Stress Analysis of Piston Using Pressure Load And Thermal Load

Subodh kumar[1], C. S. Koli[2]
[2] Assistant Professor
[1, 2] SRCEM, Banmore, Gwalior (M.P.)

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 examination, thermal behavior examination is performed. The parameters used for the investigation is operating gas pressure, temperature and material functions of piston. In I.C. Engine piston is most difficult and essential element as a result for smooth running of vehicle, piston should be in proper working condition. Piston fails mostly because of mechanical stresses and thermal stresses. Optimization of piston is done with boundary conditions, which having pressure on piston head for the period of working condition and uneven temperature variations starting from piston head to piston skirt. 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. Solid work 2016 used to design piston geometry and for FEM analysis on optimize thermal behavior of piston ANSYS 14.0 used.*

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

I. INTRODUCTION

A piston is a reciprocating component of an IC engines. It reciprocates in engine cylinder and is designed enclosed by piston rings. The primary function of piston is to transmit force from burnt gas in the cylinder to the crankshaft through a piston rod. Piston carries the cyclic gas pressure and the inertial forces at work, and this operational condition may develop the fatigue damage of piston, for example piston side break, piston head cracks and so on. So there is a necessitate to analyze the design parameters of piston by considering several parameters in this project the parameters selected are analyzed parameters of piston by acting pressure at the top of the piston surface and thermal optimization of piston at several temperatures in different stroke. This experiment could be helpful for design engineer for changes of piston at the time of design. In this project we determine the various stress calculation by using pressure analysis, thermal analysis form that we can find out the various zones or region where chances of breaking of piston are possible. From analysis it is very simple to analyze the creation of piston. The major demand of piston design is to calculate the calculation of temperature circulation on the surface of piston which is used to analyze the thermal aspects for making of piston at lesser cost. Mainly pistons are design of an aluminum alloy which has great thermal expansion coefficient, 80% larger than the cylinder bore material considered by cast iron. This leads to some differences between running and the design clearance. Therefore investigation of the piston thermal performance is extremely essential in designing more competent compressor. Proper fitting of piston within the cylinder is primary rule to design of piston, also develop the mechanical efficiency and decrease the inertia force in high speed machinery the weight of the piston also acting major role. To permit for thermal expansion, the diameter of the piston should be lesser than that of cylinder diameter. The essential clearance is considered by optimized the temperature variation between piston and cylinder by considering the coefficient of thermal expansion in piston.

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.

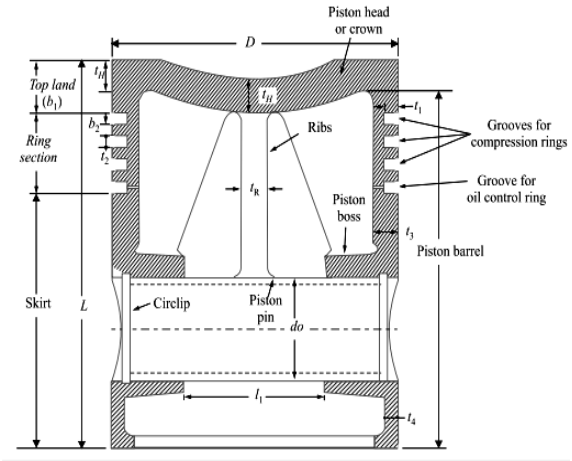

Figure: 1. Schematic diagram of Piston

II. DESIGN OF PISTON

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

Table 1: Piston design parameters after optimization

S.No	Parameters	Values
1	Cylinder Bore (D)	68 mm
2	Stroke Length (L)	69.5 mm
3	Max Gas Pressure	12.7 Mpa
4	Piston Pin Diameter	19.04 mm
5	Piston Head Thickness (t_H)	8.06 mm
6	Radial Thickness of Ring (t_1)	1.77 mm
7	Axial Thickness of Ring (t_2)	2.26 mm
8	Max Thickness of Barrel (t_3)	8.71 mm
9	Width of Top Land (b_1)	8.06 mm
10	Width of other Land (b_2)	1.58 mm
11	Length of Skirt (L_s)	40.8 mm

III. FINITE ELEMENT ANALYSIS

To execute the finite element investigation of the piston when the pressure of the gasses acts upon it, a structural examination using ANSYS Workbench V.14.0 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 then imported in ANSYS Workbench.

Experimental Piston Model 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 use it's 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 an Al-Si alloy i.e., Al 4032 and Al2618 grade alloy as the piston material. This piston material has a silicon content of approximately 12%. Composition of Al 4032 and Al2618 grade is shown in Table 2.

Table 2: Material properties of Piston

Parameters	A4032	A2618
Density (Kg/m^3)	2684.95	2767.99
Young's Modulus	79000 MPa	73700 MPa
Coefficient of thermal expansion (1/K)	7.9 × 10-6	25.9×10-6
Poisson's Ratio	0.33	0.33
Elastic modulus (Gpa)	79	73.7
Yield Strength (Mpa)	315	420
Ultimate Tensile Strength (Mpa)	380	480
Thermal conductivity(W/m/^{0}C)	154	147

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.

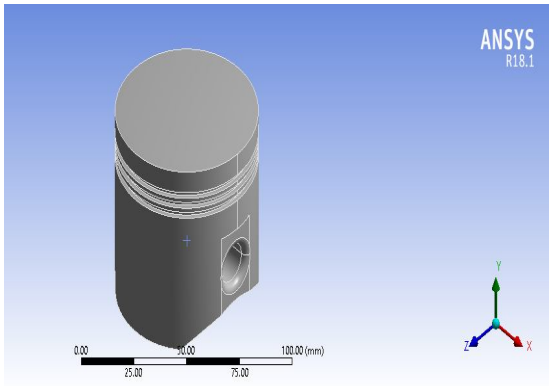

Figure 2: Model of Piston

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.

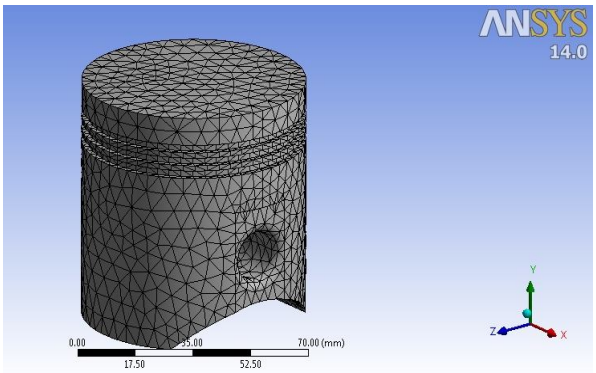

Figure 3: Meshing the piston model using ANSYS

Table 3: Nodal calculation of meshed piston

Number of nodes	Number of Elements	Size of Elements
24346	14185	4.5 mm

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.

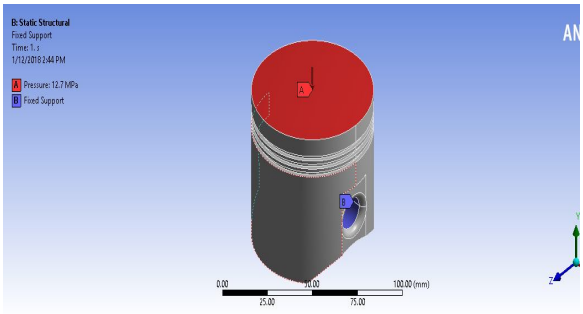

Figure 4: Static thermal boundary conditions of Piston

d) Static deformation of Piston

Firstly we check material deformation while applying pressure 12.7 MPa on the top of the piston surface. For Material Al4032 and Al 2618.

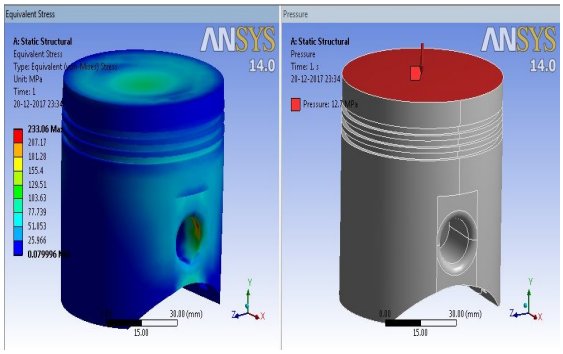

Figure 5: Deformation analysis Piston with Material Al4032

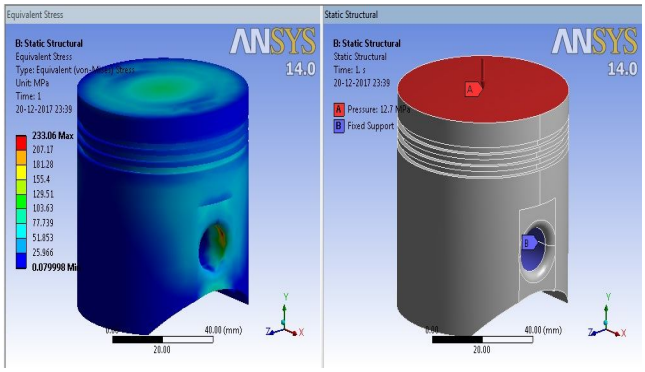

Figure 6: Deformation analysis Piston with Material Al2618

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. Figure 7 shows Temperature Distribution and Heat flux in Al4032Piston. Figure 8 shows Temperature Distribution and total heat flux in Al2618 piston. Temperature variation across various piston heights of piston in steady state condition shows and boundary conditions applied shown in figures Maximum temperature at top.

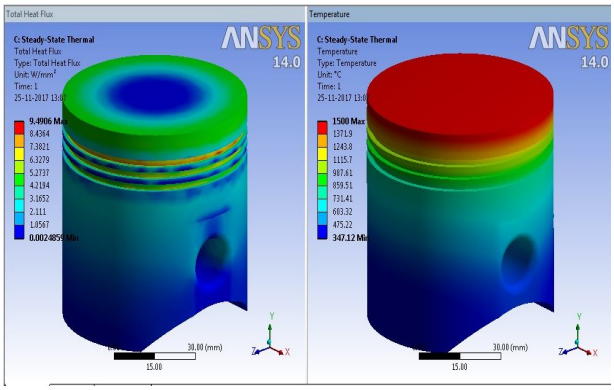

Figure 7: Thermal analysis of Piston with Al 4032

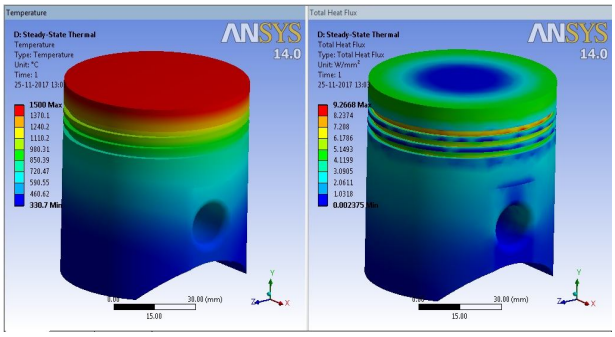

Figure 8: Thermal analysis of Piston with Al 2618

VII. COMPARATIVE ANALYSIS OF RESULTS

The piston plays a major role in the engine performance; the piston material is made up of impacts on the strength of the piston. The maximum stress intensity is on the bottom surface of the piston crown in both the materials, as it is expected. Maximum displacement is absorbed on the top of the piston of 4032 and A2618.

Highest value of maximum temperature found in piston is due to thermal conductivity of the materials and the total 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.

Table 4: Results of aluminum alloy material

Perametres	A4032	A2618
Total Deformation	0.095 mm	0.102 mm
Von Mises Stress	233.06 Mpa	233.06 Mpa
Safety Factor	1.35	1.8
Total Heat Flux	9.4906W/mm2	9.2668W/mm2
Temperature Fall Range	1500 - 347.12 deg c	1500 - 330.7 deg c
Mass	0.311Kg	0.321Kg

VIII. CONCLUSION

Design of piston is analyzed by applying temperature and convection tools. From the thermal analysis we concluded that maximum temperature of Al4032 material piston is 1500C and minimum temperature is 347^{o}C and maximum temperature of Al2618 material piston is 1500C and minimum temperature is 330.7^{o}C. The maximum Total Heat Flux of Al4032 is 9.4906W/mm^2 and minimum value of Total Heat Flux is 0.002485. The maximum Total Heat Flux of Al2618 is 9.2668 W/mm^2 and minimum value of Total Heat Flux is 0.002375. Al4032 material having factor of safety 1.5 then Al 2618 material gives 1.8 factor of safety thus Al 2618 material safe under the conditions of safety factor. The corresponding graphs and contours provide us further details. Thus, an experimental result shows that A2618 material 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.

REFERENCES

[1] Balahari Krishnan S, Aezhisai Vallavi MS, Arunkumar M and Haripraveen A, 2017, “Design and Analysis of an IC Engine Piston using Composite Material", European Journal of Advances in Engineering and Technology, **4**, pp. 209-215.

[2] Dipayan Sinha, Susenjit Sarkar,Samar Chandra Mandal, 2017, "Thermo Mechanical Analysis of a Piston with Different Thermal Barrier Coating Configuration", International Journal of Engineering Trends and Technology (IJETT), **48**, pp. 335-339.

[3] G Gopal, L. Suresh Kumar, K Vijaya Bahskar Reddy, M Uma Maheshwara Rao, 2017, "Analysis of Piston, Connecting rod and Crank shaft assembly", Elsevier, **4**, pp. 7810-7819.

[4] Molla Shehanaz, G.Shankariah, 2017, "Design and Analysis of Piston Using Composite Material",International Journal of Innovative Research in Science, Engineering and Technology, **8**, pp. 16039-16048.

[5] Ankit Kumar Pandey, Sandeep Jain, Lokesh 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, **9**, pp. 16-27.

[6] J.koteswaraRao, MD.Mansoor Ahamed, S.Raju, 2016, "Fabrication Design And Analysis Of Piston Using Metal Matrix Composites", International Research Journal of Engineering and Technology (IRJET), **11**, pp. 448-453.

[7] Jadhav Vishal, R.K. Jain,Yogendra S.Chauhan, 2016,"Design And Analysis Of Aluminum Alloy Piston Using Cae Tools", International Journal Of Engineering Sciences & Research Technology, **7**, pp. 332-339.

[8] K.venkatareddy, V.chandrashekar Goud, 2016, "Design and Analysis of the Piston by Using Composite Materials", international journal of professional engineering studies, **7**, pp. 153-162.
[9] Sundaram.K, Palanikumar.N, 2016,"Investigation And Analysis Of Piston By Using Composite Material", IJARIIE, **2**, pp. 1447-1454.
[10] Vinay Kumar Attar, Himanshu Arora, 2016, "Transient Thermal Analysis of Internal Combustion Engine Piston in ANSYS Workbench by Finite Element Method", international journal of engineering sciences & research Technology, **6**, pp. 805-810.
[11] Abino John, Jenson T Mathew, Vasdev Malhotra, Vasdev Malhotra, 2015, "Design and Analysis of Piston by SiC Composite Material", IJIRST –International Journal for Innovative Research in Science & Technology, **12**, pp. 578-590.
[12] B.A.Devan, G.Ravindra Reddy, 2015, "Thermal analysis of Aluminum alloy Piston", International Journal of Emerging Trends in Engineering Research (IJETER), **6**, pp. 511-515.
[13] Dilip Kumar Sonar, Madhura Chattopadhyay, 2015, "Theoretical Analysis of Stress and Design of Piston Head using CATIA & ANSYS", International Journal of Engineering Science Invention, **6**, pp. 52-61.
[14] Lokesh Singh, Suneer Singh Rawat, Taufeeque Hasan, Upendra Kumar, 2015, "Finite Element Analysis Of Piston In ANSYS", International journal of modern trends in engineering and research, **4**, pp.619-626 .
[15] M.Srinadh, K. Rajasekhara Babu, 2015, "Static and Thermal Analysis of Piston and Piston Rings", Inte rnational Journal of Engineering Technology, Management and Applied Sciences, **8**, pp. 51-58.
[16] R.S.khurmi and J.K. gupta, 2005 "Internal combustion Engine," in *Machine design*, delhi, Eurasia Publishing House (PVT.) LTD, pp. 1125-1210.