Modeling And Structural Analysis of A Piston of Radial Engine

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Abstract- *Piston is considered to be one of the most crucial components of an engine which coverts pressure and heat energy liberated by fuel ingestion into mechanical works. In variety of engines, radial engine is one vastly categorised type, which was used in tanks and aircrafts during the World War II. However, the usage of radial engines has drastically gone down because of its quick heating problems and occupying large area. The usage of radial engines can be brought back if the heating problems and the cross-sectional area of engine is minimised. This paper demonstrates the modelling of piston with CATIA v5R20 and structural analysis under different forces for two suitable materials, using ANSYS WORKBENCH 16.0, which shall be suitable to use in radial engines and help in increasing the performance.*

Keywords- Piston, Radial Engine, Modeling, Structural Analysis, Equivalent stress, strain

I. INTRODUCTION

Radial engines have been used in the aviation industry for a very long time where high performances were required. But when the turbine engines got underway, the radial engines turned out-dated. However, they are still used in certain groups of aircraft, including airplanes used in agriculture and by fire fighters, which implies that they are still produced [1]. One of the major drawbacks of radial engines is the high vibration and consequent heating complications. For an engine to function properly, each and every part of it plays an important role. One such part in an engine is the piston. A piston is considered to be the ‘heart’ of the engine. Therefore proper construction and working of the piston is one of the most important aspects to look onto. A piston has many constructional parameters to be focussed on for its working (figure 1)

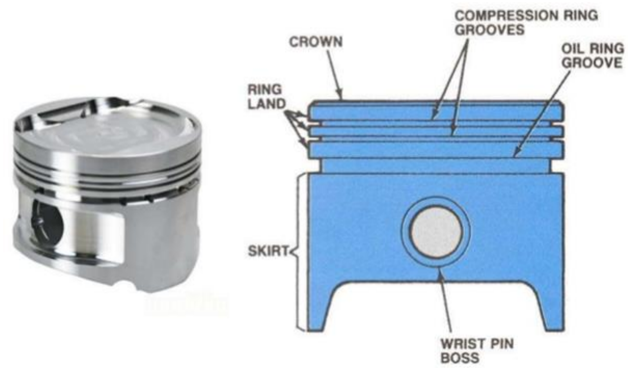


Figure 1: Parts of Piston

1.1 Piston

A piston is a reciprocating component of the engine which converts chemical ingestion of fuel into mechanical work. The purpose of the piston is to provide a means of conveying the expansion of the gases to the crankshaft via the connecting rod, without loss of gas from above or oil from below [3]. Piston is essentially a cylindrical plug that moves up and down in the cylinder. It is equipped with piston rings to provide a good seal between the cylinder wall and piston. Although the piston appears to be a simple part, it is actually quite complex from the design standpoint [2]. The piston must be as strong as possible; however, its weight should be minimized as far as possible in order to reduce the inertia due to its reciprocating mass.

II. MODELING OF PISTON

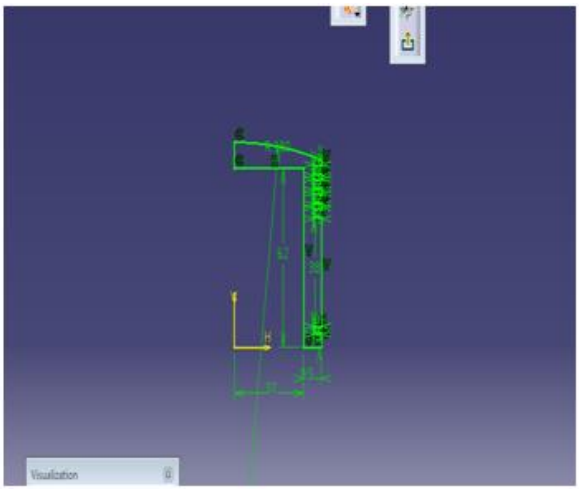
To model the piston using CATIA software v5R20, the main steps to be followed are:

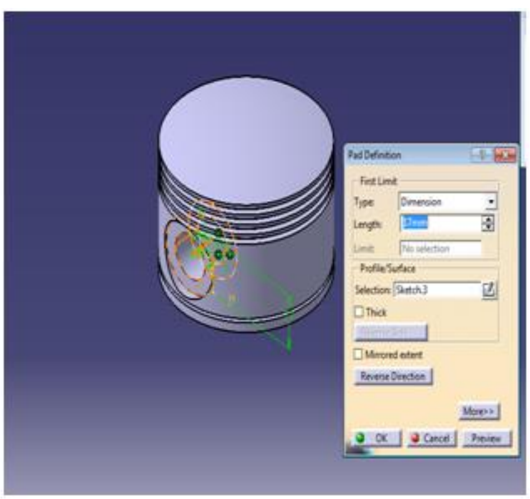
a) At first the sectioned cross section of the piston is drawn in the sketcher workbench in the CATIA software.
b) The material is added to it with the help of pad option.
c) The circular cross section of the piston is obtained with the help of revolve option in the part design workbench.

The modelling of the piston is shown in below images and the dimensions of the required modelled piston are given below Table1.

Table 1: Dimensions of the modelled Piston

S.NO	PROPERTY	DIMENSION
1	Bore Radius	180mm
2	Skirt	45mm
3	Piston Length	65mm
4	Pin Hole Radius	18mm
5	Width of Piston	93mm
6	Diameter of inside hole	22mm
7	Wrist Pin Length	17mm





III. STRUCTURAL ANALYSIS

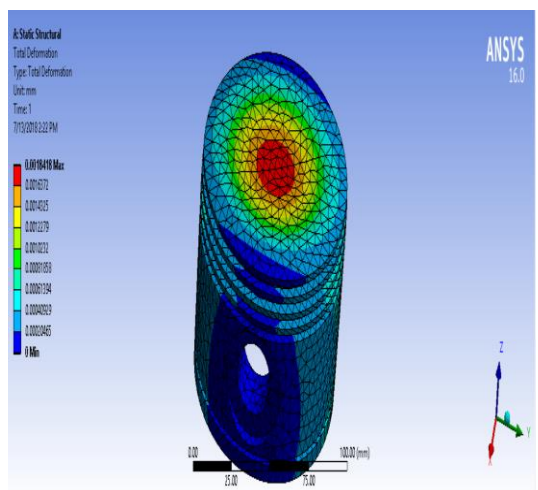
The piston is now checked for its structural transformations with different forces acting on it. Pistons are generally made of Aluminium alloys. Two out of most common aluminium alloys used for the purpose are the Al_a2024-T3.BFT_MPL (Al_a2024) and the Al_a6061-T6.BFT_MPL (Al_a6061). The chemical composition of these two alloys are mentioned below (table 2)

Table 2: Chemical composition of both alloys

S.NO	CHEMICALS	Al_a2024 (% composition)	Al_a6061 (%composition)
1	Aluminium(Al)	90.7-94.7	95.8 - 98.6
2	Chromium(Cr)	0.1	0.04 - 0.35
3	Copper(Cu)	3.8-4.9	0.15 - 0.4
4	Iron(Fe)	0.5	0.7
5	Magnesium(Mg)	1.2-1.8	0.8-1.2
6	Manganese(Mn)	0.3-0.9	0.15
7	Silicon(Si)	0.5	0.4 - 0.8
8	Titanium(Ti)	0.15	0.15
9	Zinc(Zn)	0.25	0.25

To begin with the analysis, the two materials are first added in the materials library in the engineering data of Structural Analysis in ANSYS 16.0 and cylindrical support has been given on the pin hole section of the piston after meshing. Three forces of magnitudes 500N, 1000N and 1500N has been acted on the crown of the piston to check its structural transformations like total deformation, equivalent elastic strain and stress for both the aluminium alloys used. Below images shows the observations of the experiment.

In the figures below (2, 3, 4), 500N force is applied on both the alloys i.e Al_a2024(left) and Al_a6061(right) and the total deformation, elastic strain and stresses are compared



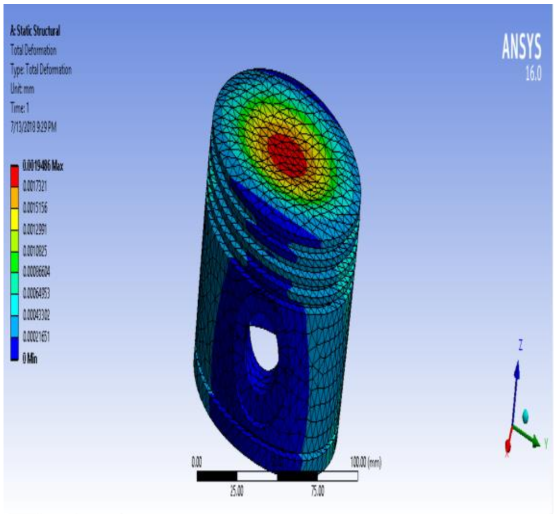


Figure 2: Total deformation occurred on both alloys with an application of 500N force

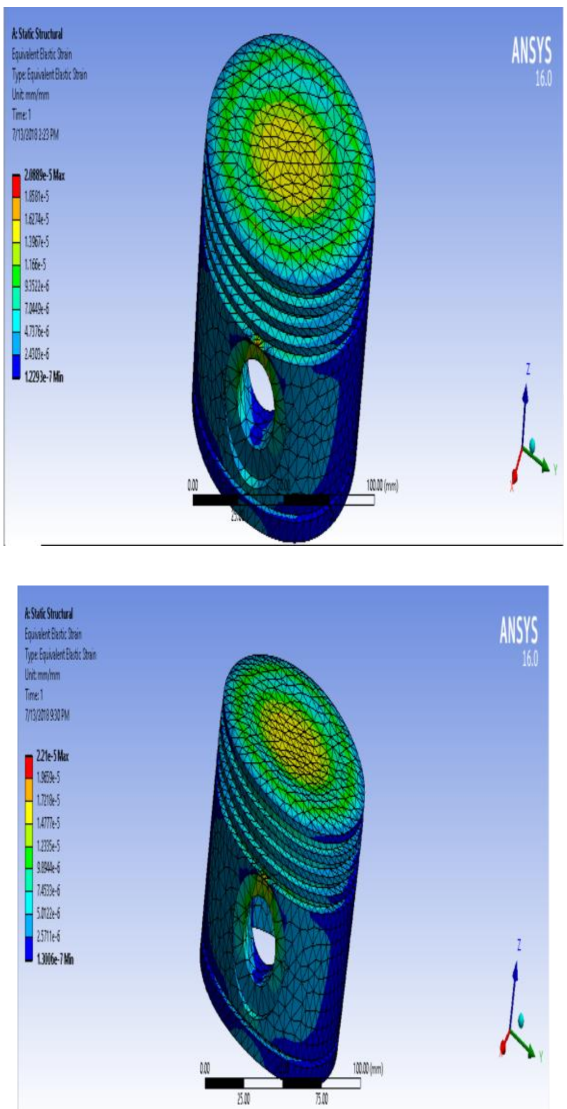


Figure 3: Equivalent Elastic Strain occurred on both alloys with the application of 500N force

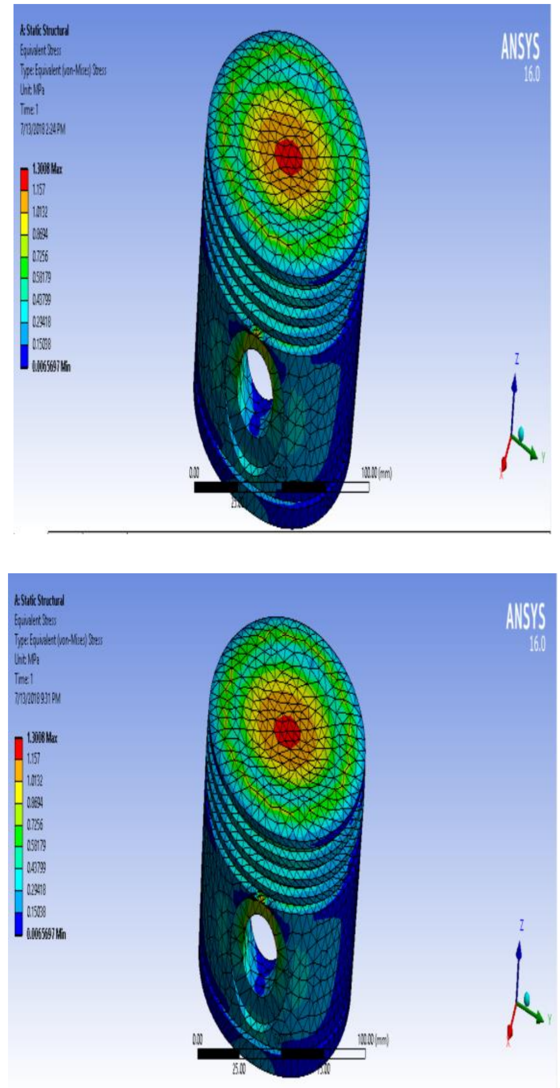
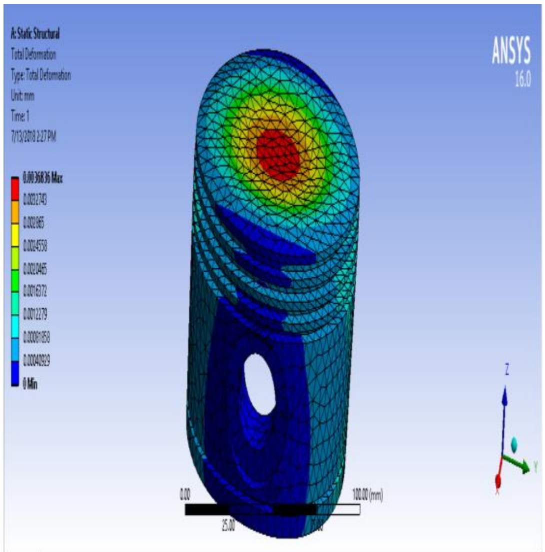


Figure 4: Elastic Stress occurred on both alloys with the application of 500N force

In the figures below (5,6,7), 1000N force is applied on both the alloys i.e Al_a2024(left) and Al_a6061(right) and the total deformation, elastic strain and stresses are compared



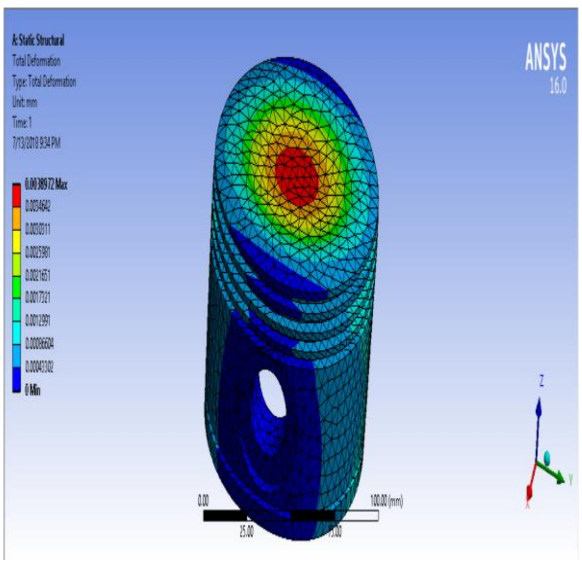
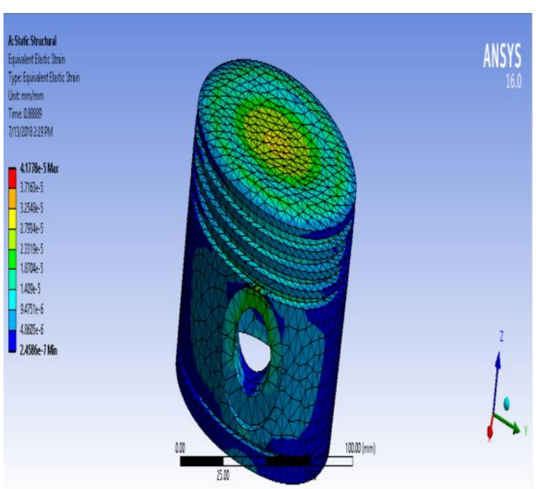


Figure 5: Total deformation occurred on both alloys with an application of 1000N force



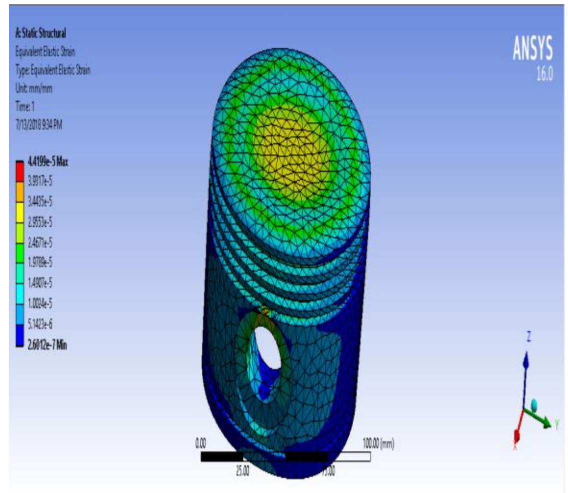
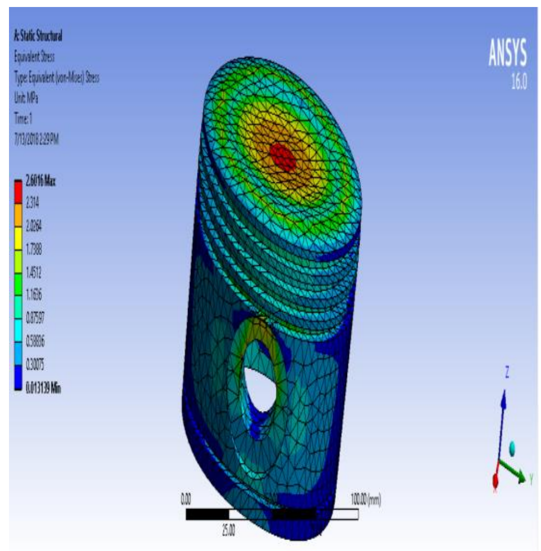


Figure 6: Equivalent Elastic Strain occurred on both alloys with the application of 1000N force



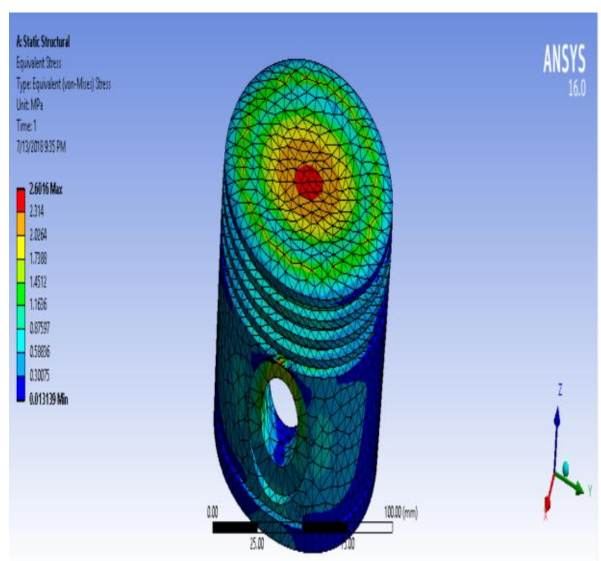


Figure 7: Elastic Stress occurred on both alloys with the application of 1000N force

In the figures 8,9,10 force of 1500N is applied on both the alloys i.e Al_a2024 (left) and Al_a6061 (right) and the total deformation, elastic strain and stresses are compared

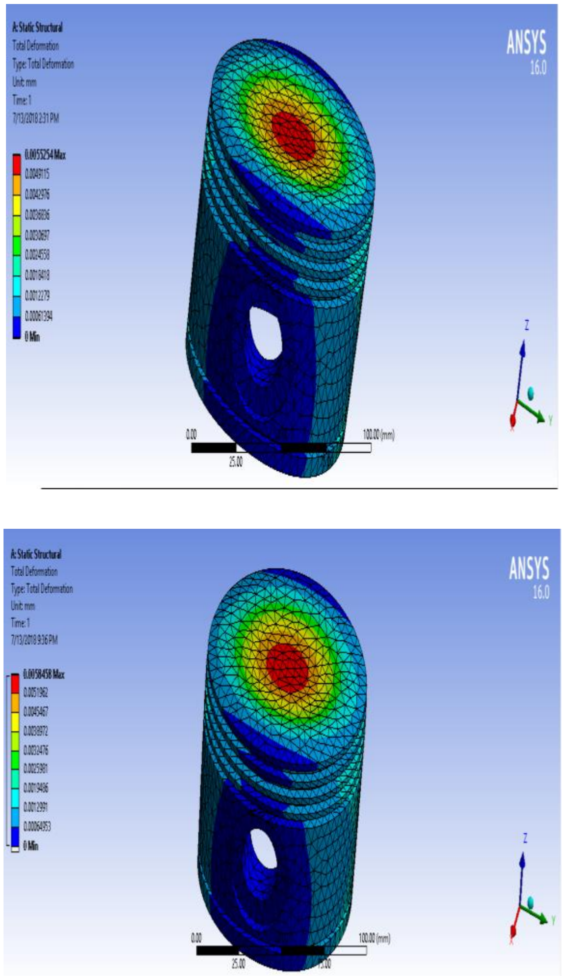
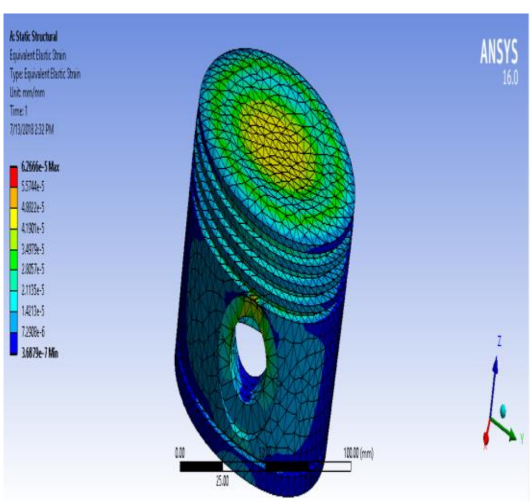


Figure 8: Total deformation occurred on both alloys with an application of 1500N force



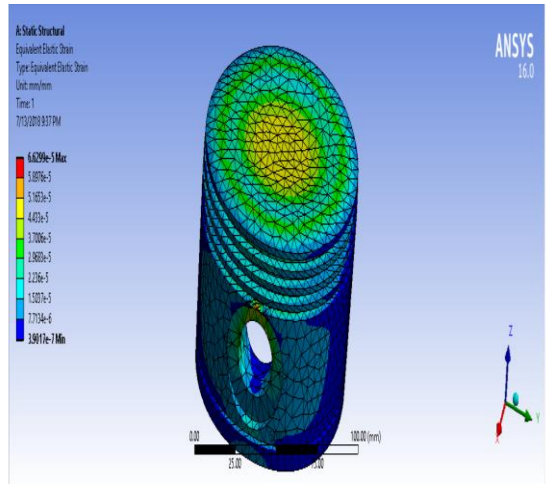


Figure 9: Equivalent Elastic Strain occurred on both alloys with the application of 1500N force

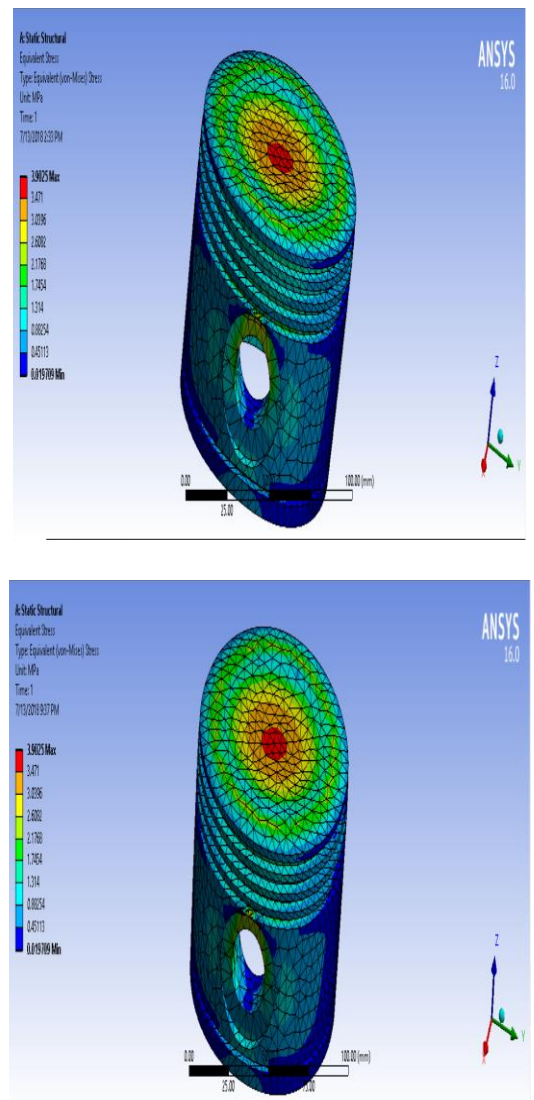


Figure 10: Elastic Stress occurred on both alloys with the application of 1500N force

IV. RESULTS

By observing the analysis on both the alloys we can list the results as follows:

Table 3: Comparison of Maximum Total Deformation for both the alloys

S.NO	FORCE	Al_a2024 (Max Total Deformation)	Al_a6061 (Max Total Deformation)
1	500N	0.00184mm	0.00194mm
2	1000N	0.00368mm	0.00389mm
3	1500N	0.00552mm	0.00584mm

Table 4: Comparison of Maximum Equivalent Elastic Strain for both the alloys

S.NO	FORCE	Al_a2024 (Max Equivalent Elastic Strain)	Al_a6061 (Max Equivalent Elastic Strain)
1	500N	2.0889e-5	2.21e-5
2	1000N	4.1778e-5	4.418e-5
3	1500N	6.266e-5	6.629e-5

Table 5: Comparison of Maximum Equivalent Stress for both the alloys

S.NO	FORCE	Al_a2024 (Max Equivalent Stress)	Al_a6061 (Max Equivalent Stress)
1	500N	1.3001MPa	1.3008MPa
2	1000N	2.6011MPa	2.6016MPa
3	1500N	3.9019MPa	3.9025MPa

V. CONCLUSIONS

Finite element analysis is effectively utilized for addressing the conceptualization and formulation for the design stages. In the present work, Static Structural Analysis have been performed on the Piston using ANSYS WORKBENCH 16.0. Based on the analysis results of the present report, the following conclusions can be drawn:

a) The Total Deformation was found to be least for Aluminium Alloy Al_a2024 when compared to Aluminium Alloy Al_a6061 under same force and support conditions.
b) The Equivalent Elastic Strain was found to be less for Aluminium Alloy Al_a2024 when compared to Aluminium Alloy Al_a6061 under same force and support conditions.
c) The Equivalent Stress was found to be less for Aluminium Alloy Al_a2024 when compared to Aluminium Alloy Al_a6061 under same force and support conditions.
d) Piston is safe under the given loading conditions.

From the above conclusions we have drawn that Aluminium Alloy Al_a2024-T3.BFT_MPL (Al_a2024) is the most suitable material for the piston which can sustain under higher conditions as well which directly affects the performance of the engine in a positive way.

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