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Thermal Analysis of Piston Using Convex and Concave Profile of Piston head

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Abstract:The purpose of this investigation work is to optimize the stress variations on the upper face of the piston at actual engine condition. In this analysis pressure on the piston surface examined, thermal behavior investigation is performed. The functions used for the investigation is operating gas pressure, temperature and material functions of piston. The analysis performed that because of temperature whether the upper face of the piston may be damaged or broken through the working conditions, as damaged or not working parts are so costly to change and usually are not simply available. Concave and convex Profile of piston designed in Solid work 2016 used to design piston geometry and for FEM analysis on optimize thermal behavior of piston ANSYS 14.0 used. Aluminum alloy and grey cast iron material used for designing of piston. The stress and displacement are analyzed for the piston by applying pressure on it in Structural analysis. By observing the analysis results, we can decide whether our designed piston is safe or not under applied load conditions. The thermal flux, thermal temperature distribution is analyzed by applying temperatures on the piston surface in Thermal analysis.

Keywords:Piston, Solid work 2016, ANSYS 14.2, Aluminum Alloy, Thermal analysis, FEM.

I. Introduction

Automobile components are in great demand these days because of increased use of automobiles. The increaseddemand is due to improved performance and reduced cost of these components. R&D and testing engineers shoulddevelop critical components in shortest possible time to minimize launch time for new products. This necessitatesunderstanding of new technologies and quick absorption in the development of new products. A piston is acomponent of reciprocating IC-engines.The piston transforms the energy of the expanding gasses into mechanical energy. The piston rides in the cylinder liner or sleeve. Pistons are commonly made of aluminumor cast iron alloys. To prevent the combustion gasses from bypassing the piston and to keep friction to a minimum, each piston has several metal rings around it.These rings function as the seal between the piston and the cylinder wall and also act to reduce friction by minimizing the contact area between the piston and thecylinder wall.The piston design should be rigid enough to prevent mechanical and thermal distortion and it should have sufficient bearing area to prevent undue wear. Piston is designed based on strength and thermal considerations. The Strengthof piston pin should be sufficient against shear failure. When the combustion takes place the piston is subjected to distortion and the energy stored inside the piston servesas determining factor to know the yield and failure conditions of a piston when subjected to static loading. Von misses yield Creation can be formulated in terms of the von misses stress or equivalent tensile stress; a scalar stressvalue can be computed from the stress tensor.

a) Fundamental of Piston

A piston is a cylindrical element of metal that reciprocates inside the cylinder which applies a force on a fluid within the cylinder. Pistons have outer rings which provide to maintain the oil leak in to the combustion chamber and the fuel and air out of the oil. Most pistons fitted in a cylinder have piston rings. Generally, there are two spring compression rings that perform as a seal between the piston and the cylinder wall, and one or more oil control ring s below the compression rings. The upper surface of the piston can be flat, bulged or other shaped. Pistons can be design by forged or cast process. The profile of the piston is normally rounded but can be different. Figure 1 shows the design of piston engine. The piston is a main element of a piston engine and of hydraulic pneumatic systems.

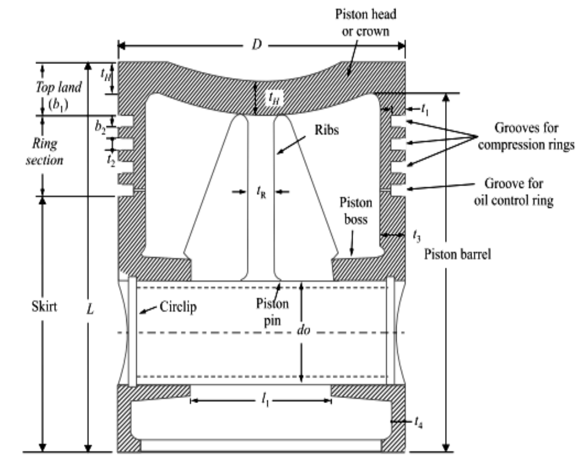


Figure 1:Schematic diagram of Piston

II. Design of Piston

The piston is designed according to the procedure and specification which are given in machine design and data reference books.

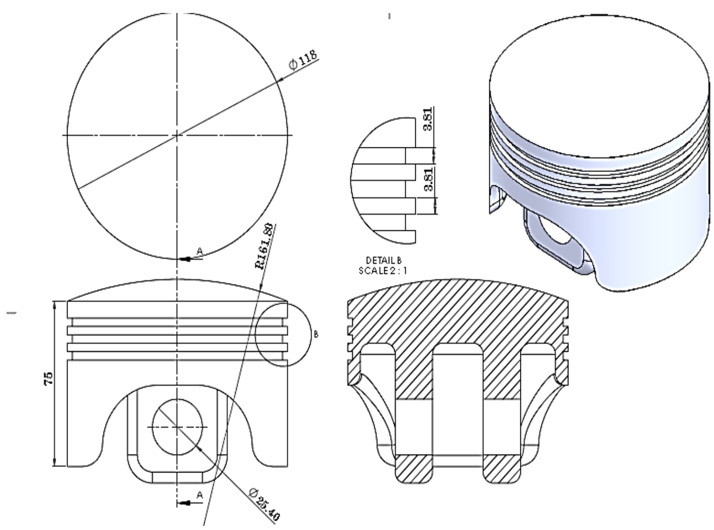


Figure: 2Drawings of The Piston

III. Finite Element Analysis

To execute the finite element investigation of the piston when the pressure of the gassesactsupon it, astructural examination using ANSYS Workbench V.14.2 takes place.At this step the investigation of the piston is a linear static one, when minor modification in rigidity take place,there are no modifications in the direction of the loading, the materials stay within linear flexible region and miner deformations and stresses are produced.The model of the piston is designed in Solidwork 2016 and saved in this file as *.igs, and thenimported in ANSYS Workbench.

Experimental PistonModel was analyzed by with ANSYS that is associate with engineering simulation commercially used software package providing a complete group that extents the complete variety of physics, offering right to use to almost several field of thermal engineering application that a design method needs. The software package usesits tools to place a virtual product through a rigorous testing procedure like testing a Piston model below totally different loading circumstances before it turns into a considerable object.

IV. Material properties of piston material

Piston analysis performed by using Aluminum alloy and Grey cast iron alloy as thepiston material. Composition ofAluminum alloy and Grey cast iron alloy grade is shown in Table 2.

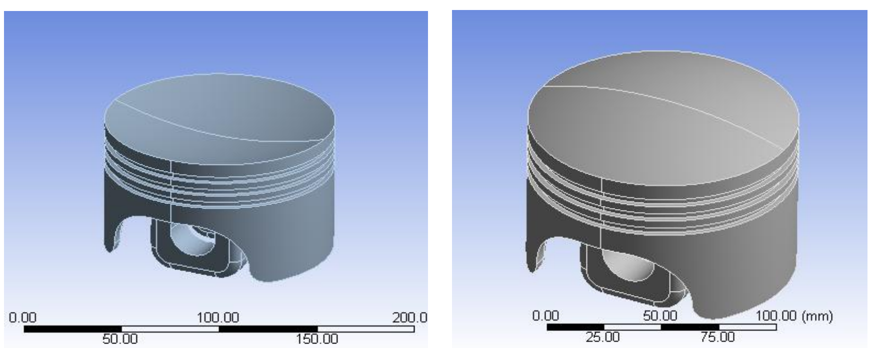
Table 2: Material properties of Piston

Parameters	Aluminum alloy	Grey Cast iron
Density (Kg/m^3)	2770	7200
Young's Modulus (MPa)	71000	110000
Coefficient of thermal expansion (1/K)	2.3×10^{-5}	1.1×10^{-6}
Poisson's Ratio	0.33	0.28
Elastic modulus (GPa)	70	124
Ultimate Tensile Strength (MPa)	310	240
Thermal conductivity(W/m/^{0}C)	140	52

V. Results and Discussion

a) Analyzing the model in ANSYS:

After designing the model in Solidwork, the. IGS FILE has been converted to IGES format. This configuration allows the design to be compatible in the ANSYS software. After importing the design in ANSYS, the process of analysis begins.



(a) Concave (b) Convex Profile

Figure 3: Design Model of Concave and convex profile piston

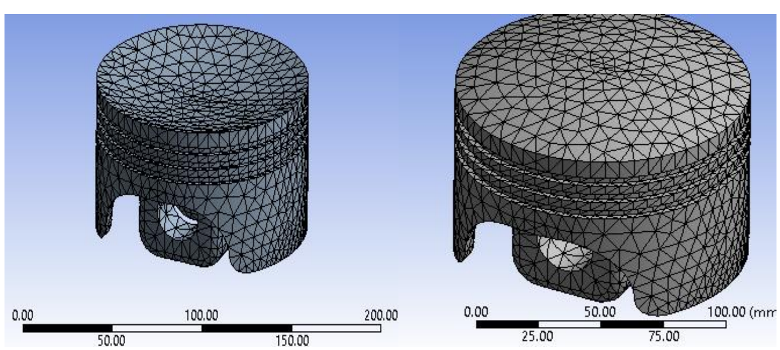


Figure 4: Meshed view of piston models

b) Meshing the model:

Mathematically, the Piston model to be investigates is subdivided into a mesh of finite sized elements of simple form. Within each component, the difference of displacement is assumed to be calculated by simple polynomial profile functions and nodal displacements. Equations for the strains and stresses are generated in terms of the unknown nodal displacements. From this, the equations of equilibrium are assembled in a matrix form which can be easily programmed.

c) Boundary conditions for analysis of S.I. engine piston using ANSYS

After the piston is meshed, we need to apply the suitable boundary condition under which the thermal Analysis will be performed.

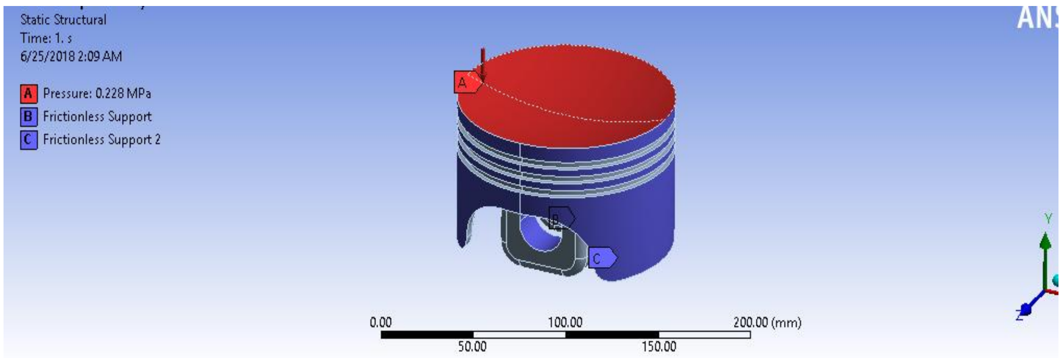


Figure 5: Piston with Concave Head profile

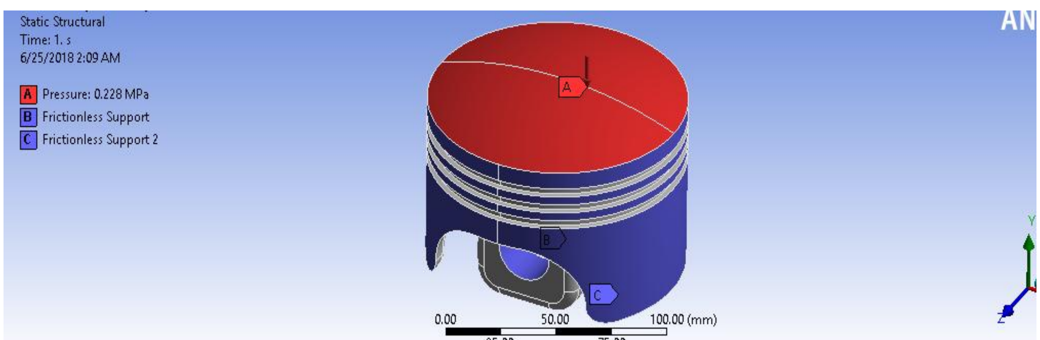


Figure 6: Piston with Convex Head profile

Static Analysis results of Piston

Table: Static analysis of Piston head with concave shape

piston head with concave shape		
	Materials	
Results	**Aluminum Alloy**	**Grey cast iron**
Total deformation (mm)	0.00188	0.00123
Stress (MPa)	4.33	4.35
Strain	0.0000619	0.0000402

Table: Static analysis of Piston head with convex shape

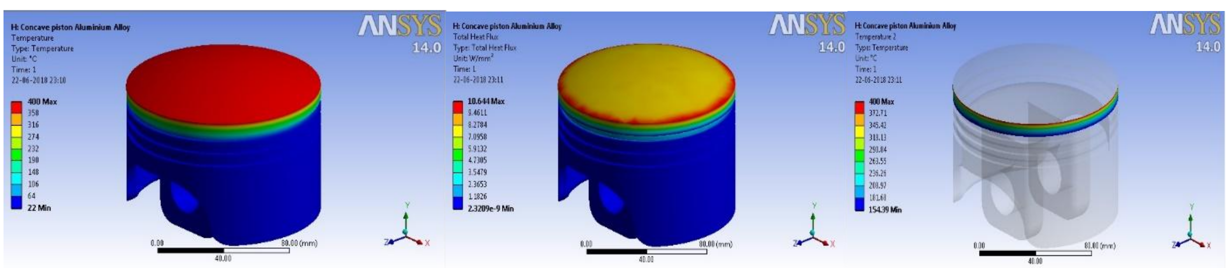
piston head with convex shape		
	Materials	
Results	**Aluminum Alloy**	**Grey cast iron**
Total deformation (mm)	0.00133	0.000868
Stress (MPa)	3.95	4
Strain	0.0000559	0.0000365

VI. Thermal Analysis of Piston Using ANSYS

Thermal analysis is a collection of methods in which the deviation of a physical property of a material is calculated as a function of temperature. The most commonly used methods are those which calculate changes of mass or changes in energy of a model of a material. Temperature variation across various piston heights of piston in steady state condition shows and boundary conditions applied shown in figures Maximum temperature at top.

After processing solution, the contours of Total Deformation, and Equivalent Elastic Strain in Static structural analysis are plotted. On other had the Temperature and Total Heat Flux in transient thermal analysis. These results as part of structural and thermal analysis are obtained for both Concave (Cup) shaped and Convex (Dome) shaped pistons.

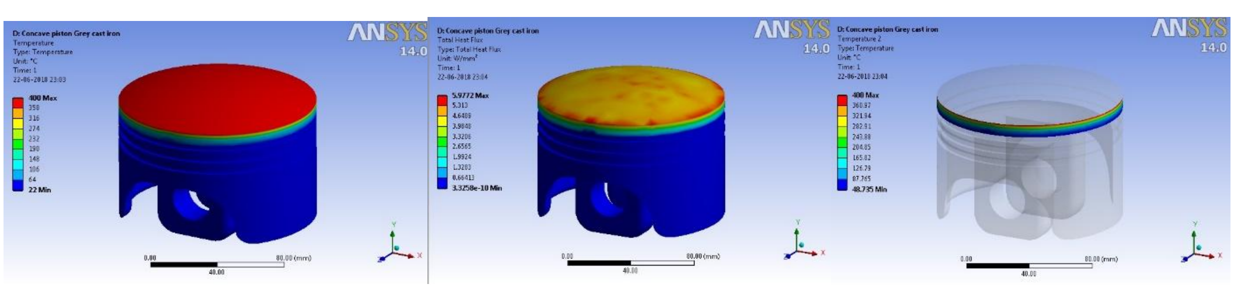
I. Piston profile with convex head with Aluminum Material



(a) Temperature distribution surface (b) Total heat Flux (c) Temperature distribution on top

Figure 7: thermal analysis of Aluminum alloy piston with convex head profile

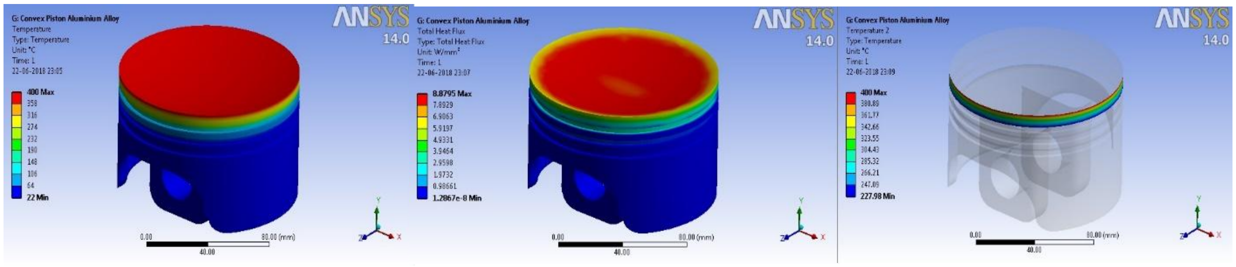
II. Piston profile with convex head with Grey cast iron Material



(a) Temperature distribution surface (b) Total heat Flux (c) Temperature distribution on top

Figure 8: thermal analysis of grey cast iron piston with convex head profile

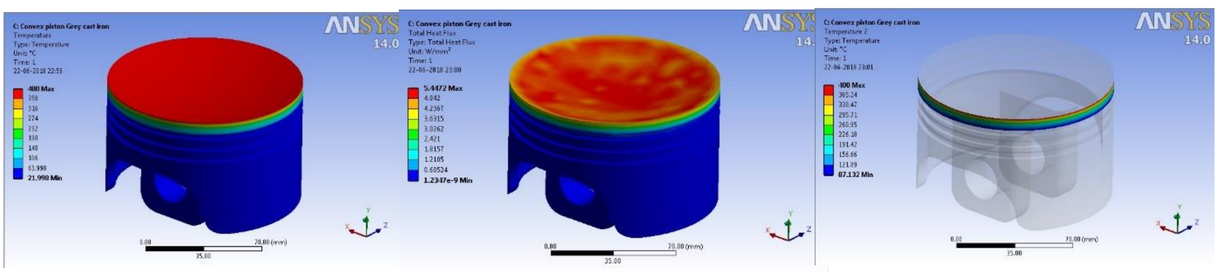
III. Piston profile with Concave head with Aluminum Material



(a) Temperature distribution (b) Total heat Flux (c) Temperature distribution on top surface

Figure 9: thermal analysis of Aluminum alloy piston with concave head profile

IV. Piston profile with Concave head with Grey cast iron Material



(a) Temperature distribution (b) Total heat Flux (c) Temperature distribution on top surface

Figure 10: thermal analysis of Grey cast iron alloy piston with concave head profile

Table: Comparison thermal results of Piston with concave shape

piston head with concave shape		
Results	Aluminum Alloy	Grey cast iron
Total heat flux	8.87	5.44
Temperature drop on top surface piston	227.98	87.13

Table: Comparison thermal results of Piston with Convex shape

piston head with convex shape		
Results	Aluminum Alloy	Grey cast iron
Total heat flux	10.64	5.97
Temperature on top surface piston	154.39	48.73

- **Graph of thermal analysis of piston with Convex shape**

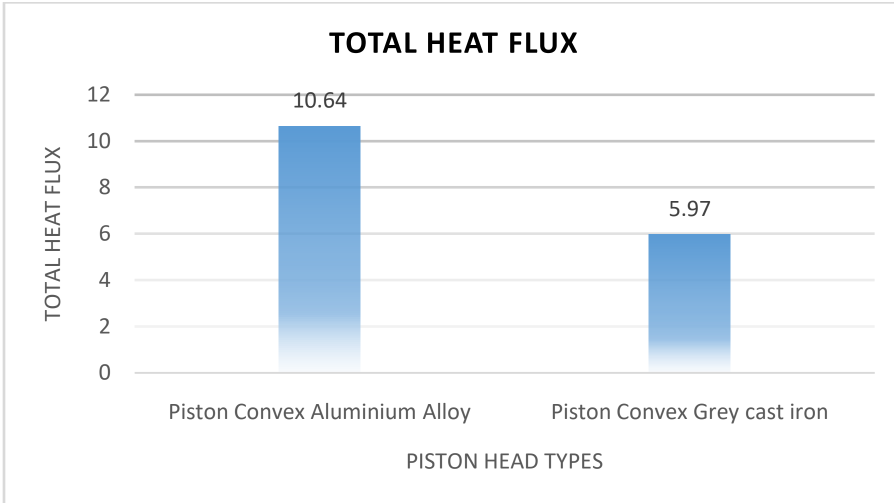


Figure 11: Comparison of total heat flux in Al Alloy and grey cast iron

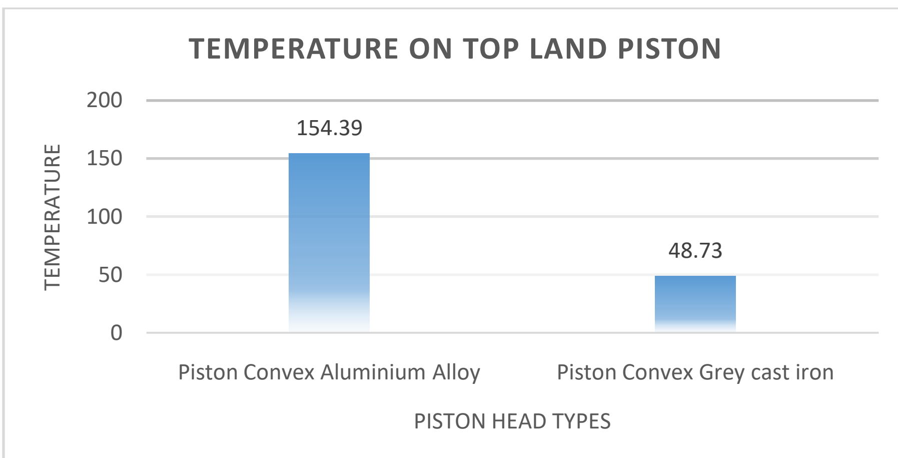


Figure 12: Comparison of Temperature on top surface in Al Alloy and grey cast iron

- **Graph of thermal analysis of piston with Concave shape**

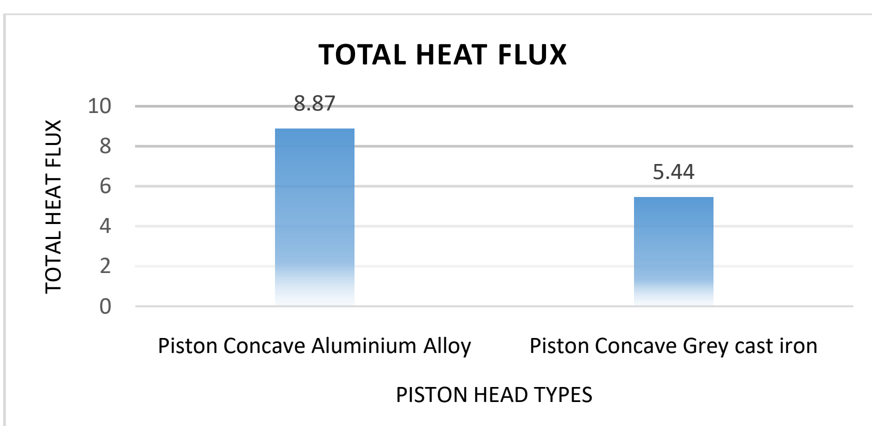


Figure 13: Comparison of total heat flux in Al Alloy and grey cast iron

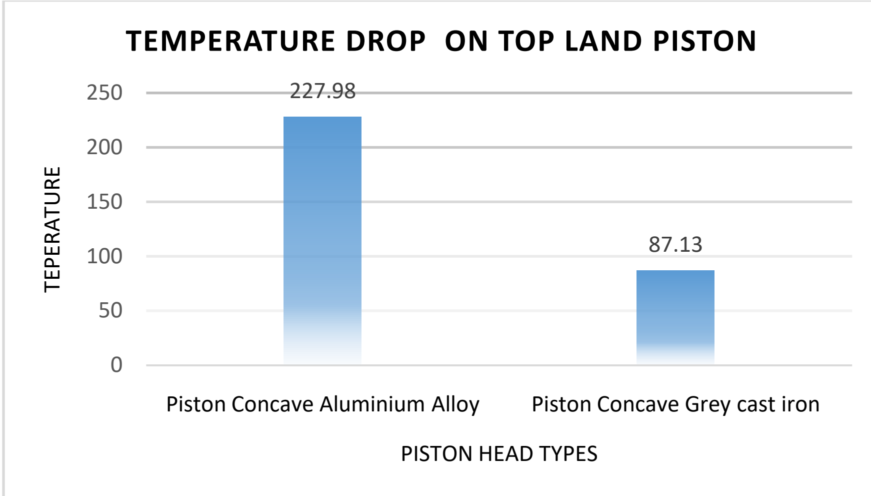


Figure 14: Comparison of Temperature on top surface in Al Alloy and grey cast iron

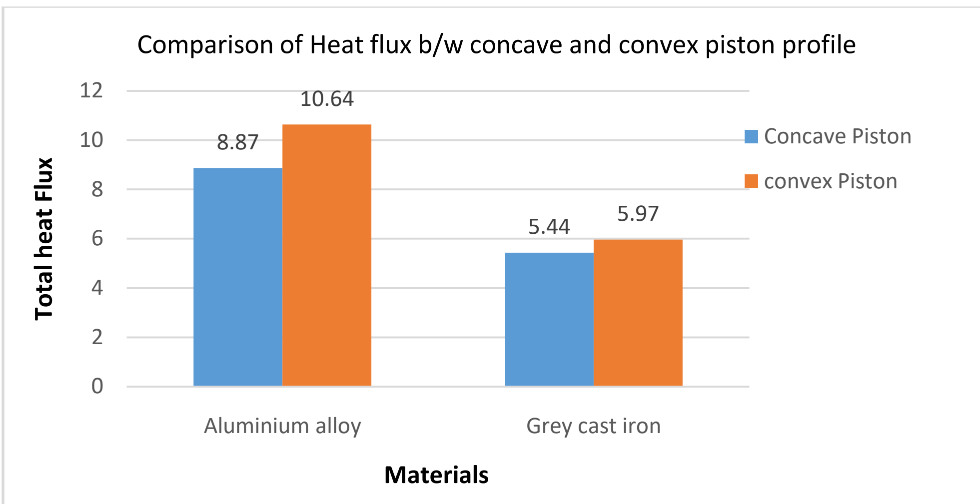


Figure 15: Comparison of Heat flux b/w concave and convex piston profile

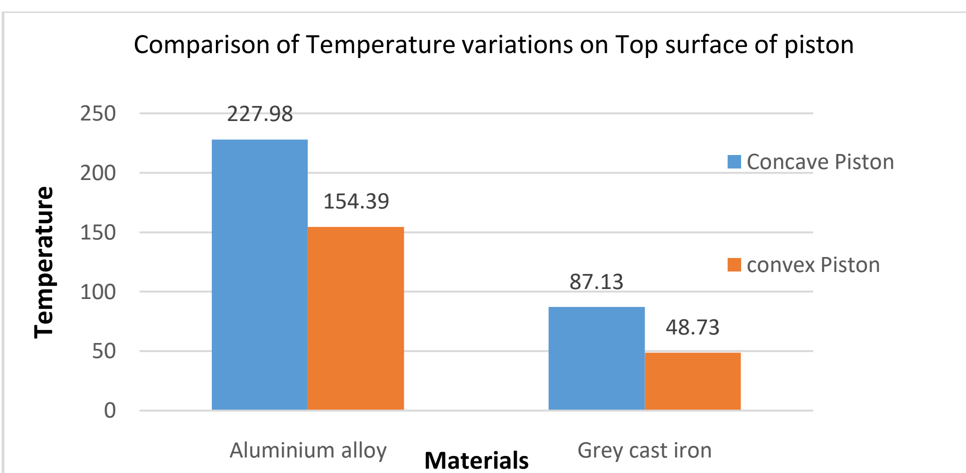


Figure 16: Comparison of Temperature variations on Top surface of piston

VII. Conclusion

The piston plays a major role in the engine performance; the piston material is made up ofimpacts on the strength of the piston. The maximum stress intensity is on the bottom surface of the piston crown in boththe materials, as it is expected. Maximum displacement is absorbed on the top of the piston of aluminum alloy and grey cast iron Highest value of maximum temperature found in piston is due to thermal conductivity of the materials and thetotal maximum heat flux is absorbed in both the piston materials. Thus, further research can be carried with the advance materials and different designing,analysis tools.designs for which the analyses are carried out, the stresses and total deformations observed in concaveshaped piston are larger than the convex shaped piston. So this justifies the usage of concave or cupshaped pistons in IC Engines which use diesel as fueland for large sized engines.

As per above study it is concluded that Total heat flux found maximum 10.64 W/mm^2 in aluminum alloy piston with convex shape and minimum temperature found on top surface of piston in convex shape i.e. 154.39 ^{0}C. so it is concluded that concave type piston shows better thermal properties in this analysis. Thus, an experimental result shows that Convex head type piston having better thermal properties to design piston as per thermal conditions of material. The concluded analysis is performed on ANSYS 14.5 analysis software. These results are based on Finite Element Method. Thus further research can be carried with the advance materials and different designing, analysis tools.

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