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Research Article

Analysis and Comparison of Different Materials for a Single Cylinder Four Stroke 225cc Piston using FEA

Mandeep Singh†* and Manish Bhargava†

†Department of Mechanical Engineering, Maharishi Arvind Institute of Engineering & Technology, Jaipur, Rajasthan, India

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Abstract

A piston is a component of reciprocating engines which transfer force from expanding gas in the cylinder to the crank shaft via piston rod and a connecting rod. It is one of the most complex components of an automobile, so engine performance is influenced by the weight & design of the piston. In this work explained the distribution of stress in two different alloys of Aluminum and Titanium Alloy with the help of simulation tool. For this purpose, a single cylinder four stroke 225cc engine is used. Analytical design strategy of above mentioned materials is demonstrated. Piston is modeled with the help of Pro/ENGINEER software. The model is analyzed with the help of ANSYS workbench. Then the Von misses stress, Von misses strain, thermal stresses, factor of safety and deformations are calculated which influenced a lot in piston material selection. Thus, the best piston material is ensured by the piston analysis process.

Keywords: *Piston, Fatigue, Design Analysis, Al Alloy, Cast Iron, Ti Alloy, ANSYS.*

1. Introduction

All internal combustion engines have a moving part called Piston. It is surrounded by the cylinder and piston rings are used to gas tightened the piston. Power is transferred by piston from cylinder to crankshaft through connecting rod. Piston experiences high mechanical and thermal stresses. Due to this reason, the main cause of the failure are thermo-mechanical stresses. Thus, to improve the quality and performance of the piston, it has become very important to discuss the thermal and mechanical stresses. The following points are important in customer demand point view;

a) Piston must have higher strength to resist the high pressure.

b) Piston must have less weight to resist the inertia forces.

c) Piston must provide enough bearing area to control undue wear.

d) Piston should not produce any unwanted noise.

e) Piston must be stiff making to resist mechanical distortions.

In spite of all the improvements and advancements in the technologies there exists large number of defective or damaged pistons. In the designing of pistons, thermal and mechanical fatigue plays a prominent role. Large numbers of complex fatigue tests are carried out by piston manufacturers but this involves very high cost and time. Thus, finite element analysis is carried out for stresses, temperature gradient, and deformation and fatigue characteristics. In this paper, a detailed stress analysis of piston is done under various thermal and structural boundary conditions which are applied to the finite element model of the piston. Structural, thermal and coupled thermo-mechanical stresses and temperature gradient are obtained from the analysis. Life and Factor of safety for the piston are obtained from fatigue analysis. Practical guidelines can be provided for engine piston design in order to improve performance and efficiency based on the results from the analysis.

2. Material

The material chosen for the analysis are Al Alloy 2024 T3 tempered, Al Alloy 8090 T3 tempered, Ti Alloy.

Table 1 Properties of the material

Parameters	Al Alloy 2024	Al Alloy 8090	Ti Alloy
Young's Modulus (GPa)	71	77	96
Ultimate Tensile Strength (MPa)	310	340	1070
Yield Strength (MPa)	280	210	930
Poisson's Ratio	0.33	0.33	0.36
Thermal Conductivity (w/mk)	121	95.3	640
Coefficient of Thermal Expansion (1/k)	$23x10^{-6}$	$21.4x10^{-6}$	$9.4x10^{-6}$
Density (kg/m³)	2770	2540	4620

*Corresponding author: **Mandeep Singh; Dr. (Prof) Manish Bhargava** is working as Professor & Principal

3. Model of piston

In this study, a full three-dimensional solid model of piston is introduced to the ANSYS software. The three kinds of the stress fields, named as thermal stress field, mechanical stress field, thermal and mechanical coupling stress field, can be obtained by the imposition of the boundary conditions and loads on the FEA model. Model of the piston is shown in figure 1.

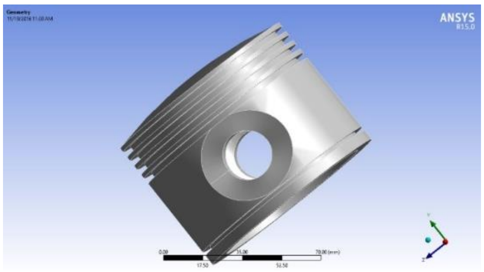

Fig.1 Model of Piston

4. Mesh generation

Finite element mesh is generated using triangular elements (133424 elements). The von- mises stress is checked for convergence. An automatic method is used to generate the mesh in the present work. The meshing of piston is shown in figure 2.

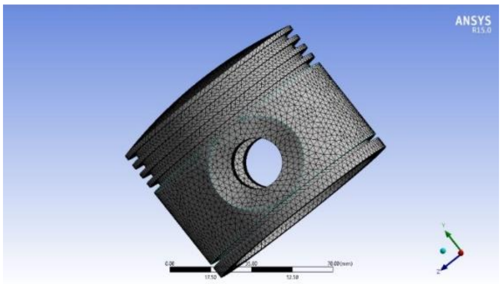

Fig.2 Meshing of Piston

5. Thermal boundary condition

In the thermal analysis for model in ANSYS, the upper part of the piston is having very high temperature because of direct contact with the gas. So, a temperature of 560 degrees is provided to the upper surface of the piston. The thermal boundary conditions of the piston are shown in figure 3,4,5.

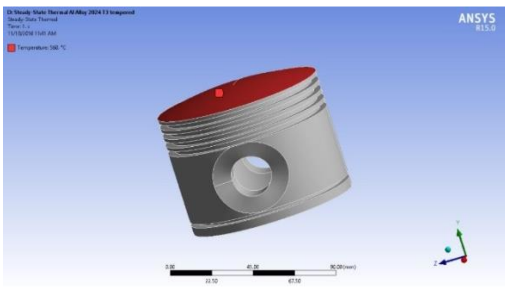

Fig.3 Thermal Boundary condition of Al Alloy 2024 T3 Tempered

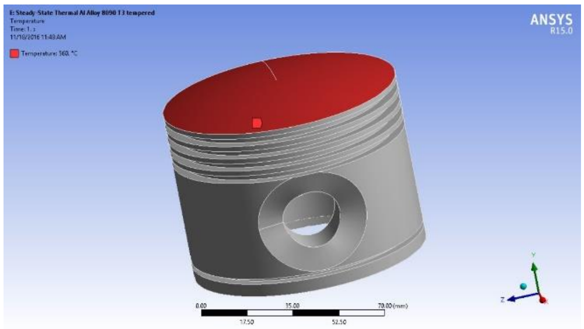

Fig.4 Thermal Boundary condition of Al Alloy 8090 T3 Tempered

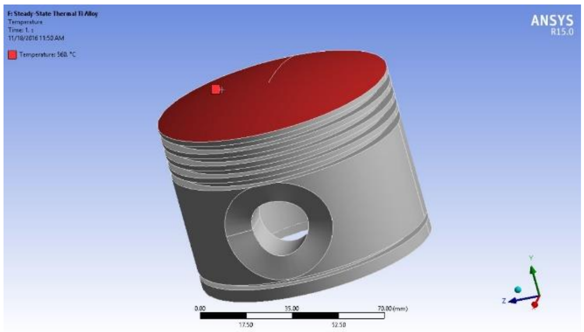

Fig.5 Thermal Boundary condition of Ti Alloy

6. Mechanical boundary condition

The maximum explosive pressure is 10 MPa, and it acts uniformly on the piston head. A fixed support has been given to the piston. The boundary conditions are as shown in figure 6,7,8.

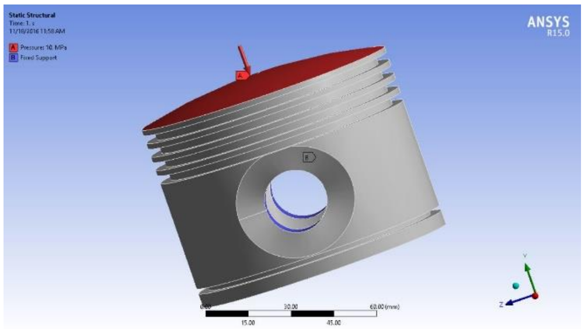

Fig.6 Mechanical Boundary condition of Al Alloy 2024 T3 Tempered

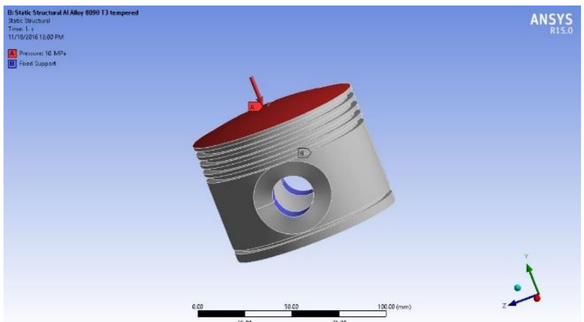

Fig.7 Mechanical Boundary condition of Al Alloy 8090 T3 Tempered

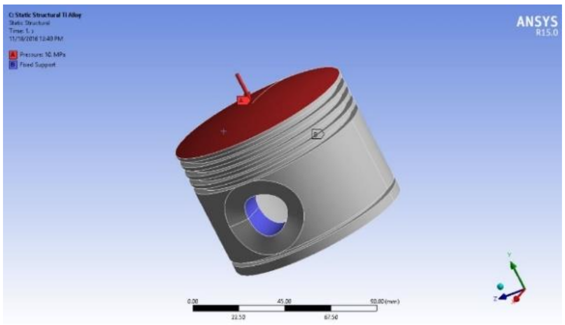

Fig.8 Mechanical Boundary condition of Ti Alloy

7. Result of the thermo-mechanical analysis

The various boundary conditions and load is imposed on the FEA model of piston. Different kinds of the stress field can be obtained. The total von-mises stresses distribution on the whole surface of piston has shown in figure 8,9,10. Figures 11,12,13 shows the total deformation.

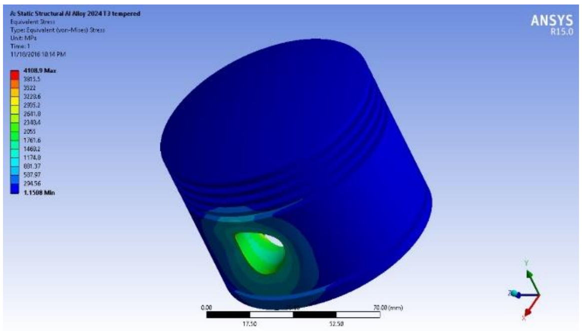

Fig.8 Total Von-Mises Stresses on Al Alloy 2024 T3 Tempered

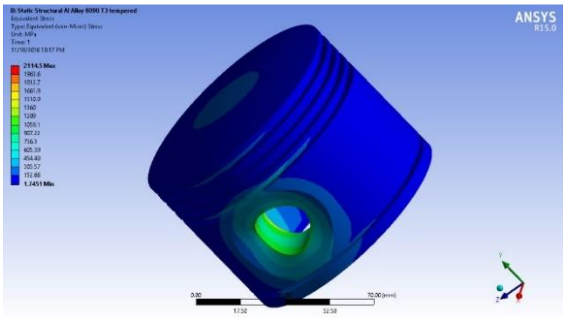

Fig.9 Total Von-Mises Stresses on Al Alloy 8090 T3 Tempered

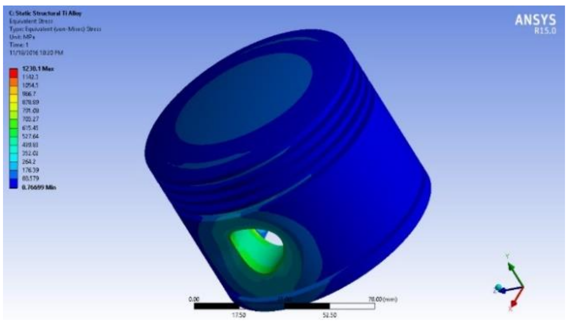

Fig.10 Total Von-Mises Stresses on Ti Alloy

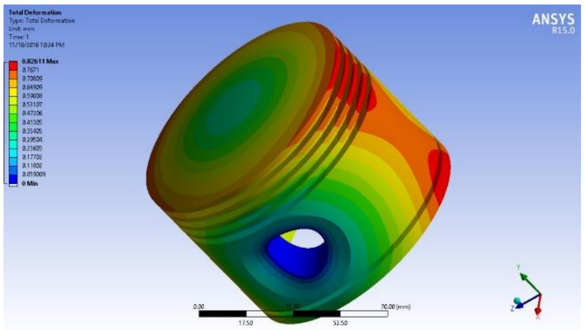

Fig.11 Total Deformation on Al Alloy 2024 T3 Tempered

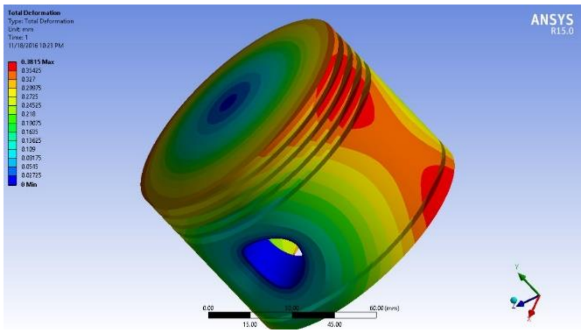

Fig.12 Total Deformation on Al Alloy 8090 T3 Tempered

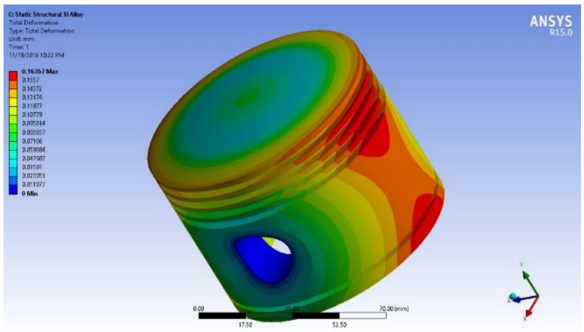

Fig.13 Total Deformation on Ti Alloy

Conclusion

It was observed that when considering all the aspects on the same conditions on different materials, Ti alloy has the minimum deformation (0.167167mm). And considering about life cycles Al Alloy 8090 has the maximum life cycles among all the materials. Considering these result layouts the best material for the design of the piston is Al Alloy 8090.

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