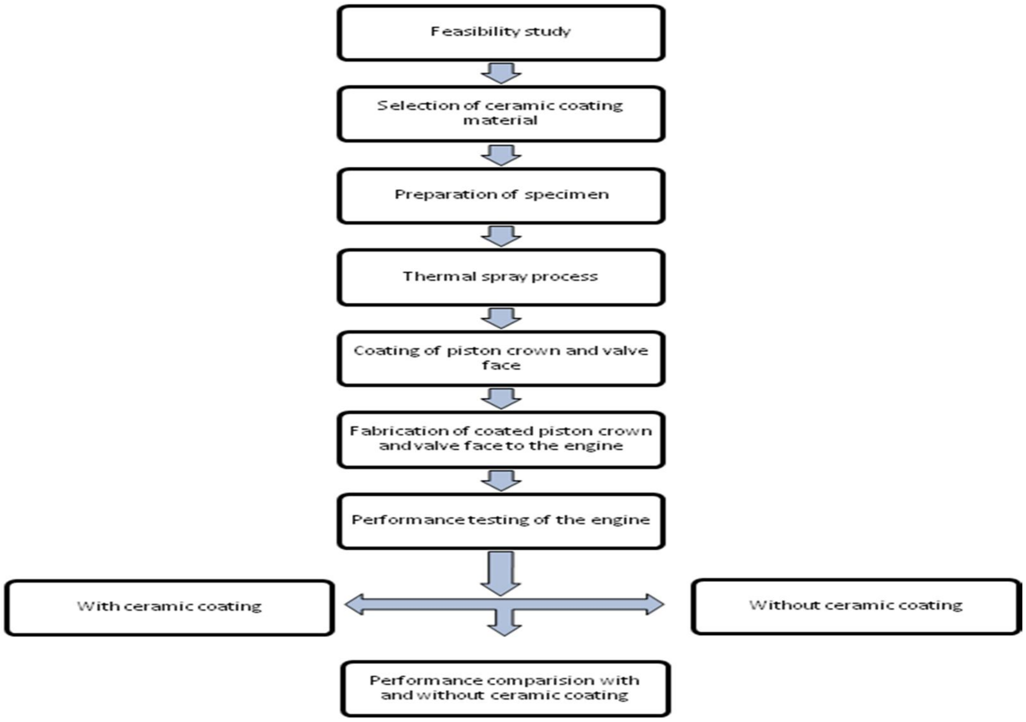

Fig.1 Process involved in the project

V. DETAIL OF ANALYSIS IN ANSYS

A. Condition No. 1

1) First we have to analyze the piston with material Aluminium and Temperature about 1260 kelvin.
2) Temperature act on the top of the piston.
3) We have to find the thermal conductivity, Thermal expansion.

B. Condition No. 2

1) Now we are applying Aluminium silicon alloy coating on the top of the piston for 0.5mm thickness.
2) So now coating is Aluminium silicon alloy and Piston is Aluminium.
3) Now we have to done the analysis again for the same input 1260k temperature and we have to calculate the thermal conductivity, Thermal expansion , Thermal diffusivity, specific heat, if possible wear
4) Finally we have to take all the reading and graphs and prove that with coating is better.

Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent
920	-0.106	0.213	-0.47	1000	0.2

Table 2 Strain-Life Parameters

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.e+005	0.3	1.6667e+005	76923

Table 3 Isotropic Elasticity

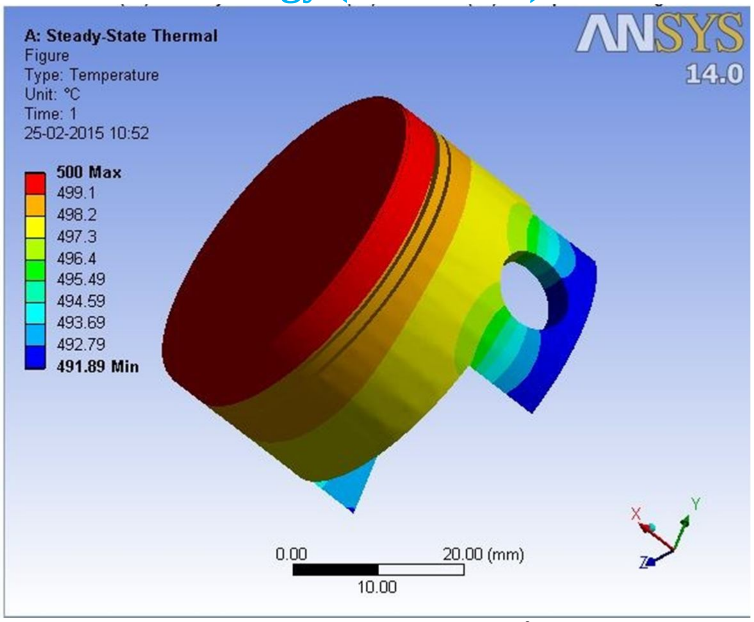

Fig 2 Maximum Temperature 500^{0}C

VI. RESULT AND DISCUSION

At the end of 30 seconds simulation, the results of temperature distribution obtained for each of the five IC Engines discussed are as tabulated in table . i know, lower heat rejection from the combustion chamber in thermally insulated components are causes an increase in available energy which in turn would increase the in-cylinder work and the amount of energy carried by the exhaust gases, which could also be utilized in later stages by using LHR (Low Heat Rejection) systems.

TEMPERATURE AT VARIOUS SECTION	Al-18%Si	GCI(ASTM GRADE 40)	STRONTIUM ZIRCONATE	BLT
On the Wall of Combustion Chamber	1173K	1173K	1173K	1173K
Cylinder Block	1000-820K	1073-550K	950-500K	730-450K
Liner Part	1173K	1173K	1050K	750K
Fins	730K	373K	373K	373K
Piston Body	1173-333K	1173-450K	1000-373K	730-373K
Valve Head	1173K	1173K	1050K	750K
Overhead Block	1173-820K	1173-373K	700-373K	700-373K

Table 4 Engine body temperature of various engine materials

In other words, the combustion process tends to be more adiabatic (isentropic) in nature which means we are making the cycle a better approximation to Otto Cycle. Hence, we can say that the use of Aluminium -silicon TBC will increase the thermal efficiency of the IC Engine and thereby the net work output during the cycle. When TBC is used, the heat dissipated into the engine body is further reduced than in the case of Aluminium - silicon ; making it the better of two proposed engine models using TBCs when it comes to improving its thermal efficiency.

VII. CONCLUSIONS

In The 3D Finite Element Thermal Analysis is performed on 5 different models of IC Engines. Upon the thermal analysis, we can saw that the use of TBCs greatly reduced that heat dissipation through the engine body during combustion. The following inferences are made by the system.

A. Use of TBCs in IC Engines is improve the thermal efficiency.

B. Furthermore, BLT TBC is found to be the most viable TBC material for use in petrol (gasoline) based IC Engine, on account of its high thermal phase stability and low thermal conductivity.

C. The Smaller engine cooling technique is sufficient.

D. The manufactured aluminium-silicon alloys have homogenous distribution of silicon throughout the cast.

E. The amount of primary silicon increases with the increase in silicon amount in the cast.

F. Total no.of elongation decreases with the increase of weight percentage of silicon.

G. Material Hardness of the Al-Si composite increases with the increase in amount of silicon present.

H. The height loss due to wear decreased on the percentage of silicon increases.

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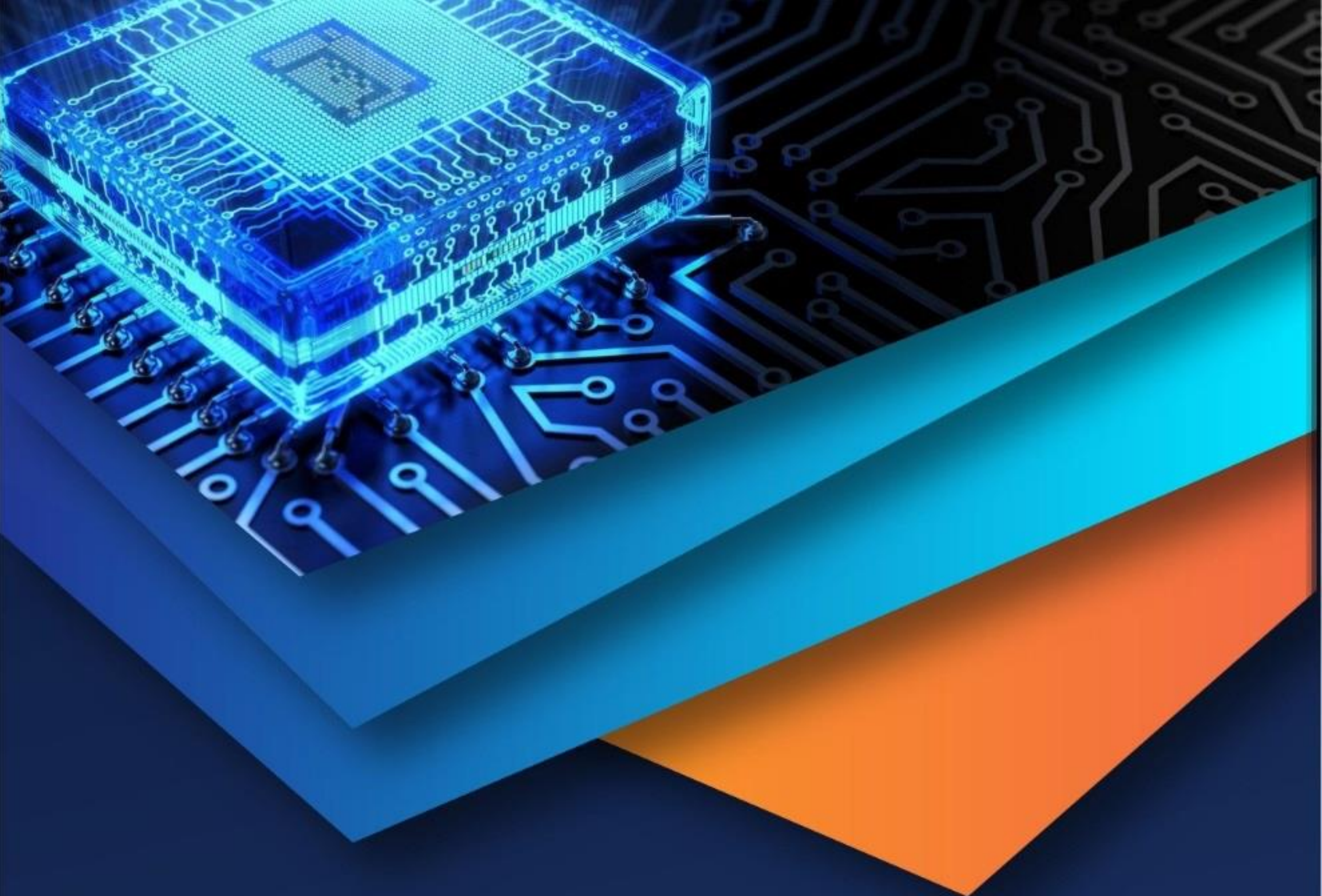

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