Thermal Analysis of Different Piston Head Profiles by Using FEM

D.Hari krishna[1], CH.Veeru Naidu[2], A.Narendhra Kumar[3]

[1]Mtech Scholar, Mechanical Engineering Dept, Visakha Institute of Engineering and Technology
[2,3]Assistant Professor, Mechanical Dept, Visakha Institute of Engineering and Technology, VSKP.

Abstract

The objective of this research work is to optimize the stress variations at the top of the piston in real engine conditions. During this pressure analysis on the examined surface of the piston, the thermal behavior is examined. The operating gas pressure, temperature and piston material functions are used as investigation functions. The analyzes carried out showed that the upper part of the piston could be damaged or broken due to the temperature caused by the working conditions, as the replacement of damaged or non-functioning parts is very expensive and usually difficult to obtain. Concave and convex piston profile designed in Solid Work 2023, used to design the piston geometry and for FEM analysis to optimize the thermal behavior of the used ANSYS R23.0 piston. Aluminum alloy and gray cast iron material for piston construction. Stress and displacement are analyzed for the piston by applying pressure to it in the structural analysis. By observing the results of the analysis, we can decide whether the piston we are designing is safe or not under the applied load conditions. Heat flow and thermal temperature distribution are analyzed using piston surface temperatures in thermal analysis.

Keywords: Concave, convex piston, Solid, ANSYS R23.0, Aluminum Alloy, Thermal analysis, FEM.

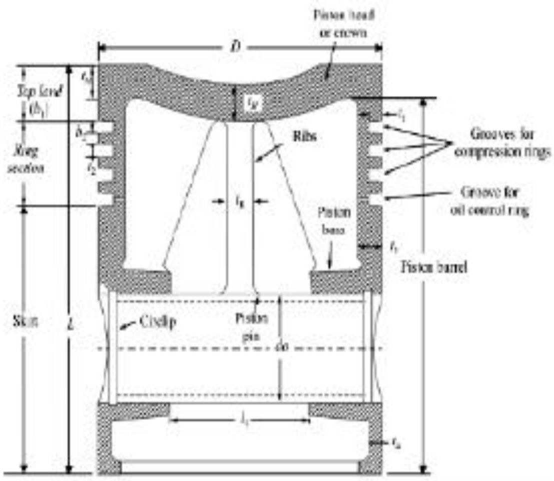
1. Introduction

Nowadays, automotive components are in high demand due to the increasing use of automobiles. The increase in demand is due to the improved performance and lower cost of these components. R&D and test engineers must develop critical components as quickly as possible to minimize time to market for new products. This requires understanding new technologies and rapidly adopting new product developments. A piston is a component of reciprocating internal combustion engines. The piston converts the energy of the expanding gases into mechanical energy. The piston slides in the cylinder liner or sleeve. Pistons are generally made of aluminum alloys or cast iron. To prevent combustion gases from passing the piston and minimize friction, each piston is surrounded by several metal rings. These rings act as a seal between the piston and the cylinder wall and also reduce friction by minimizing the contact area between the piston and the cylinder wall. The piston design must be rigid enough to prevent mechanical and thermal deformation and must have sufficient bearing surface to prevent excessive wear. The piston was designed with resistance and temperature considerations in mind. The strength of the pin must be sufficient to resist shear fracture. During combustion, the piston undergoes deformation, and the energy stored in it is a crucial factor in the performance and failure conditions of a piston under static load. The production of Von Misses yield stress can be formulated as Von Misses stress or equivalent tensile stress; A scalar stress value can be calculated from the stress tensor.

a) Fundamental of Piston

A piston is a cylindrical metal element that moves back and forth within the cylinder and applies force to the fluid in the cylinder. The pistons have outer rings that prevent oil from entering the combustion chamber and fuel and air from escaping from the oil. Most pistons mounted in a cylinder are equipped with piston rings. There are typically two spring-loaded compression rings that act as a seal between the piston and the cylinder wall, as well as one or more oil control rings below the compression rings. The top of the piston may be flat, curved or otherwise shaped. Pistons can be made by forging or casting processes. The piston profile is usually rounded but can vary. Figure 1 shows the structure of the piston engine. The piston is the main element of a piston machine and pneumatic-hydraulic systems.

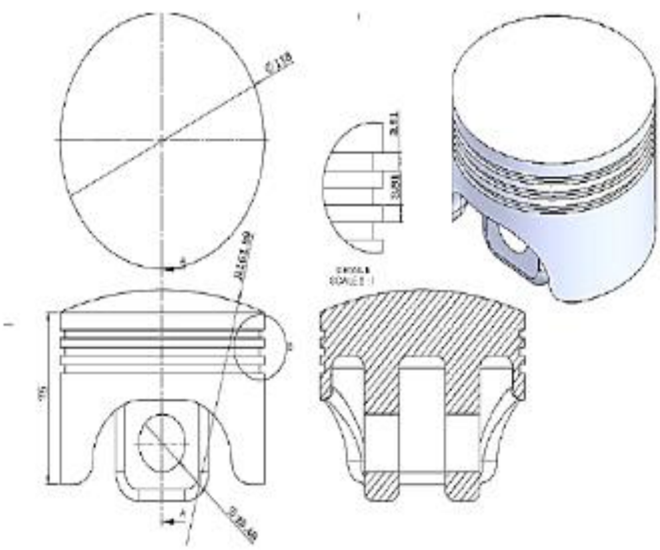
Figure 1: Schematic Diagram of Piston



2. Piston Design

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

Figure 2: Drawings of the Piston



3. Finite Element Analysis

To perform a finite element study of the piston when gas pressure is applied to it, a structural study is performed using ANSYS Workbench R23.0. In this phase the examination of the piston is static and linear. When small changes in stiffness occur, there is no change in the direction of loading, the materials remain in the linear flexible region, and deformations and mineral stresses appear. The piston model is designed in Solid Work 2023 and saved in this file as *.igs, then imported into ANSYS Workbench.

The experimental piston model was analyzed by ANSYS, which is linked to the commercially used engineering simulation software package, providing a comprehensive assembly that expands the entire variety of physics and gives the right to use in almost various fields of engineering applications requiring a design method. The software package uses its own tools to put a virtual product through a rigorous testing process, such as testing a piston model under various loading conditions, before it becomes an extraordinary object.

4. Material properties of piston material

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

Table 2: Material properties of Piston

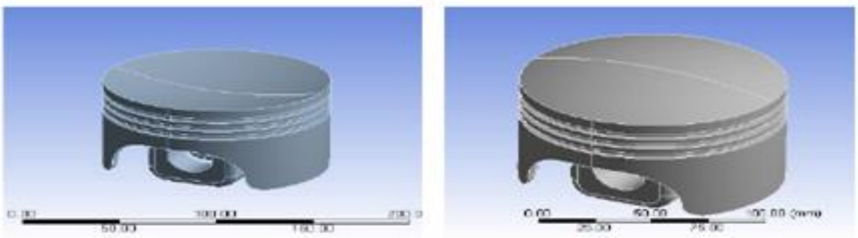
Parameters	Aluminum alloy	Grey Cast iron
Density (Kg/m^3)	2770	7200
Young's Modulus (MPa)	71000	110000
Coefficient of thermal expansion (1/K)	2.3×10^{-5}	1.1×10^{-5}
Poisson's Ratio	0.33	0.28
Elastic modulus (GPa)	70	124
Ultimate Tensile Strength (MPa)	310	240
Thermal conductivity(W/m/^{0}C)	140	52

5. Results and Discussion

a) Analyzing the model in ANSYS:

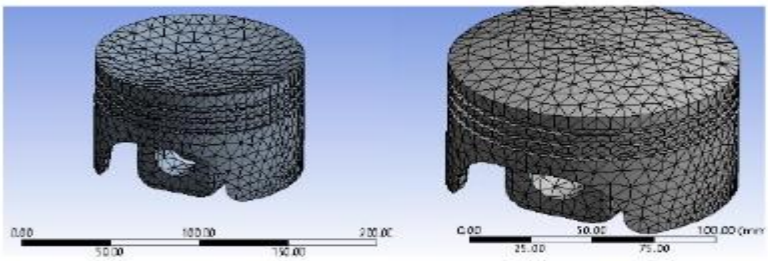
After designing the model in solid work, IGS FILE has been converted to IGES format. This configuration allows the design to be compatible in the ANSYS software. After importing the design in ANSYS, the process of analysis begins

Figure 3: Design Model of Concave and convex profile piston



(a) Convex (b) Concave Profile

Figure 4: Meshed view of piston models



b) Meshing the model:

Mathematically, the piston model to be examined is decomposed into a network of finite-dimensional elements of simple shape. It is assumed that the displacement difference within each component is calculated using simple polynomial profile functions and nodal displacements. Strain and stress equations are created using unknown nodal displacements. From there, the balance equations are assembled into a matrix form that 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 Convex Head profile

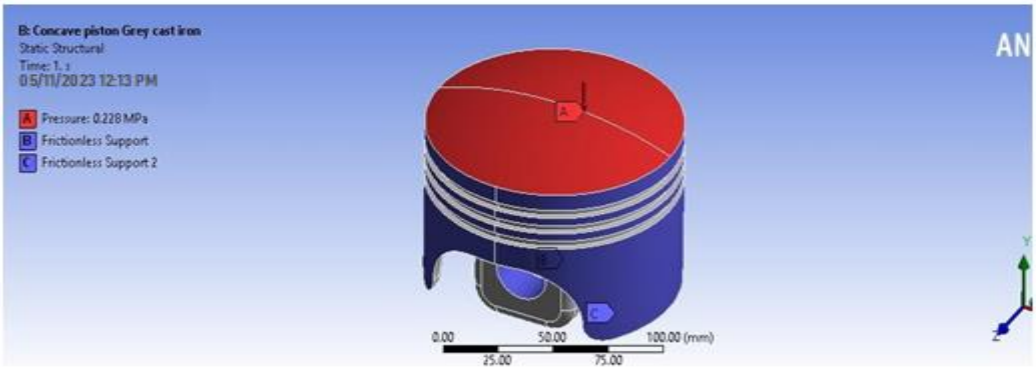
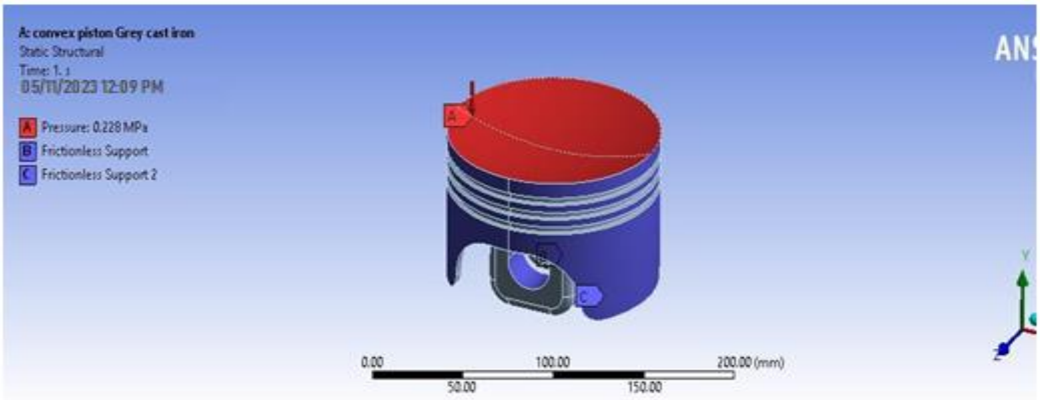


Figure 6: Piston with Concave Head profile



d) Static Analysis results of Piston

Table: Static analysis of Piston head with convex shape

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

Table: Static analysis of Piston head with Concave shape

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

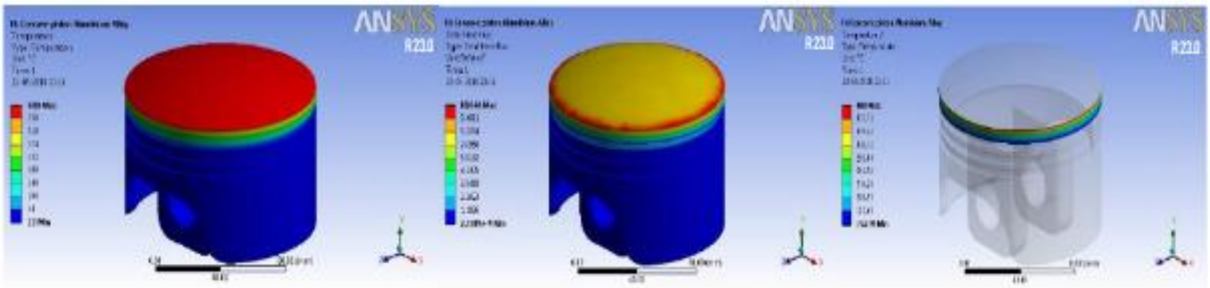
6. Thermal Analysis of Piston Using ANSYS

Thermal analysis is a set of methods used to calculate the variation of a physical property of a material as a function of temperature. The most commonly used methods are those that calculate changes in mass or energy of a material model. The figures show the temperature curve between different piston heights in steady state conditions and the applied boundary conditions are shown. Maximum temperatures at the summit.

After solution processing, the contours of total strain and equivalent elastic strain are recorded in the static structural analysis. On the other hand, in the transient thermal analysis, the temperature and total heat flux were present. These structural and thermal analysis results are obtained for concave (cup) and convex (dome) pistons.

a) Piston profile with concave head with Aluminium Materials

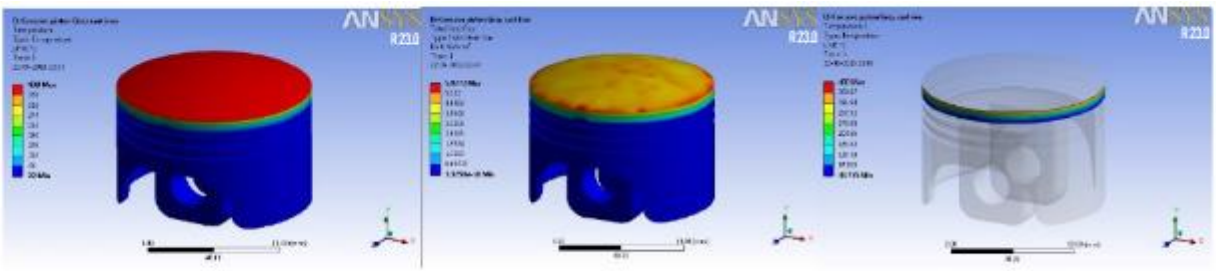
Figure 7: Thermal Analysis of Aluminium alloy piston with concave head profile



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

b) Piston profile with concave head with Grey cast iron Material

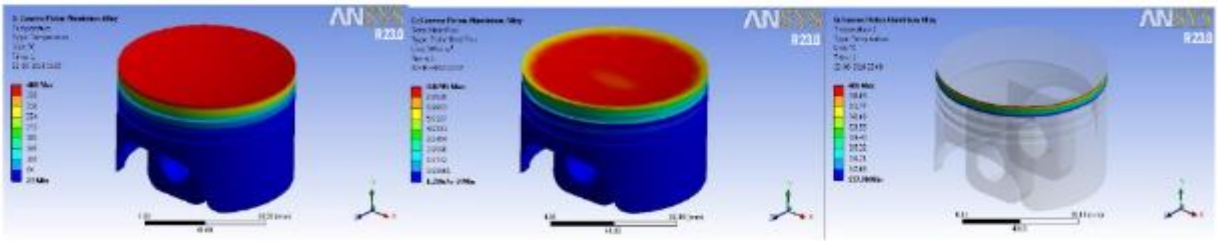
Figure 8: Thermal Analysis of Grey cast iron piston with concave head profile



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

c) **Piston profile with Convex head with Aluminum Material**

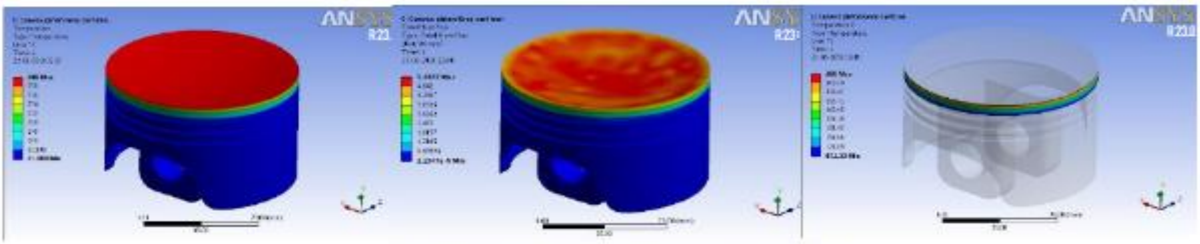
Figure 9: Thermal Analysis of Aluminium alloy piston with convex head profile



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

d) **Piston profile with Convex head with Grey cast iron Material**

Figure 10: Thermal Analysis of Grey cast iron piston with convex head profile



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

Table: Comparison thermal results of Piston with convex shape

piston head with convex 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 Concave shape

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

Figure 11: Comparison of Heat flux b/w concave and convex piston profile

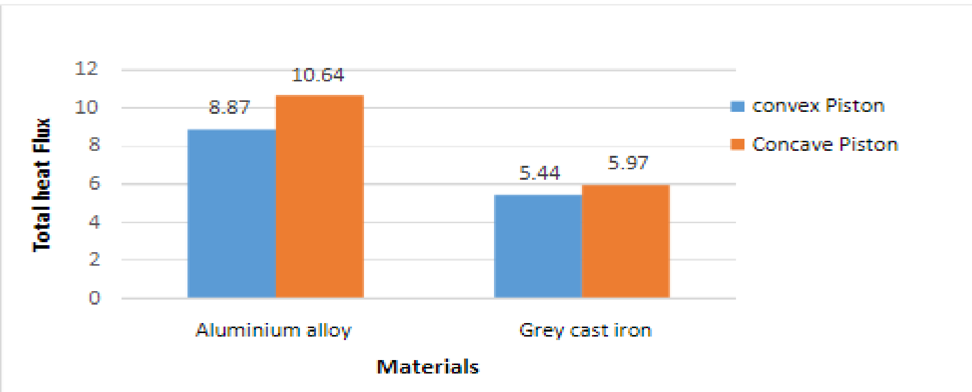
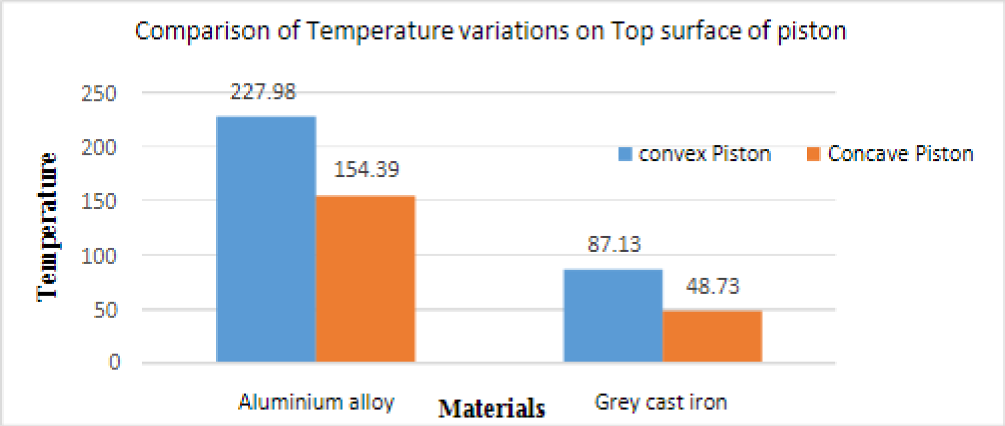


Figure 12: Comparison of Temperature variations on Top surface of piston



7. Conclusion

The piston plays an important role in engine performance; The piston material is made by changing the resistance of the piston. As expected, for both materials the highest force intensity is recorded in the elastic band. It got the maximum displacement on top of the aluminum alloy and gray cast iron piston. The higher maximum force in the piston temperature is due to the thermal conductivity of the material, and the maximum heat flux is absorbed in both piston materials. Therefore, in-depth research can be carried out using advanced materials and various analysis methods and tools. In the designs for which the analyzes are performed, the total stresses and strains observed in the concave-shaped piston are greater than those observed in the convex-shaped piston. This demonstrates the use of hollow or copper-shaped pistons in internal combustion engines using diesel in furnaces and large engines.

From the above study it is concluded that the total heat flux in the aluminum alloy hollow piston was 10.64W/mm^2 and the minimum temperature on the surface of the hollow piston was 154.390°C. In this analysis, it is concluded that the hollow piston type has better thermal properties. Therefore, the experimental results show that the hollow piston head has better thermal properties to design the piston according to the thermal conditions of the material. The analysis performed is presented in Ansys Analysis R23.0. These results are based on the finite element method. Therefore, a more in-depth investigation can be carried out using advanced materials and various analysis methods and tools.

8. REFERENCES

1. Krishnan S, Vallavi MS, kumar M, Hari Praveen A, 2017, “Design and Analysis of an IC Engine Piston using Composite Material", European Journal of Advances in Engineering and Technology, pp. 209-215.
2. Sinha, Sarkar,Mandal, 2017, “Thermo Mechanical Analysis of a Piston with Different Thermal Barrier Coating Configuration", International Journal of Engineering Trends and Technology (IJETT), pp. 335-339.
3. G Gopal, L. Kumar, K Reddy, Rao, 2017, "Analysis of Piston, Connecting rod and Crank shaft assembly", Elsevier, pp. 7810-7819.
4. Shehanaz, Shankariah, 2017, "Design and Analysis of Piston Using Composite Material",International Journal of Innovative Research in Science, Engineering and Technology, pp. 16039-16048.
5. Pandey, Jain, Bajpai, 2016, "Design, Analysis and Optimization of Four Stroke S.I. Engine Piston

using Finite Element Analysis in ANSYS software", International Journal of Advance Engineering and Research Development, pp. 16-27.
6. KoteswaraRao, Mansoor Ahamed, Raju, 2016, "Fabrication Design and Analysis Of Piston Using Metal Matrix Composites", International Research Journal of Engineering and Technology (IRJET), pp. 448-453.
7. JainVishal,Chauhan, 2016,"Design And Analysis Of Aluminum Alloy Piston Using Cae Tools", International Journal Of Engineering Sciences & Research Technology, **7**, pp. 332-339.
8. Reddy, Goud, 2016, "Design and Analysis of the Piston by Using Composite Materials", international journal of professional engineering studies, pp. 153-162.
9. Sundaram, Palanikumar, 2016,"Investigation and Analysis of Piston by Using Composite Material", IJARIIE, pp. 1447-1454.
10. Attar, Arora, 2016, "Transient Thermal Analysis of Internal Combustion Engine Piston in ANSYS Workbench by Finite Element Method", international journal of engineering sciences & research Technology, pp. 805-810.
11. John, Mathew, Malhotra, Malhotra, 2015, "Design and Analysis of Piston by SiC Composite Material", IJIRST –International Journal for Innovative Research in Science & Technology, pp. 578-590.
12. Devan, Reddy, 2015, "Thermal analysis of Aluminum Alloy Piston", International Journal of Emerging Trends in Engineering Research (IJETER), pp. 511-515.
13. Sonar, Chattopadhyay, 2015, "Theoretical Analysis of Stress and Design of Piston Head using CATIA & ANSYS", International Journal of Engineering Science Invention, pp. 52-61.
14. Singh, Rawat, Hasan, Kumar, 2015, "Finite Element Analysis Of Piston In ANSYS", International journal of modern trends in engineering and research, pp.619-626.
15. Srinadh, Babu, 2015, "Static and Thermal Analysis of Piston and Piston Rings", International Journal of Engineering Technology, Management and Applied Sciences, pp. 51-58.