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# ANALYSIS OF CERAMIC COATING ON PISTON SURFACE WITH $SiO_2$ AND $ZrO_2$

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## ABSTRACT

*Aim of this report is to improve the efficiency, structural analysis of piston surface coated with ceramic layer. Generally aluminium alloy is used for piston material in I C engines and this material can withstand the structural, thermal analysis and power produced from the combustion of fuel. In this report the ceramic material like silicon and zirconium 0.4 mm thickness coating was applied on the surface of piston and test the coated surface using ansys software to analyze the structural analysis in order to get better results. The obtained results were deformation, stress, strain, safety factor and were comparable with the aluminium alloy.*

***Keywords: Ansys, Ceramic Coating, Piston, Structural Analysis.***

## I. INTRODUCTION

Today's generation I.C engines are playing very impotent role in an automobiles and mechanical machineries. The piston is a part of IC engine; it plays a vital role in almost all types of vehicles [1]. The main function of the piston of is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod [2]. And also disperse a large amount of heat from the combustion chamber to the cylinder walls. Cast iron, Aluminium Alloy and Cast Steel etc. are the common materials used for piston of an I.C Engine and to compare behaviour of the piston made of different type of materials under structural and thermal load [3]. The new composite material was primarily considered due to low hysteresis of the coefficient of thermal expansion for heating and cooling [4]. Piston skirt is the main area of the piston at which the deformation may appear usually it causes the crack on the upper end of piston head, due to this deformation, the greatest stress concentration is caused [5]. The existing piston is redesigned using Pro-E software and analyzed by ansys software. The coating of ceramic (magnesium oxide (MgO) and zirconium oxide (ZiO)) over existing aluminum alloy piston is done and behaviour is analyzed to improve the performance of the given engine [6]. The finite element results show that steel piston is showing maximum surface temperature than AlSi alloy piston, it is also observed from the results the surface temperature in uncoated piston is less than coated piston [7]. The maximum surface temperature of the coated piston with material which has low thermal conductivity has improved approximately by 14%. Because of reduced heat losses, efficiency will improve. According to the experimental results, brake thermal efficiency and indicated thermal efficiency have improved by 5.89% and 11.14% respectively [8]. The numerical simulations clearly show that temperature and thermal stress distribution are a function of coating thickness [9]. The maximum von mises stress in the piston crown is reduced with increase in bond coating thickness [10].

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## II. DESIGN PARAMETERS

In this work, we have design one piston model by using CAD tool (CATIA) and then imported into CAE tool (ANSYS). To change the design of the piston by adding additive like $SiO_2$ and $ZrO_2$ 0.4 mm thickness ceramic layer on the top surface of piston and applied 6 MPa pressure and analyzed the results using ANSYS.

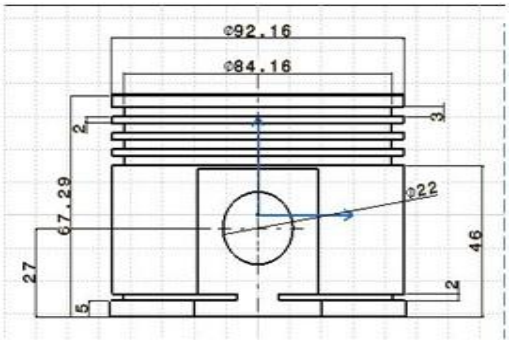


Fig.1. Piston Dimensions

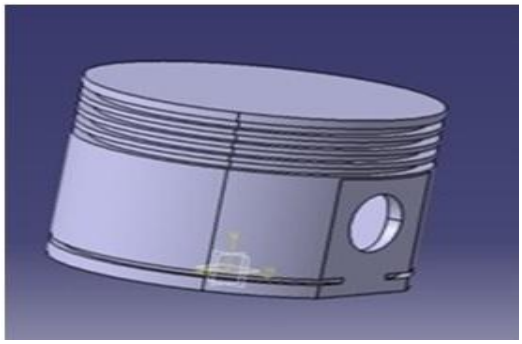

Fig.2. 3D Model of Piston

| Material | Young's modulus (Pa) | Poisson ratio | Density ($Kg/m^3$) | Yield strength (MPa) | Conductivity (W/m.k) |
|---|---|---|---|---|---|
| Aluminium alloy | $71.1 \times 10^9$ | 0.33 | 2770 | 280 | 160 |
| Zirconia($ZrO_2$) | $94.5 \times 10^9$ | 0.33 | 6530 | 280 | 2 |
| Silica($SiO_2$) | $74.8 \times 10^9$ | 0.19 | 2650 | 155 | 1.5 |

## III.STRUCTURAL ANALYSIS

ANSYS is the standard finite element analysis (FEA) software tool. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solve them all, this type of analysis is typically used for analyze the structural analysis as follows.

**Table.1. Properties of Aluminium Alloy**

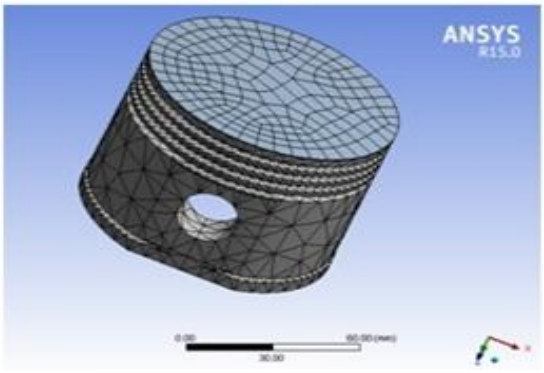


**Fig.3. Finite Element**

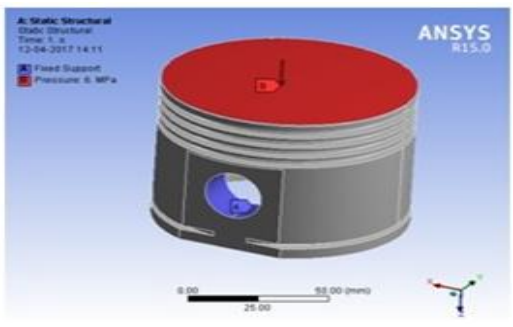


**Fig.4. Fixed supports on**

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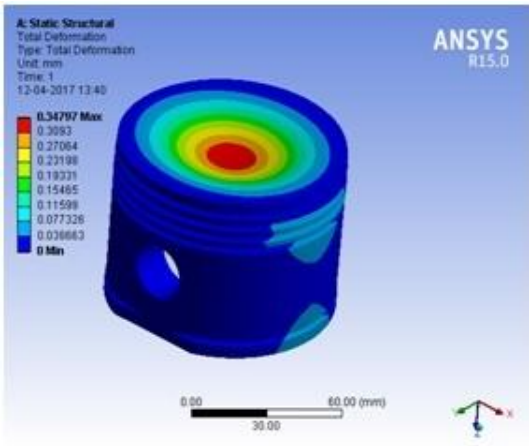


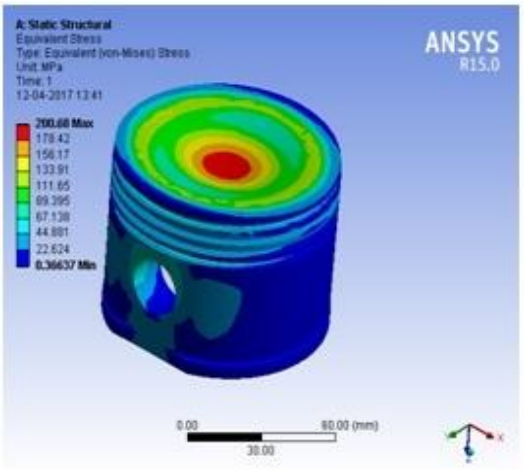


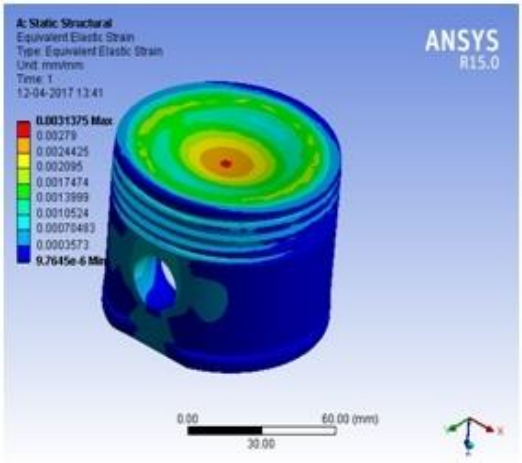


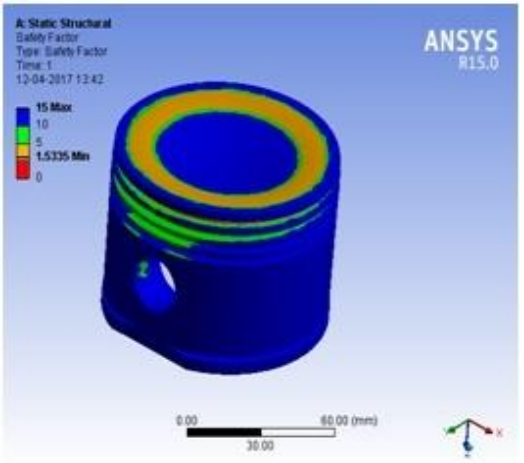


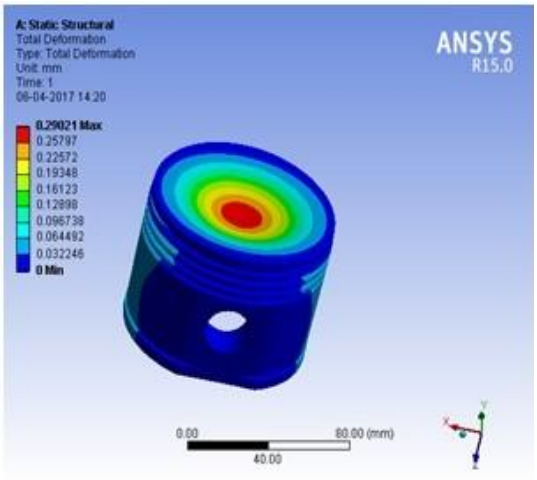


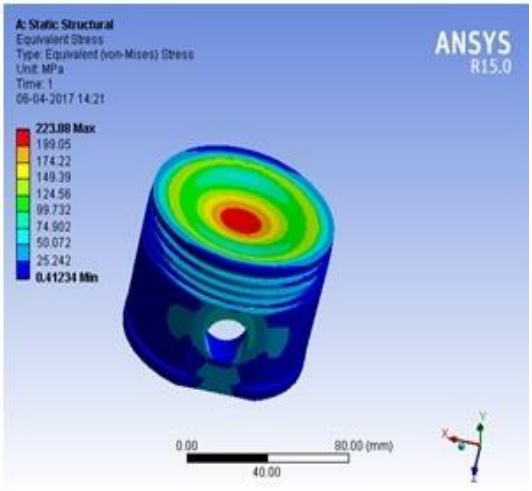

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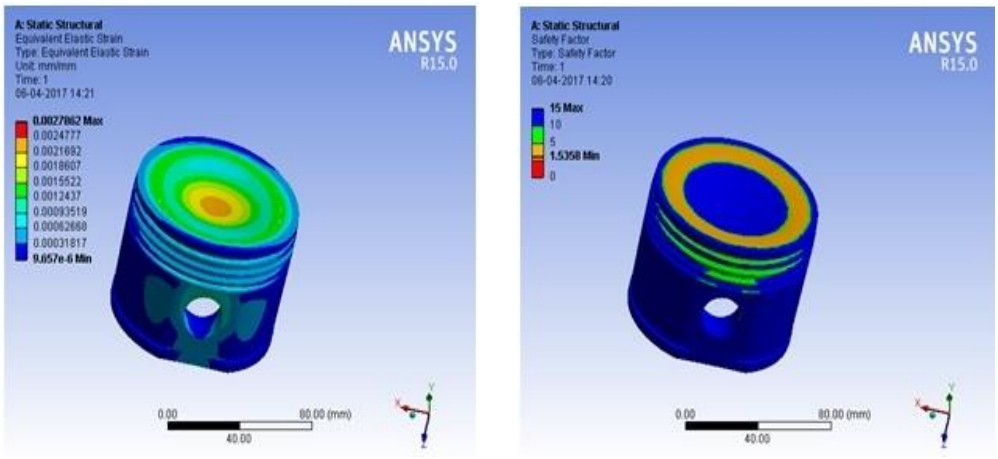


Fig.6. Structural analysis of Aluminium Alloy with $ZrO_2$ Material

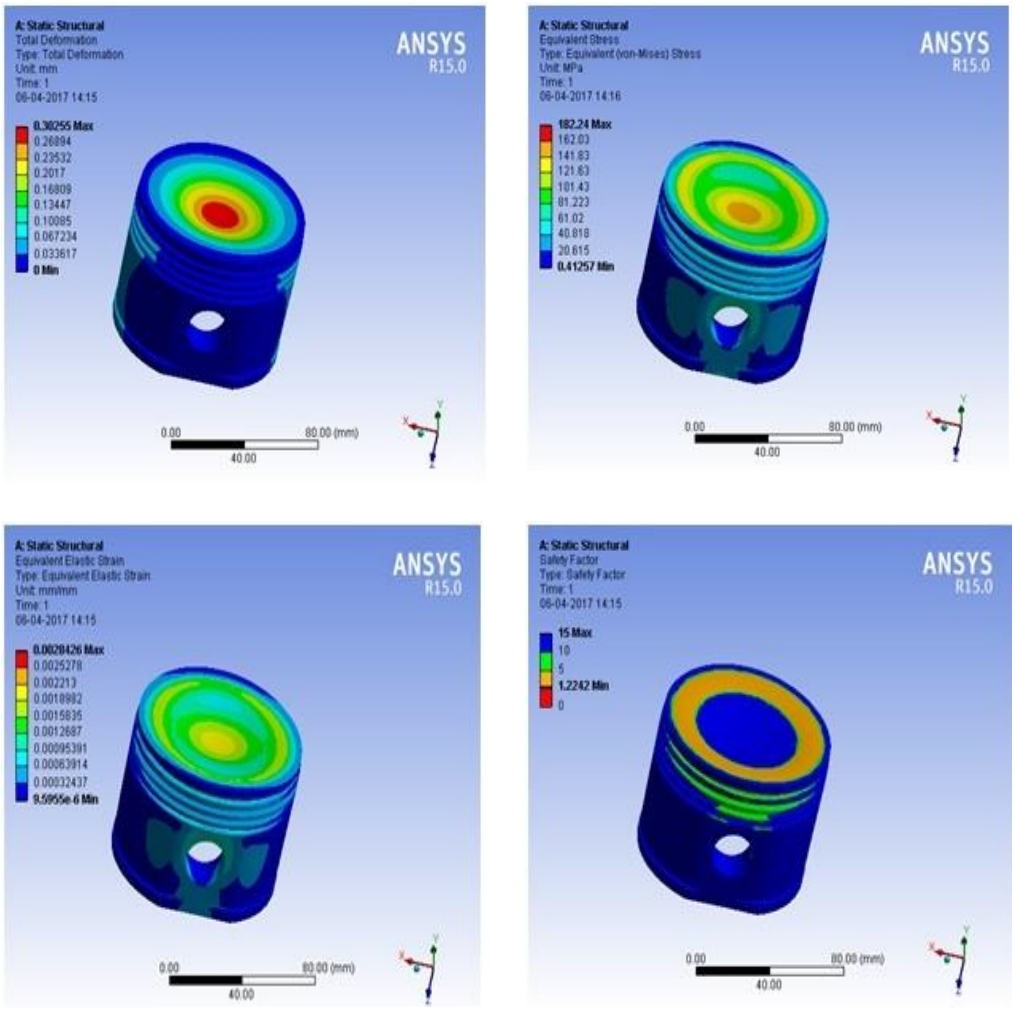


Fig.7. Structural analysis of Aluminium Alloy with $SiO_2$ Material

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## IV. RESULTS AND CONCLUSION

| Aluminium Alloy Coated with Ceramic Material | | | | |
|---|---|---|---|---|
| **Material** | **Deformation (mm)** | **Stress (MPa)** | **Strain** | **Safety Factor** |
| Al-alloy | 0.34797 | 200.68 | 0.0031375 | 1.5335 |
| Al-$ZrO_2$ | 0.29021 | 223.88 | 0.0027862 | 1.5358 |
| Al-$SiO_2$ | 0.30255 | 182.24 | 0.0028426 | 1.2242 |

Using ANSYS software the structural analysis of aluminium alloy coated with $ZirO_2$ and $SiO_2$ has been carried out as shown in table below.2.

From the above table Deformation, Stress, Strain and Safety Factor were analyzed. It is observed that the values of Stress and Safety Factor are lower in Al-$SiO_2$.and higher in Al-$ZrO_2$ as compare to Aluminium Alloy.

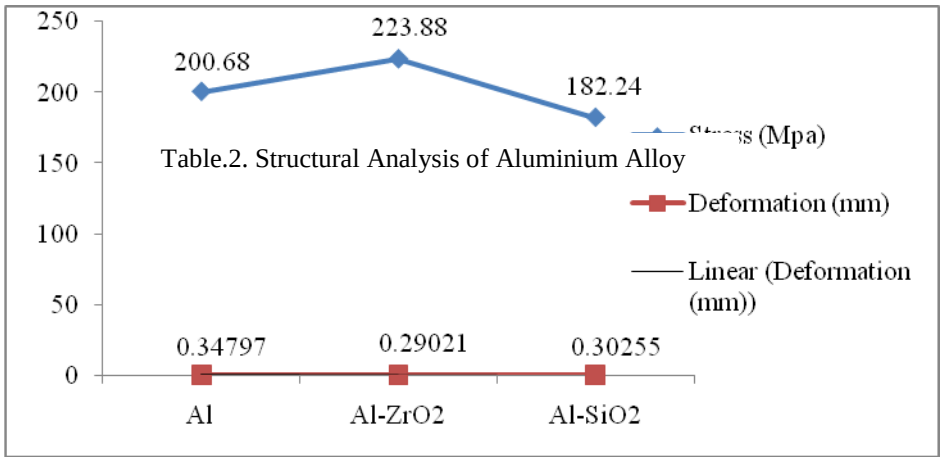


Table.2. Structural Analysis of Aluminium Alloy

**Fig.8. Material Vs Stress and**

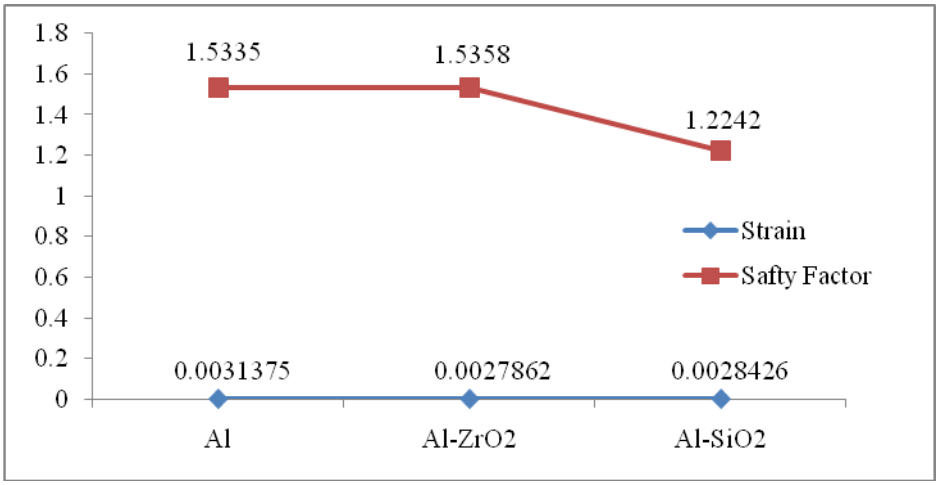


**Fig.9. Material Vs Strain and Safety**

From the above graph it is observed that the stress is higher in A1-$ZrO_2$ and lower in A1-$SiO_2$. Safety Factor is higher in Aluminum Alloy and lower in Al-$SiO_2$, Strain and Deformations in A1-$ZrO_2$ and A1-$SiO_2$ are closer to the Aluminium Alloy.

## V. CONCLUSIONS

- In this work a 3D model Piston has been designed, developed and analyzed.
- In static conditions when we applied 6Mpa pressure, on existing piston (Aluminium Alloy) produced 200.68MPa by changing design and by coated with $SiO_2$ is reduced to 182.24 Mpa and coated with $ZrO_2$ increases to 223.88 MPa.
- 18.44 Mpa Stress has been reduced by coated with $SiO_2$ on surface of piston.
- Strain and Deformations in A1-$ZrO_2$ and A1-$SiO_2$ are closer to the Aluminium Alloy.
- We conclude that the Aluminium Alloy coated with $SiO_2$ will satisfy the static conditions and it increases the piston efficiency.

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