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INVESTIGATION OF APPROPRIATENESS OF COATED STEEL PISTON FOR ALUMINIUM ALLOY PISTON FOR SMALL ENGINES

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Abstract

Materials substitution is imperative research area. The aim of those research are may be the cost reduction, improved performance on its physical, chemical or mechanical properties like improved strength, reduced weight or in terms of performances. The objective of this paper is to investigate the possibilities to use the steel piston in place of the aluminium alloy piston for small engine applications like portable generator. Aluminium alloy piston, uncoated steel piston, nickel coated steel piston and hard chrome coated steel piston considered. Steel pistons plated standard thickness and physically experimented. The thermal analysis like thermal deformation, total and directional heat flux analysis were carried out in ANSYS software. For the outperformed piston the CFD analyses on contoured particles carried out with help of ANSYS Fluent software. The CFD analysis on contoured particles includes the static pressure, velocity as well as directional velocity components and path line of contoured particles.

I INTRODUCTION

Computer aided design and analysis and Computational Fluid Dynamics (CFD) play vital role engineering in particularly in new design, finding alternate materials and analysis of failures etc. Some cases are: [1] using ANSYS to investigate the steady-state temperature analysis, transient temperature, and static structural analysis of an aluminium alloy, Al-4032 piston. [2] investigated the influence of nickel coated piston which increases the efficiency as well as wear resistance. [3] using ANSYS to improve the thermal performance of the piston different Thermal Barrier Coatings (TBC) have been imposed and their thermo mechanical performance have been evaluated through couple-field analysis in ANSYS. Recently automotive industries are used the simulation results by CFD for optimization and development of new engines for their cars [4]. [4] conducted combustion analysis by means of CFD with the piston for a diesel engine uncoated and platinum coated pistons. [5] coated the surface of the ZS1115 piston with tungsten carbon-nitride (WCN) by PVD method for diesel engine applications. They achieved by WCN coating on ZS1115 piston that rapid increase of hardness from 1.2 to 33GPa and reduced total wear volume from 9153 to 113.0 mm^3. [6] Studied the friction and wear behaviour of piston skirt coatings such as standalone Mn-P coating and polymer-graphite composite coating with a manganese phosphate (Mn-P) interlayer in diesel engine piston. The polymer-graphite coating caused a higher wear rate, than standalone Mn-P coating. Lin et al [7] used TiSiCN Nano-composite coatings for piston ring and achieved the 18% frictional loss, weight loss less 28% in top ring and 40% lower second ring than uncoated piston rings. [8] Used finite element method by using ANSYS for carried out thermal analysis on the Yttria-stabilized Zirconia ceramic coated on Al–Si piston with holes of radius 1.5, 2. And 2.5 mm on its surface. The experiment resulted that maximum temperature distribution at highest hole radius of 2.5 mm and the substrate temperature decreased with increase of the hole's radius. In this research focuses the investigation of possibilities of alternate material for aluminium alloy piston as steel piston. In this regard the steel uncoated piston, steel with nickel coated piston and steel with hard chrome coated pistons considered. The numerical analysis by using ANSYS for Thermal Analysis, ANSYS Fluent for CFD analysis preferred. [9] using Yttria-stabilized zirconia was used for the top coat and NiCrAl alloy was used for the bond coat which decreasing the temperature of the substrate reduced thermal fatigue while increasing the temperature of the top surface reduced fuel consumption thus leading to an overall improvement in performance. [10] Determine the structural behaviour of the partially ceramic coated piston

II MATERIALS AND METHODS

Coating on the material generally employed in engineering components to improve their properties either to enhance resistance to abrasion and corrosion or to improve the triboligical properties and aesthetic qualities or add make up undersized parts etc. Here it is preferred for improving surface quality of the piston.

Sample Preparation & Testing

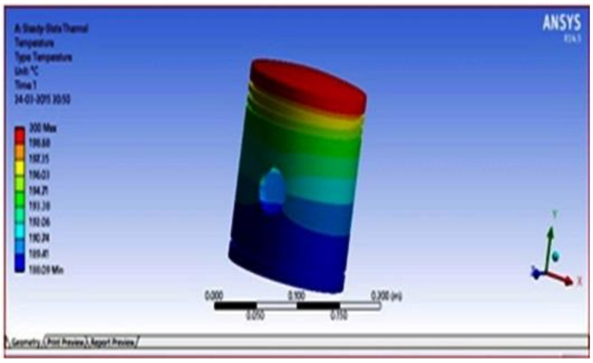
For performing the nickel coating on the first sample steel piston, the electro-plating method is employed. The set up preferred with semi-bright bath composition. In the 2^{nd} steel piston sample, as the piston is a component in wear applications the thinner deposition was preferred to increase the life, corrosive resistance of the piston. The Hard chrome is cold process (Temperature range 50-60^{O}C) was preferred. The coated pistons were under gone to chemical & type of coating test (ASTM E 415-2014) in XRF analyser. The OES- Foundry master-Pro, Oxford, Germany was employed for the above test. The coated pistons confirmed to BS970 with respect to the tested parameters concerned. The uncoated aluminium also tested for OEM surface quality by Chemical- OES (ASTM E 1251 -2011). The piston sample confirmed to IS 733 Gr.63400 with respect to the tested parameters concerned. Apart from the some mechanical properties considered for modelling and analysis (refer Table 1). The average coating thickness of semi-bright nickel coating as well as hard chrome coating is 12.6 microns.

Table 1. The piston materials and their properties

Sl.No	Piston Material	Thermal Conductivity (W/mK)	Young's Modulus (GPa)	Poisson Ratio
1	Steel (Steel UC)	57	68.3	0.34
2	Steel with semi-bright Nickel Coated (Steel NC)	35	165	0.21
3	Steel with Hard Chrome Coated (Steel CC)	24	205	0.30
4	Aluminium Alloy (AA UC)	25	230	0.24

Modelling and Analysis

The modelling and analysis were carried out for each piston case by using ANSYS R14.5 software. The thermal deformation, total heat flux, heat flux in X, Y and Z directions were considered as measure of performances in the first part. The details are illustrated by screen shots from Figure 1 to Figure 5 for uncoated steel piston. The Figure 6 to Figure 10 are for Steel piston with semi-bright Nickel Coated, the Figure 11 to Figure 15 for Steel piston Hard Chrome Coated and the Figure 16 to Figure 20 are for Aluminium Alloy piston.



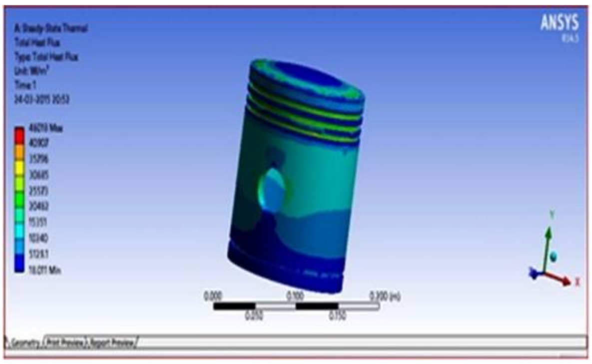
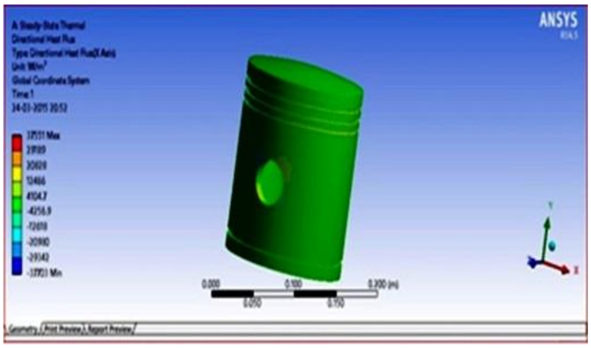


Fig.1. Thermal Deformation Analysis on Steel UC Piston

Fig. 2. Total Heat Flux on Steel UC Piston



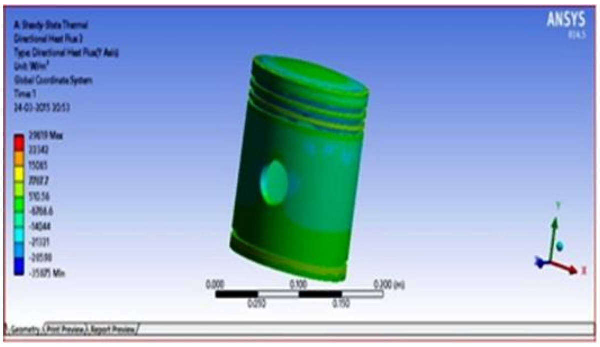
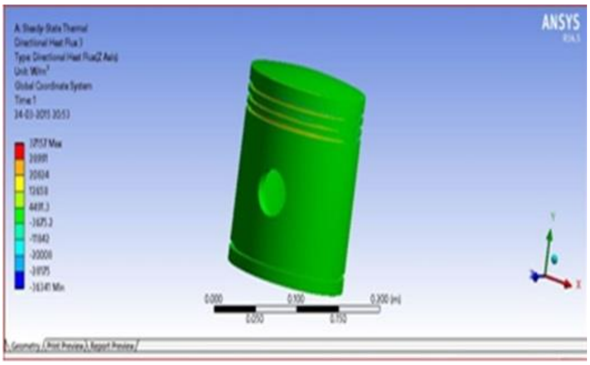


Fig.3. X - Directional Heat Flux on Steel UC Piston

Fig.4. Y - Directional Heat Flux on Steel UC Piston



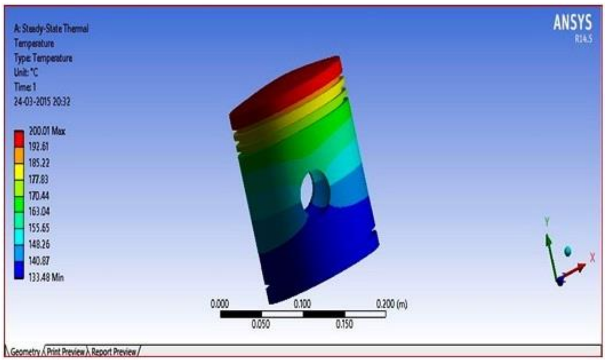
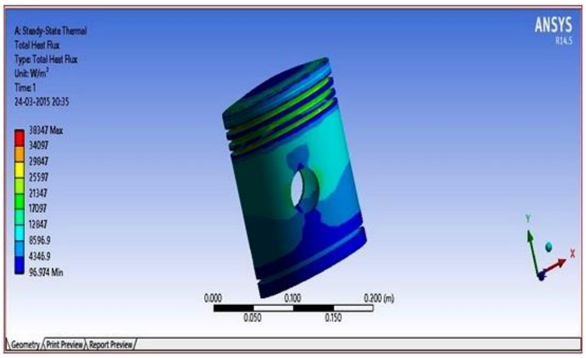


Fig.5. Z -Directional Heat Flux on Steel UC Piston

Fig.6.Thermal Deformation Analysis on Steel NC Piston



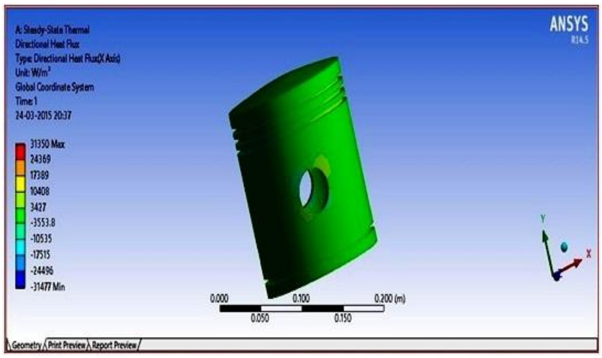
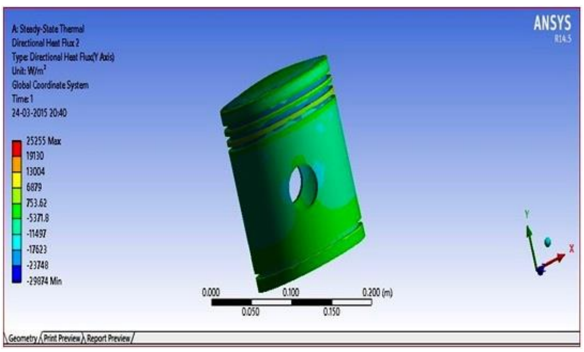


Fig. 7: Total Heat Flux on Steel NC Piston

Fig.8. X - Directional Heat Flux on Steel NC Piston



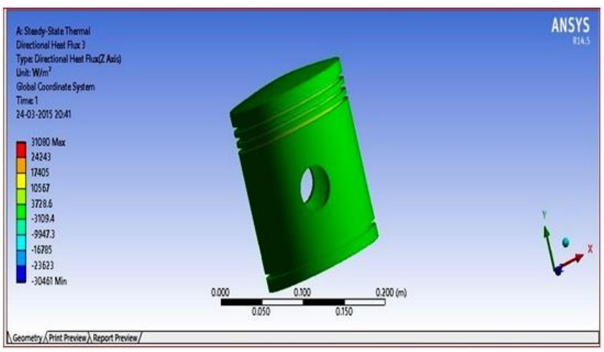


Fig.9. Y - Directional Heat Flux on Steel NC Piston

Fig.10. Z - Directional Heat Flux on Steel NC Piston

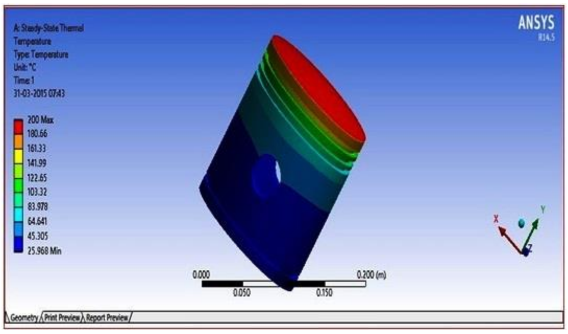


Fig.11. Thermal Deformation Analysis on Steel CC Piston

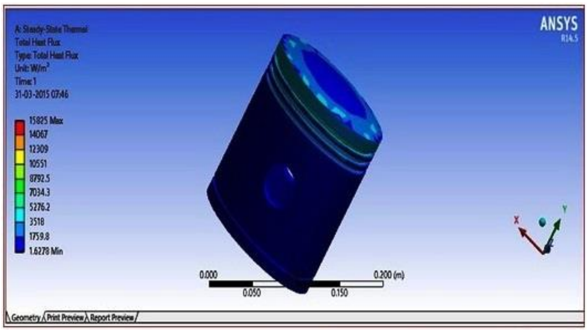


Fig.12: Total Heat Flux on Steel CC Piston

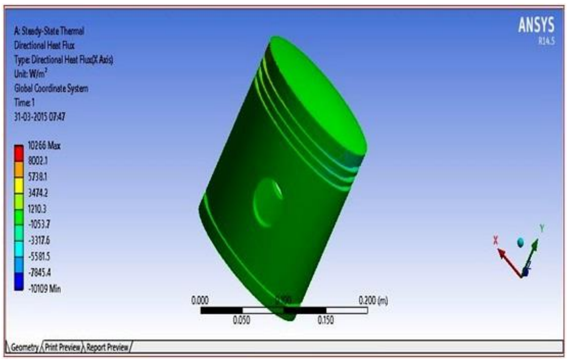


Fig.13. X - Directional Heat Flux on Steel UC Piston

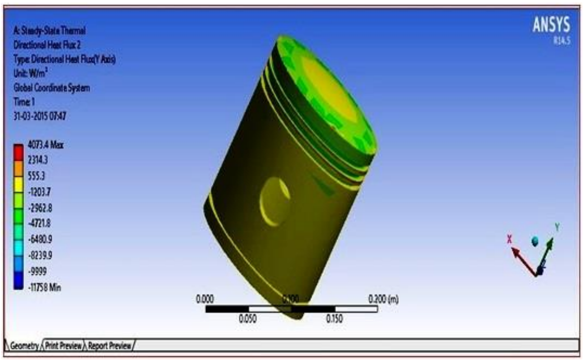


Fig.14. Y - Directional Heat Flux on Steel CC Piston

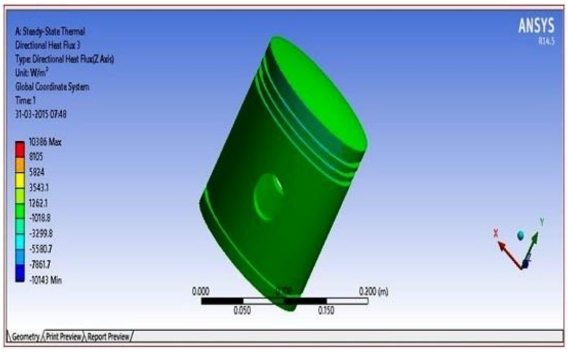


Fig.15. Z - Directional Heat Flux on Steel CC Piston

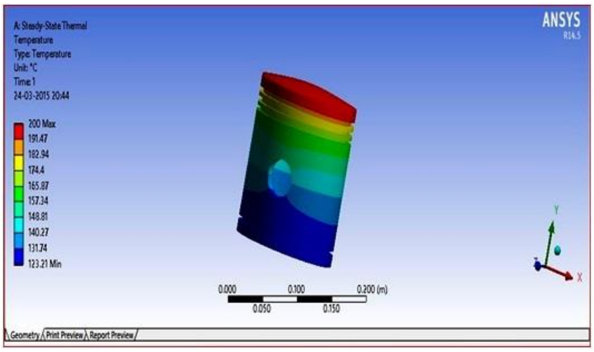


Fig.16. Thermal Deformation Analysis on AA UC Piston

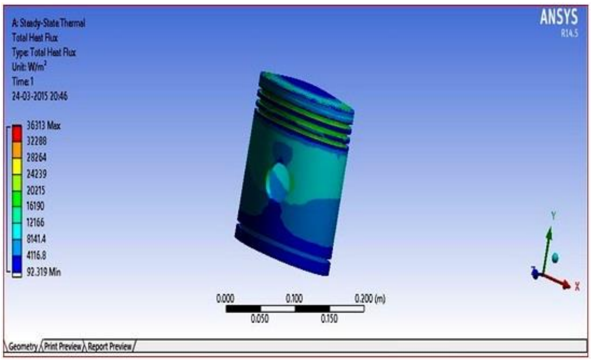


Fig. 17: Total Heat Flux on AA UC Piston

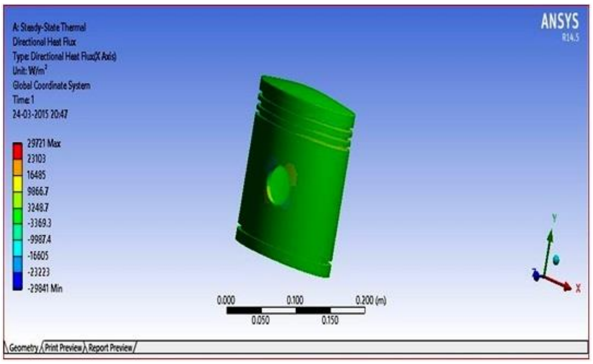


Fig.18. X - Directional Heat Flux on AA UC Piston

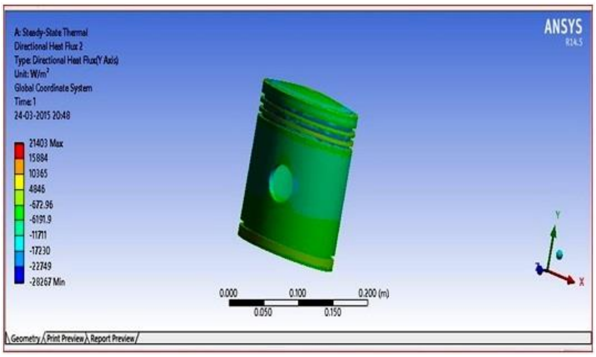


Fig.19. Y - Directional Heat Flux on AA UC Piston

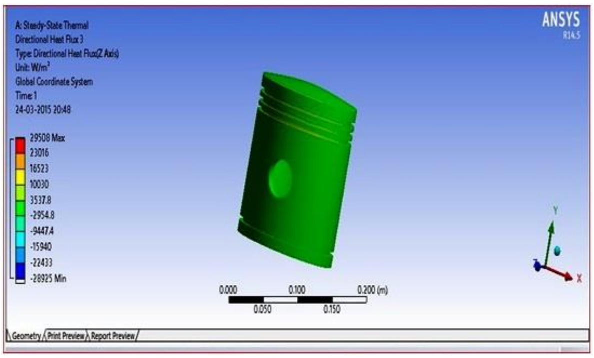


Fig.20. Z - Directional Heat Flux on AA UC Piston

III RESULTS AND DISCUSSION

The thermal analysis results were consolidated and presented in the Table 2. The comparison of thermal deformation and Directional heat fluxes with respect to the piston illustrated in the Figure 21. The steel piston with hard chrome coated suffered by less heat flux in all three directions as well as the total heat flux. Hence the thermal stability is more than other kind of pistons. Apart from this for that hard chrome coated steel piston CFD analysis like static pressure, directional velocity compounds (X,Y and Z), Velocity magnitude and path lines of contoured particles were carried out with ANSYS Fluent 14.5. The same was depicted from the Figure 22 to Figure 27 as above said order. The results are found satisfactory. On other hand of Numerical analysis the actual performance was evaluated. According actual testing statistics that thermal efficiency is increased by 3.8% than, that is the performance of the engine is increased and it is expected that the piston cracks will be deduced. The cost of coating and coating materials are less compared to gain of life time.

Table 2. Consolidate Results of Thermal Analysis

Analysis Criteria	Piston Type			
	Steel UC	Steel NC	Steel CC	AA UC
Total Heat Flux	46018	38347	15825	36313
X- Directional Heat Flux (W/Sq.m.)	37551	31350	10266	29721
Y- Directional Heat Flux (W/Sq.m.)	29619	25255	04073	21403
Z- Directional Heat Flux (W/Sq.m.)	37157	31080	10386	29508

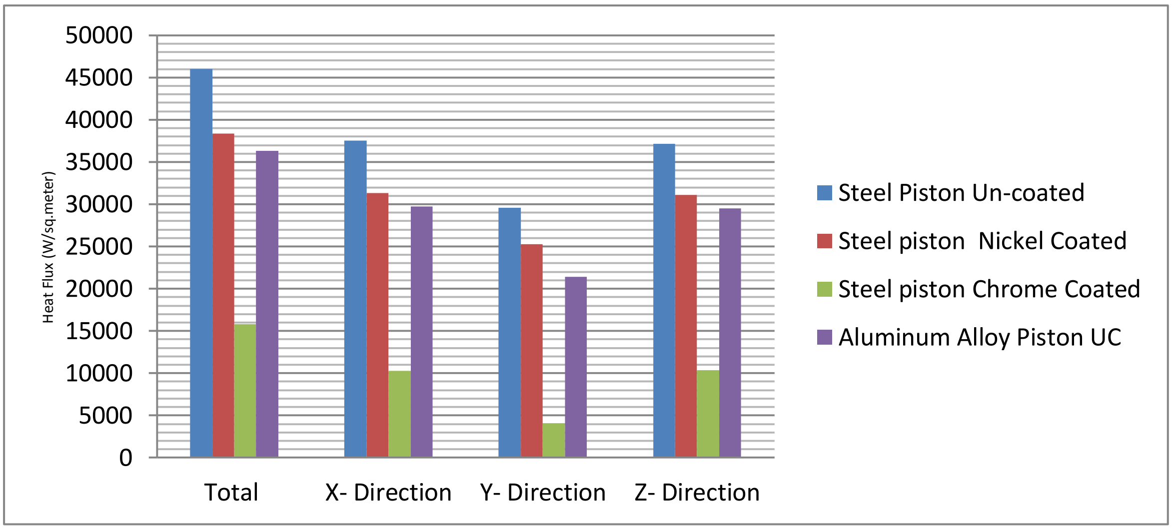


Figure 21 Comparative Results of Thermal Analysis

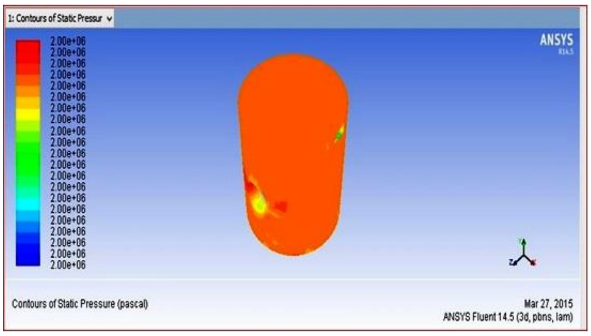


Figure 22. Static Pressure analysis on Contoured particles

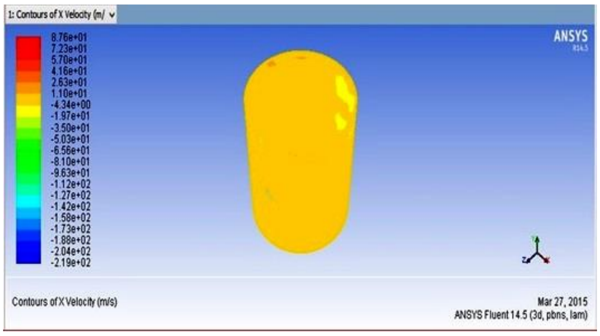


Figure 23 X directional Velocity Components on Contoured particles

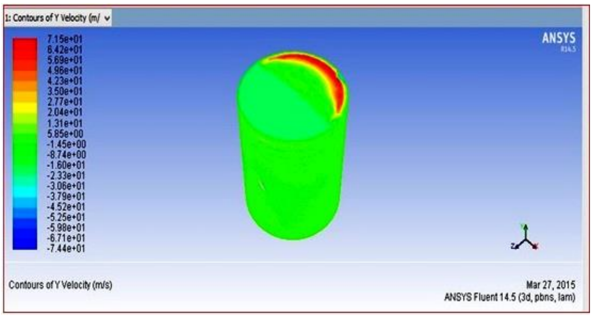


Figure 24 Y- directional Velocity Components on Contoured particles

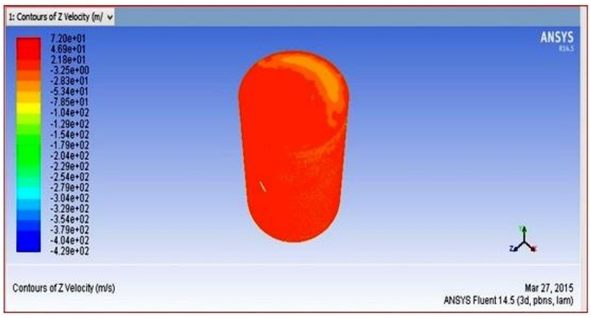


Figure 25 Z- directional Velocity Components on Contoured particles

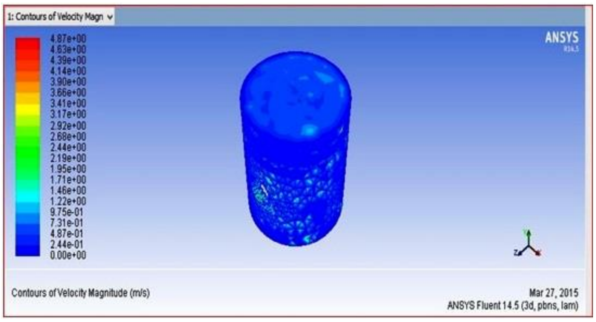


Figure 26 Total Velocity of particles at contour

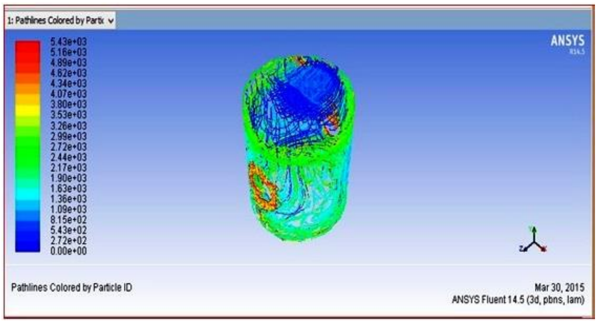


Figure 27 path-lines of particles at contour

IV CONCLUSION

The piston of small types which applications like Honda generators is considered in this paper. Replacement of aluminum alloy piston with steel reduces the cost. Hence in this work the uncoated steel piston, Nickel coated steel piston, Hard Chrome coated steel piston and Aluminum alloy steel pistons were considered. The thermal analysis results reveal that steel piston which hard chrome coated thermally more stable than others especially aluminum alloy piston. So hard chrome coated steel piston further analyzed by CFD in terms of static pressure, directional velocities, velocity magnitude and path lines of contoured particles of the piston. The results are found satisfactory. Hence it is recommended that the aluminum alloy piston for small applications can be replaced by hard chrome coated steel piston.

REFERENCES

1. Kumar C, Singh NK, (2018), 'Structural and thermal analysis of an I.C. Engine piston using ANSYS, Advanced science, Engineering and Medicine, Vol.10, pp.369-373
2. Boehm G, Harrer J, (1990), 'Nickel coated pistons for improved durability in knock control engine', SAE Transactions, Journal of Engines, Vol.99, pp. 1031-1038.
3. Dipayan Sinha, Susenjit Sarkar, Samar Chandra Mandal,(2017), Thermo Mechanical Analysis of a Piston with Different Thermal Barrier Coating Configuration, Vol 48, pp.335-349

4. Hiregoudar Yerrennagoudaru, K. Manjunatha, (2017) 'Combustion analysis of modified inverted "M" type piston for diesel engine with platinum coating and without coating by using CFD', Materials Today: Proceedings, Vol. 4 (2), Part A, pp. 2333-2340
5. Hongjian Zhao, Fuxing Ye, (2016) 'Investigation of sputtered WCN coating for diesel engine pistons applications', Vacuum, Vol. 126, pp. 5-9.
6. Austin H. Shaw, Jun Qu, Chinpei Wang, Roger D. England, (2017) 'Tribological study of diesel piston skirt coatings in CJ-4 and PC-11 engine oils', Wear, Vol. 376–377, Part B, pp. 1673-1681.
7. Jianliang Lin, Ronghua Wei, Daniel Christopher Bitsis, Peter M. Lee. (2016) 'Development and evaluation of low friction TiSiCN nano-composite coatings for piston ring applications', Surface and Coatings Technology, Vol. 298, pp. 121-131.
8. Ravindra Gehlot, Brajesh Tripathi, (2016), 'Thermal analysis of holes created on ceramic coating for diesel engine piston', Case Studies in Thermal Engineering, Vol. 8, pp. 291-299.
9. Vaibhav Kumar Banka, Ramesh M R, (2018), 'Thermal Analysis of a Plasma Sprayed Ceramic Coated Diesel Engine Piston, Transaction of the Indian institute of metals, Vol 71, pp.319-326
10. Mahajan K S , Deshmukh S H (2016), 'Structural and Thermal Analysis of Piston, International Journal of Current Engineering and Technology', E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.