INFLUENCE OF CERAMIC COATING ON PISTON SURFACE IN I.C ENGINE

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ABSTRACT

Aim of this work is to improve the structural analysis coated with ceramic layer on surface of the piston. Generally cast steel material is used for piston in I C engines; it can be withstanding the structural and thermal analysis, and producing the power from the combustion. In this work the ceramic material like zirconium and silicon coating is applied on the surface of piston with 0.4 mm thickness in order to get better results and testing the piston using ansys software analyze the structural analysis. The results obtained in this work were deformation, stress, strain and safety factor, the obtained results were comparable with the steel material.

Keywords: Piston, Ceramic Coating, Ansys, Structural analysis.

I. INTRODUCTION

Now days, internal combustion engines are used in most of the automobiles and mechanical machineries. The piston is a part without which no internal combustion engine can work i.e., piston plays a vital role in almost all types of vehicles [1]. The main function of the piston of an IC engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod [2]. The piston must 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 Internal Combustion Engine and to compare behaviour of the piston made of different type of materials under 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]. The piston skirt is the main area of the piston at which the deformation may appear while at work, which usually causes crack on the upper end of piston head. Due to this deformation, the greatest stress concentration is caused on the upper end of piston [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 for selected boundary conditions and coatings. It is due to lower thermal conductivity of steel material than AlSi material. 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].

II. DESIGN PARAMETERS

In this work, we have design one piston model by using CAD tool (CATIA) and then imported into CAE tool (ANSYS). We selected steel and additives to the steel material. 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.

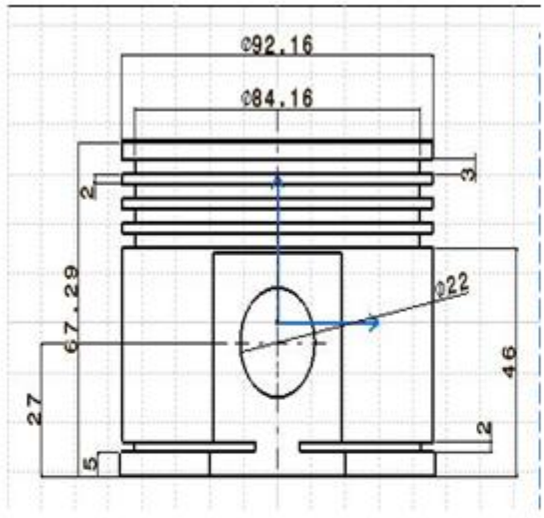


Fig.1. Dimensions of reference piston

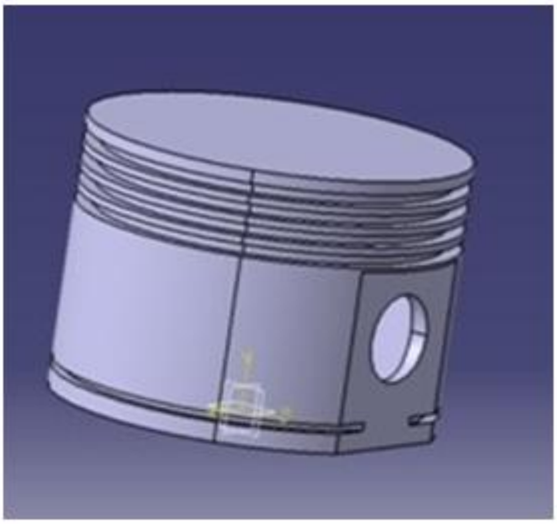


Fig.2. 3D model of piston

Table.1. Properties of Steel Material

Material	Young's modulus (Pa)	Poisson ratio	Density (Kg/m^3)	Yield strength (MPa)	Conductivity (W/m.k)
Steel	2.0 x 10^{11}	0.3	7850	250	60.5
Zirconia(ZrO_2)	94.5 x 10^9	0.33	6530	280	2
Silica(SiO_2)	74.8 x 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.

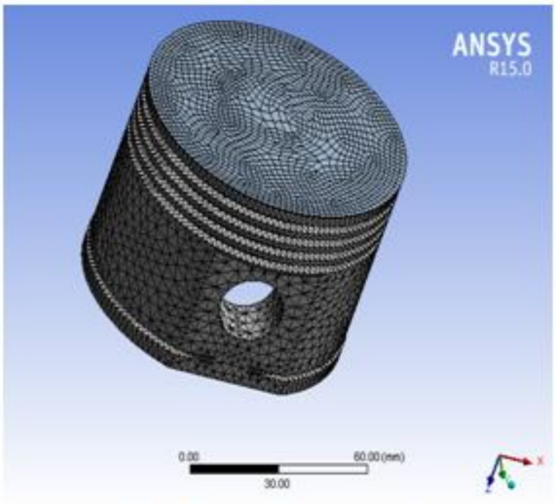


Fig.3. Finite element Analysis

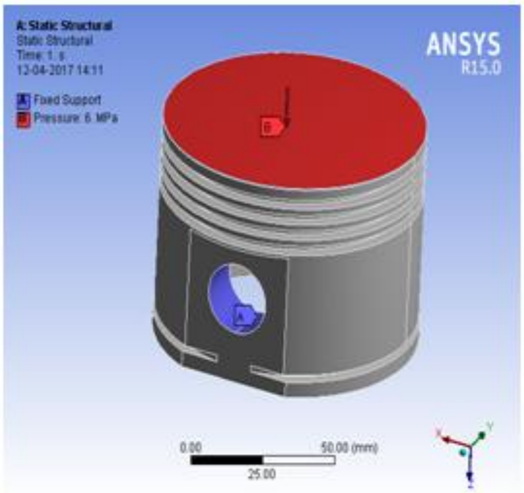


Fig.4. Fixed supports on piston

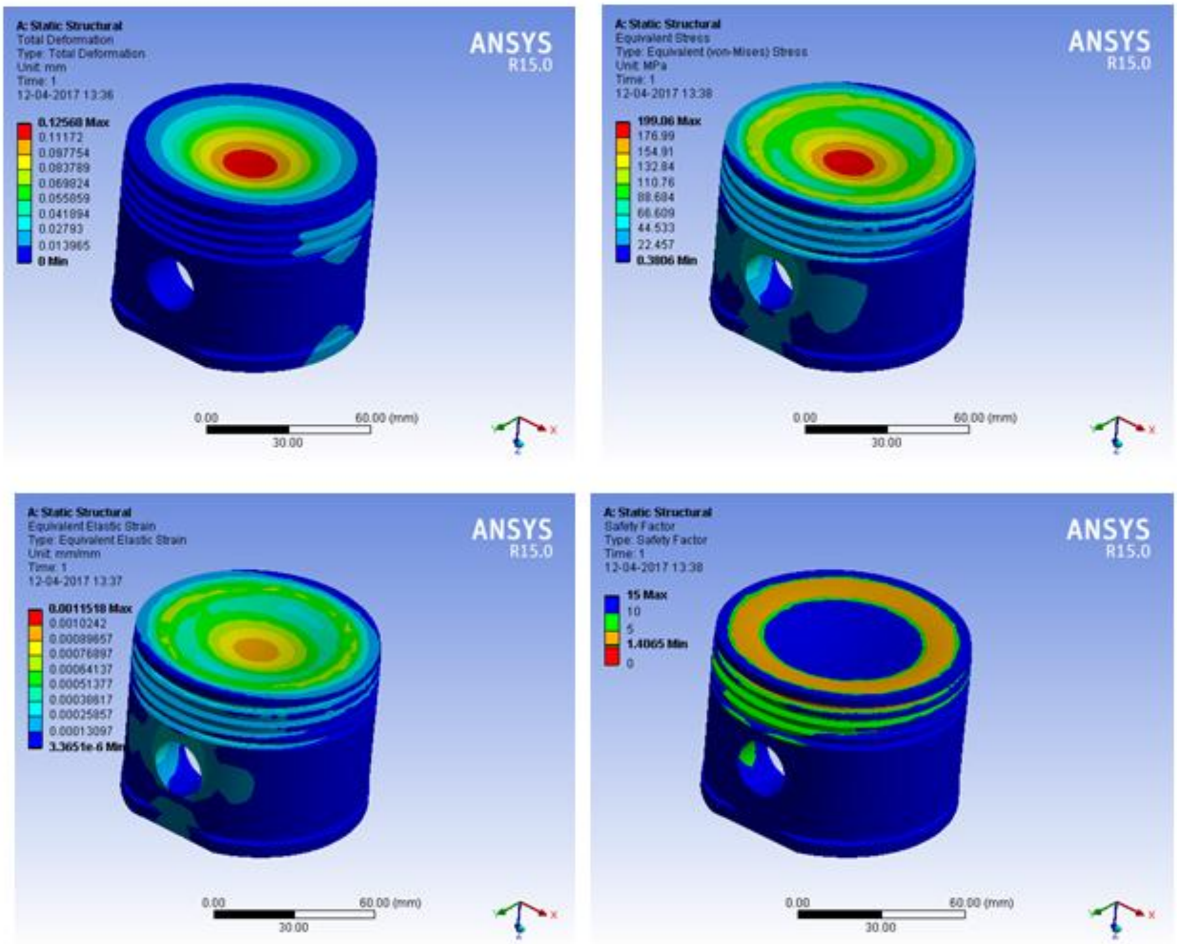


Fig.5. Structural analysis of Steel Material

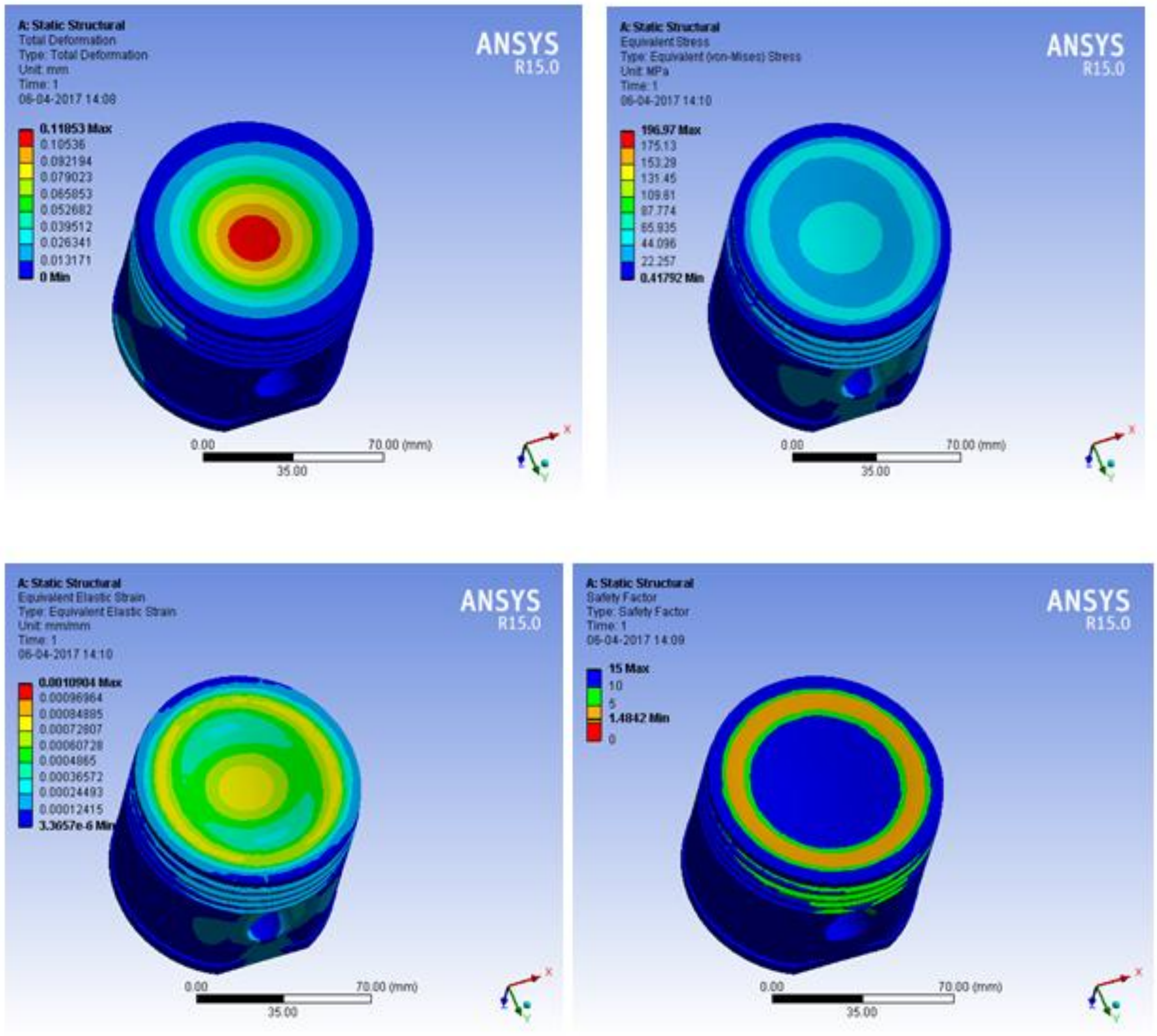
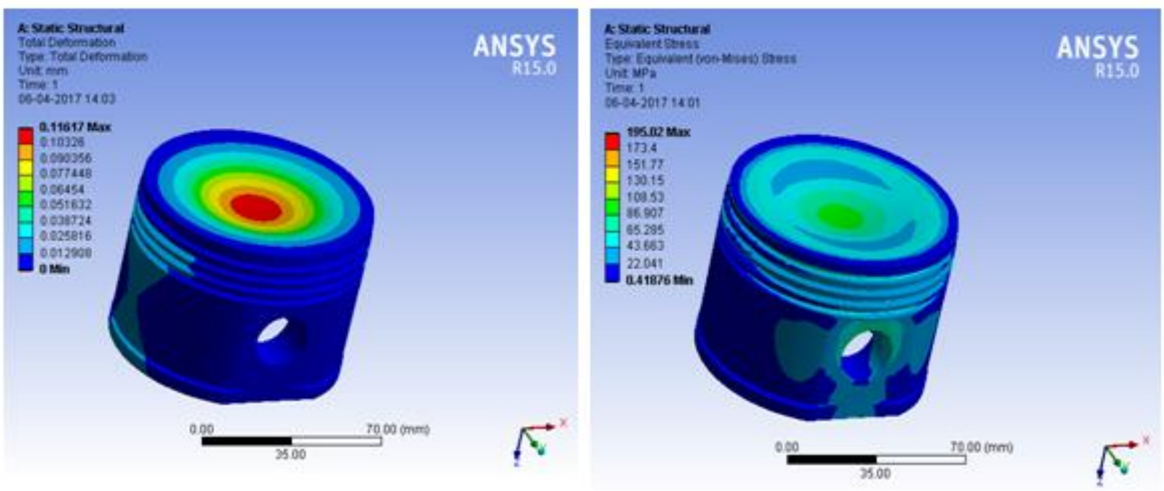


Fig.6. Structural Analysis of Steel coated with SiO_2



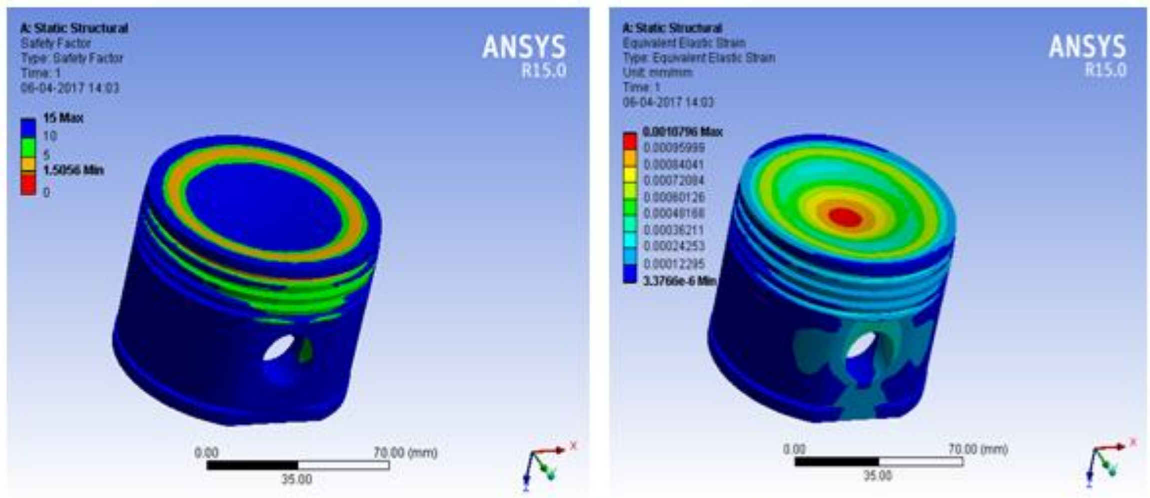


Fig.7. Structural Analysis of Steel coated with ZrO_2

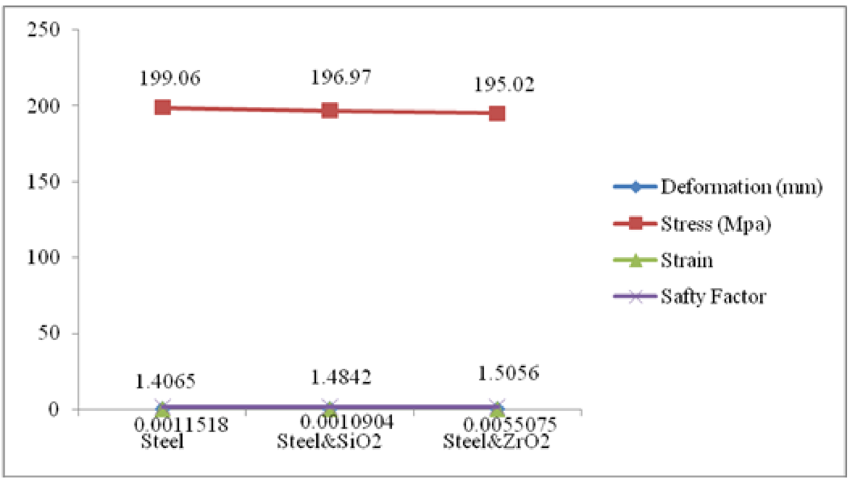
IV. RESULTS AND CONCLUSION

Using ANSYS software the structural analysis has been carried out as shown in table below.

Steel				
Material	**Deformation (mm)**	**Stress (MPa)**	**Strain**	**Safety factor**
Steel	0.11397	199.06	0.0011518	1.4065
Steel-SiO_2	0.11853	196.97	0.0010904	1.4842
Steel-ZrO_2	0.11617	195.02	0.0055075	1.5056

Table 2.Structural Analysis of steel and its alloy

From the above table the analyses like deformation, stress and strain are nearly closer to the steel and safety factor is higher than the steel.



From the above graph it is observed that the stress factor of SiO_2 and ZrO_2 are lower than the Steel. Deformation, Strain and safety factor of SiO_2 and ZrO_2 values are nearly closer to the steel value.

V. CONCLUSIONS

- In this work a 3D model Piston has been designed, developed and analyzed by adding additives.
- In static conditions when we applied 6Mpa pressure, on existing piston (steel) produced 199.06MPa by changing design and by adding SiO_2 and ZrO_2 coating and reduced to 195.02Mpa.
- 4Mpa stress has been reduced by coating with SiO_2 and ZrO_2 0.4 mm thick layer on surface of piston.
- Finally we conclude that the **Steel** with SiO_2 and ZrO_2 ceramic coated piston will satisfy the static conditions and it increases the piston efficiency.

REFFERENCES

[1]. Nagarjuna.Jana, K.Komali "Design and Analysis on a Ceramic Coated Diesel Engine Piston using ANSYS" (IJSETR)- ISSN 2319-8885 Vol.04(1), 2015, pp.0016-0019

[2]. Vinod Kumar Yadav, Yogesh Mishra "Design and Structural Analysis of Ceramic Coated Petrol Engine Piston Using Finite Element Method" Int. J. Innovative Research in Science, Engineering and Technology, Vol. 4(6), 2015.

[3]. S.Sathyamoorthi, M.Prabhakaran, S.A.Muhammed Abraar "Numerical investigation of ceramic coating on piston crown using Finite Element Analysis" International Journal of Scientific Engineering and Applied Science (IJSEAS) – Vol.2(4), 2016,pp.2395-3470

[4]. Narsaiyolla Naresh, (M.Tech), P.Sampath Rao, M.Tech,(PhD)"Structural Analysis of a Ceramic Coated Diesel Engine Piston Using Finite Element Method" SSRG International Journal of Mechanical Engineering, Vol.1(5).

[5]. R.Silambarasan, S.Balakrishnan , A.Selvarasu have written a paper on "Design and thermal analysis of partial ceramic coated piston of spark ignition (SI) Engine" International Advanced Research Journal in Science, Engineering and Technology, Vol. 2(4)..

[6]. Ravinder Reddy Pinninti have written a paper on "Temperature and Stress Analysis of Ceramic Coated Sic-Al Alloy Piston Used in a Diesel Engine Using FEA" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4(8),2007.

[7]. Telkar Mahesh1 Sunil Kumar2 V.Vinay3 P.Saisrikanth Goud4 have written a paper on "Temperature and Thermal Stress Analyses of a Ceramic-Coated Aluminium Alloy Piston in a Diesel Engine" IJSRD || National Conference on Recent Trends & Innovations in Mechanical Engineering || April 2016, pp.2321-0613.

[8]. Ravinder Reddy P., Ramamurthy G., "Computer Aided Analysis of Thermally Air Gap Insulated Pistons made of Composites", National Conference on Machines and Mechanisms (NACOMM-95), Jan 20-21, 1995, pp. 177-180, CMERI, Durgapur.

[9]. K. BalaShowry, A.V.S. Raju, P. Ravinder Reddy, "Multi-Dimensional Modeling of Direct Injection Diesel Engine and Effects of Split Injection", International Journal of Scientific and Research Publications, Vol. 2(1), 2012, pp. 1-8.

[10]. Pradeep Halder, Edla Franklin, Dr. P. Ravinder Reddy, "Combustion and Mixing Analysis of a Scramjet Combustor Using CFD", International Journal for Scientific Research & Development (IJSRD),Vol. 2(9), 2014, pp.27-33.

[11]. Dr. K. BalaShowry, Dr. P. Ravidrer Reddy, "Reducing Particulate and NOX Emissions by Using Split Injection", International Journal of Science and Research, Vol. 4(3),2015.

[12]. T.M. Yonushonis, "Overview of thermal barrier coatings in diesel engines", J. Therm. Spray Technol. Vol. 6, 1997, pp.50-56.

[13]. M. Cerit, "Thermo mechanical analysis of a partially ceramic coated piston used in an SI Engine", Surf. Coat. Technol, Vol. 205, 2011, pp.3499-3505.

[14]. E. Buyukkaya, "Thermal analysis of functionally graded coating AlSi alloy and steel pistons", Surf. Coat. Technol. Vol. 202,2008, pp.3856-3865.

[15]. E. Buyukkaya, M. Cerit, "Thermal analysis of a ceramic coating diesel engine piston using 3D finite element method", Surf. Coat. Technol. Vol. 202, 2007, pp.398-402.

[16]. H.W. Ng, Z. Gan, "A finite element analysis technique for predicting as-sprayed residual stresses generated by the plasma spray coating process", Finite Elem. Anal. Des. Vol. 41, 2005, pp.1235-1254.

[17]. E. Buyukkaya, A.S¸ Demirkıran, M. Cerit, "Application of thermal barrier coating in a diesel engine", Key Eng. Mater. 264e268 ,517e520,2004

[18]. E. Buyukkaya,M. Cerit, "Experimental study of NOx emissions and injection timing of a low heat rejection diesel engine", Int. J. Therm. Sci. Vol. 47,2008, pp.1096-1106.

[19]. A. Parlak, V. Ayhan, "Effect of using a piston with a thermal barrier layer in a spark ignition engine", J. Energy Inst. Vol. 80, 2007, pp. 223-228.

[20]. E. Buyukkaya, T. Engin, M. Cerit, "Effects of thermal barrier coating on gas emissions and performance of a LHR engine with different injection timings and valve adjustments", Energy Conv. Manage. Vol. 47,2006, pp. 1298-1310.

[21]. M. Cerit, V. Ayhan, A. Parlak, H. Yasar, "Thermal analysis of a partially ceramic coated piston: effect on cold start HC emission in a spark ignition engine", Appl. Therm. Eng. Vol. 31 (3), 2011, pp.336-341.