# YTTRIA STABILIZED ZIRCONIA (YSZ) IS USED AS A CERAMIC COATING APPLIED TO PISTON IN THE DESIGN AND ANALYSIS OF IC ENGINES

[1]Sadu Chandrakanth, [2]Luha Sundar Shyam, [3]Ramasing Ramasing, [4]Polepally Shiva
[1,2,3]Assistant Professor, [4]UG Student, [1,2,3,4]Department of Mechanical Engineering, Brilliant Grammar School Educational Society Group of Institutions Integrated Campus, Hyderabad, India

## ABSTRACT

Nowadays, car exhaust emissions are a major cause of pollution. The number of transportation vehicles and cars is rising daily along with the population and style of living. Also, during the past 20 years, the number of two-wheelers has sharply increased. The ozone layer is being depleted, the greenhouse effect is occurring, and all of these are increasing exhaust pollution. This study examines the steady state thermal analysis of a ceramic-coated diesel engine piston with holes on its surface. Using Ansys, a finite element-based programme, the temperature distribution on the piston's top surface and substrate surface is examined. Zirconia that has been Yttria-stabilized is utilized as a ceramic coating for an Al-Si crown. The 2 thickness of ceramic top coatingis about 0.4 mm and for Ni Cr Al bond coat it is taken to be 0.1 mm. Temperature distributions is investigated by choosing various radiuses of holes created on the ceramic coating surface about 1.5 mm, 2 mm and 2.5 mm. From the results it is observed that the top surface (coated surface) temperature is increasing with increase the radius of the holes.
Maximum temperature of coated surface is occurring for highest hole radius of about 2.5 mm. Compared with coating have no hole, a significant increase in the pistons top surface temperature occurs with coating having holes. Although, the substrate temperature is decreasingwith increase the radius of the holes.

## INTRODUCTION

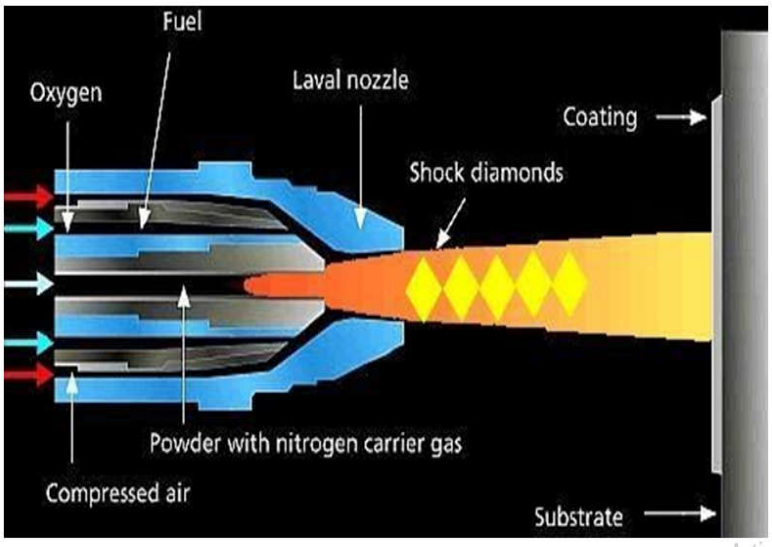
A primary mover that transforms chemical energy into mechanical energy is an internal combustion engine. In I.C Engine, the engine is sometimes referred to as the "heart" of a vehicle, with the piston perhaps being seen as its most crucial component. It is the moving part that is enclosed in a cylinder and sealed off from the gas by piston rings. Its function in an engine is to use a piston rod to transmit force from the expanding gas in the cylinder to the crankshaft. An IC engine's piston must be strong enough to withstand gas pressure, light enough to move without making much noise, have enough bearing surface to avoid wear, and seal oil from the top and gas from the bottom, must disperse the heat generated during combustion, must have good resistance to distortion under heavy forces and heavy temperature.

## METHODOLOGY

The work on performance of TBC on various piston materials, as seen in the methodology, they have shown simulated results using finite elements method-based software as ANSYS, inmajority. It can be seen that almost all studies are done on diesel engine and many of them done on piston material as aluminium alloys. The main material in composition of TBC is seento be NiCrAl and YSZ (Yttria stabilized zirconia) followed by others which are mullite, alumina, zirconium etc. The major performance measures studied by various authors are temperature distribution, deformation, thermal stresses, fuel and brake thermal efficiency. The temperature distribution in piston is crucial parameter influencing the thermal stresses and deformation. The thermal insulation thus obtained is supposed to lead, to an improvement in the engine’s heat efficiency and a reduction in fuel consumption. The 2 thickness of ceramic top coating is about 0.4 mm and for Ni Cr Al bond coat it is taken to be 0.1 mm. Temperaturedistribution is investigated by choosing various radiuses of holes created on the ceramic coatingsurface about 1.5 mm, 2 mm and 2.5 mm. From the results it is observed that the top surface (coated surface) temperature is increasing with increase the radius of the holes. Maximum temperature of coated surface is occurring for highest hole radius of about 2.5 mm.

**PLASMA SPRAY TECHNIQUE;**

Plasma is a dense gas which has equal number of electron and positive ion and generally named This method has two primary priorities; it can provide very high .as fourth state of the matter temperatures that can melt all known materials and provides better heat transfer than other gives opportunity to operate ,High operating temperature of plasma spray coating .materials Also using plasma spray coating in inertOxidation problem of the subject material.with metals and alloys having high melting points.surroundings is another positive side of the method All .hydrogen and nitrogen ,is reduced due to inert gas usage in plasma spray such as argon materials that are produced in powder form and having a specific grain size can be used in this The main objective in plasma spraying is to constitute a thin layer that has high .method The process is applied as spraying coating .protection value over a non-expensive surface material in powder form molten in ionized gas rapidly to coated surface the system primarily spraying gun and ,cooling system ,gas supply unit ,powder supply unit ,consists of power unit an amorphous structure is attained because of fast solidification. ,control some layers




TBC Materials

The term ceramic now covers a very wide range of materials including building materials sanitary were ,table ,refractories ,dielectrics ,magnetic ceramics ,insulators ,etc .Materials that are used for engineering in its mechanical sense can be considered to be the stronger ones , usually specially developed for their fine grain size and high density .They can be divided conveniently into two groups :oxides and non-oxides .In the former group fall traditional Porcelains ,alumina ,magnesia and other refractory oxides .In the latter are silicon carbide , silicon nitride ,boron carbide ,boron nitride ,molybdenum disilicate and other such compounds ,of which the first three are probably the most important .The ceramic materials of principal interest for heat engine applications are silicon nitride ,silicon carbide ,zirconia and lithium aluminium Silicate (LAS .)Although it has good thermal properties ,LAS has very poor

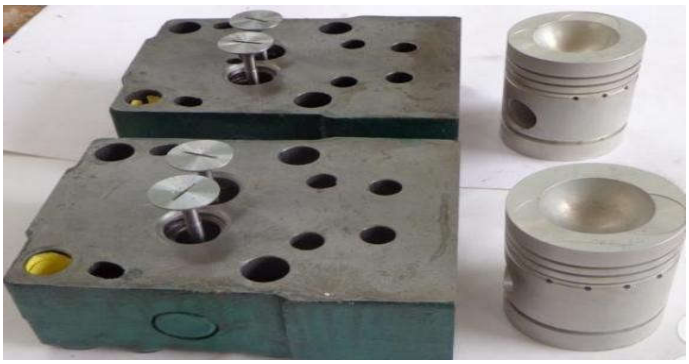


Figure:2 Engine Piston, Head & Valve without Coating

Figure.3. Engine Piston, Head & Valve without Coating of YSZ

**DIMENSIONS OF A PISTON**

| S.No. | Dimensions | Size in mm |
|---|---|---|
| 1 | Length of the Piston(L) | 152 |
| 2 | Cylinder bore/outside diameter of the piston(D) | 140 |
| 3 | Thickness of piston head ($t_H$) | 9.036 |
| 4 | Radial thickness of the ring ($t_1$) | 5.24 |
| 5 | Axial thickness of the ring ($t_2$) | 5 |
| 6 | Width of the top land ($b_1$) | 10 |
| 7 | Width of other ring lands ($b_2$) | 4 |

GEOMETRICAL SKETCH OF A PISTON

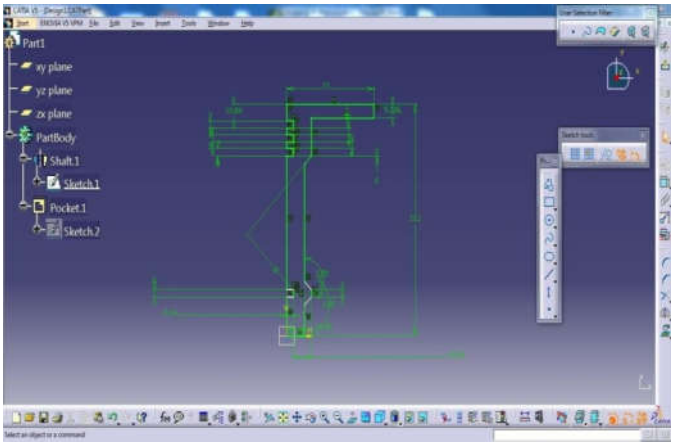



Figure.4. geometrical sketch

**RESULTS AND DISCUSSIONS**

The main aim of the project is to determine the static and thermal analysis of the piston coated with yttria stabilized zirconia (YTZP) of three different thicknesses and comparing them with conventional (i.e., uncoated) piston. With these results we can investigate heat flux, temperature, deformation, stress and strain of the coated and uncoated pistons. Here analysis of the piston model has been performed to obtain the value and parameters at which the piston would be damaged. Damages may have different origins: mechanical stresses; thermal stresses; wear mechanisms; temperature degradation, oxidation mechanisms; etc

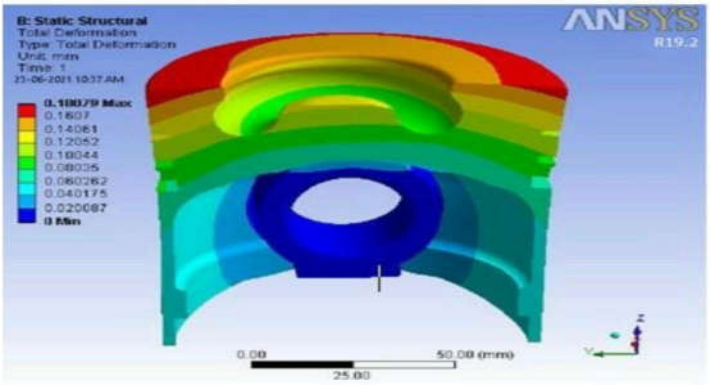
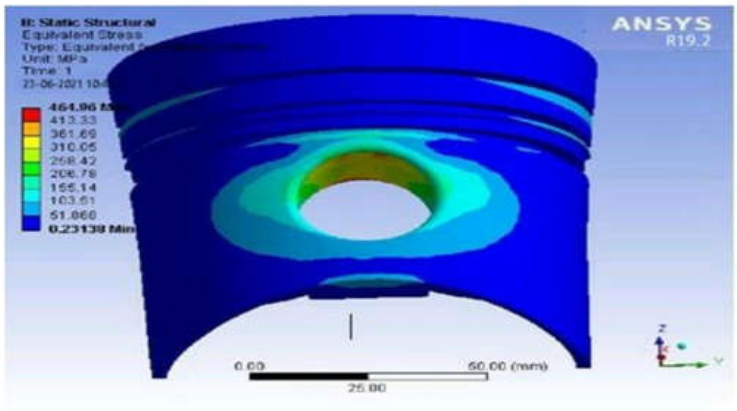



Figure.5. The temperature field of piston in the thermal load acts (Internal)



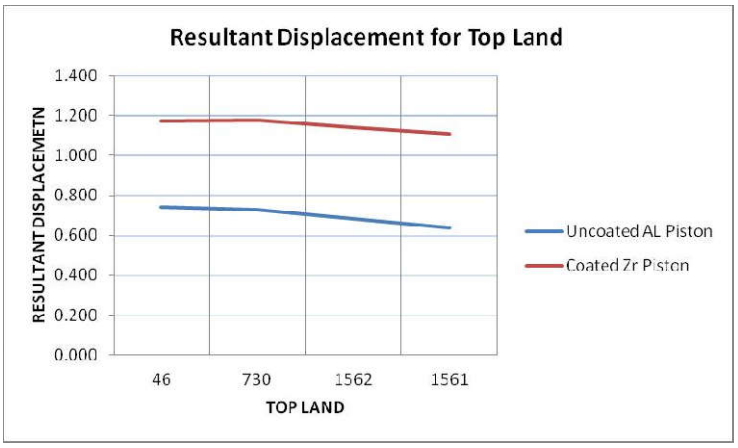




Figure.6. Resultant Displacement comparison for Ring Land for Uncoated and CoatedPiston for Design1:

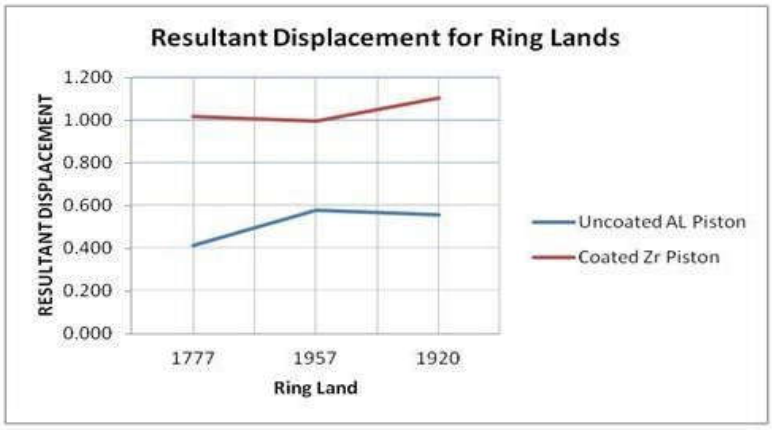



Figure.7. Vonmises Stress comparison for Top Land for Uncoated and Coated Piston forDesign1:

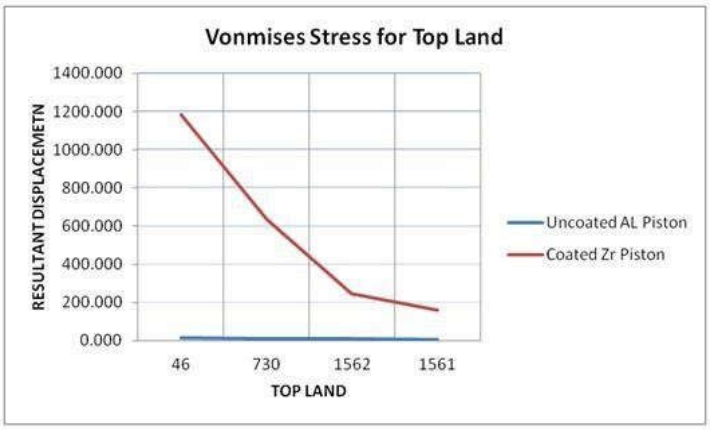



Figure.8. Resultant Displacement comparison for Top Land for Uncoated and CoatedPiston for Design2:

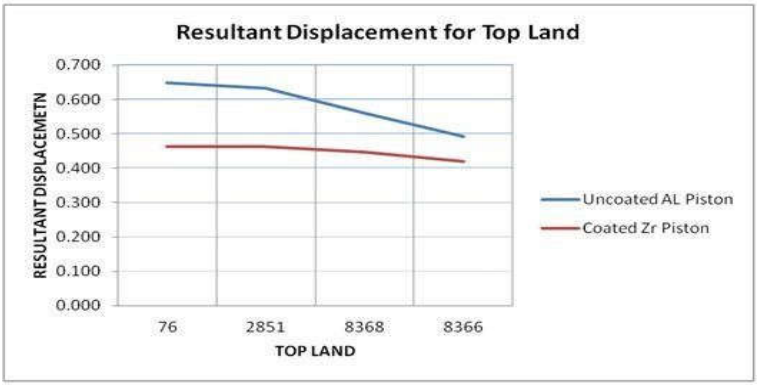
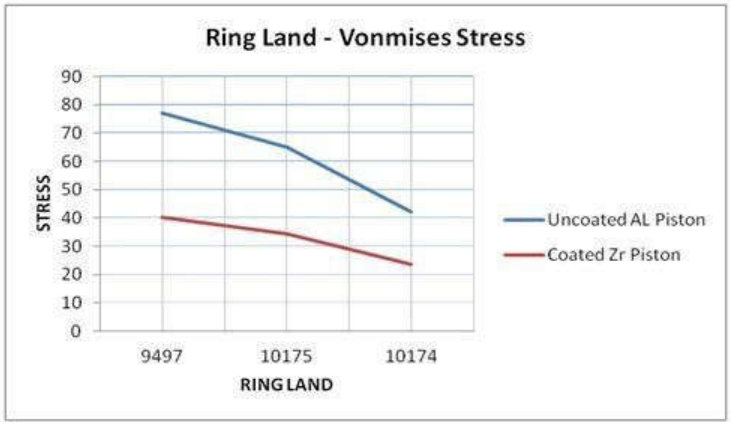



Figure.9. Vonmises Stress comparison for Ring Land for Uncoated and Coated Pistonfor Design2:




## CONCLUSION

Yttria stabilised zirconia coated piston showed 24.86% increased heat flux over conventional. A uniform temperature distribution was observed in coated piston over conventional piston. More heat of 2.458% is converter into work using YTZP coating on piston crown which leadsto overall increased performance of engine. From the analysis it was observed oil used for lubrication was not evaporated due to YTZP coating, resulted temperature (273°C to 311°C) was within the limit which indicates the safe guard to liner. retains its strength at high temperatures > 500°C.n Aluminium oxide (alumina), silicon oxide (silica), calcium oxide (lime) magnesium oxide (magnesia) and fireclays are used to manufacture refractory materials.

Zirconia - extremely high temperatures.

**ADVANTAGES**

a. Operate at high temperatures
b. high efficiencies
c. Low frictional losses
d. Operate without a cooling system
e. Lower weights than current engines

**FUTURE SCOPE**

This project focuses mainly on the individual performance of piston crown; a coupled analysis can be done with cylinder to obtain the performance of the engine as a whole. Different piston materials and coating materials can be tested. Coating surface is also an important factor which affects the work done and heat rejection in engine, but from the thermal barrier coating literature it was found that rough coating surface was best suited for better performance

**REFERENCES**

1. Vikrant Garud Dom Kunwar A.V., Dom Kunwar V.M., "A Course in Internal Combustion Engine. 2nd Revised Edition, 2006 Dhanpat Rai & Co., pp.1.1
2. Ekrem Buyukkaya "A Course in Internal Combustion Engine. 2nd Revised Edition, 2006 Dhanpat Rai & Co., pp.20.1-2.15
3. G. Sivakumar Mohit Gupta., "Design of Thermal Barrier Coatings" A modelling Approach, 2015 Springer International publishing pp. 17-32
4. Ravindra Gehlot, "Thermal analysis of holes created on ceramic coating for diesel engine piston", Case Studies in Thermal Engineering 8(2016) 291-299.
5. X Q Cao, R. Vassen, D. Stoever "Ceramic materials for thermal barrier coatings". Journal of the European Ceramic Society 24 (2004) 1-10.
6. Adnan Parlak, Halit Yasar, Can Hasimoglu, Ahmet Kolip " The effects of injection timing on NOx emissions of a low heat rejection indirect diesel injection engine". Applied Thermal Engineering 25 (2005) 3042-3052.
7. Serder Salman, Ramazan Kose, Levent Urtekin, Fehim Findik "An Investigatin of different ceramic coating thermal properties". Materials and Design 27(2006) 585-590.
8. Helmisyah Ahmad Jalaludin, "Experimental Study of Ceramic Coated Piston Crown for Compressed Natural Gas Direct Injection Engines", Procedia Engineering 68(2013) 505-511.