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STATIC STRUCTURAL ANALYSIS OF LANDING GEAR FOR DIFFERENT TITANIUM ALLOYS

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Abstract - *The landing gear is an assembly of various structural members which supports the aircraft frame. It also consists of energy absorption components and brakes. It is one of the major components of the aircraft design. Landing gear has to withstand heavy load during landing and take-off without any detrimental deformation to its structure and provide comfort to the passengers. The material used for landing gear must have sufficient strength to withstand such heavy landing and take-off loads. Pure titanium and titanium alloy represented as Ti-6Al-4V are generally used for shock absorber struts. This paper tells about structural analysis of outer cylinder of oleo pneumatic shock absorber modelled in CREO 3.0 and compares the results of three titanium alloys for shock absorber on the basis of static structural analysis performed in ANSYS 19.2.*

***Key Words*: Structural analysis, Titanium alloy, Oleo cylinder, Deformation, Stress.**

1. INTRODUCTION

The landing gear is most vulnerable to failure as landing produces very high impact loads on this structure. These loads generated, which are significantly high, may be the determining parameters for designing of the main body of an aircraft called fuselage. A typical pneumatic shock absorber strut uses energy absorbing elements like nitrogen and a hydraulic fluid to absorb and dissipate shock loads. Shock strut is constructed of two cylinders that collapse in to each other by sliding and are closed at external ends. The outer or the Oleo cylinder is fixed to the aircraft while the inner cylinder if free to rotate and move up and down within the outer cylinder. Constrained motion is provided to these cylinders by 'torque links' which themselves are connected by the help of torque arm as pin joint. These torque arm connects the inner and steering collar that are located at the outer cylinder.

Titanium and titanium alloys have proven their worth over the decades. They are technically superior for various applications including aerospace industries and marine equipment. They are also utilized in commercial products due to their cost effectiveness [1]. Titanium alloys have great static strength, fatigue strength and fracture toughness. Moreover, titanium alloys have replaced steel-based components like frames and joints which requires more strength, thus reducing the overall weight. Vinicius A. R. Henriques discussed some remarkable properties of titanium, namely, composite compatibility and heat resistance[17].

TIMETAL 834 is castable, and hence require minimal tooling. It also has good weldability with all the existing welding techniques for titanium, in addition to good forgeability. It is being used as blades in aeroengines. Another alloy of titanium, Ti-7Al-4Mo which is mainly used as compressor blades, possess higher strength and creep resistance than Ti-6Al-4V. Aluminium, which is the most commercially used alpha stabilizer is added to titanium. It contributes to increase the tensile strength and creep strength along with additional advantage of low density. Molybdenum is a beta stabilizer, which provides the advantage of lower deformation and makes it heat treatable.

Material of the shock absorber strut plays a pivotal role in providing strength to the whole landing gear assembly of the aircraft. In this paper outer cylinder of the shock absorber is analysed for three different titanium alloys to compare the results. The material used in landing gear should be light weight and be able to absorb shocks. The objective is to compare other two titanium alloys with the commonly used Ti-6Al-4V. All the analysis related to this paper is done in ANSYS 19.2.

2. METHODOLOGY

The analysis of landing gear will be done for different Titanium alloys. The landing gear with different alloys will be tested by applying a force during the landing under static structural analysis in ANSYS 19.2. Then the total deformation, maximum principal stress and strain were calculated for different alloys after applying the boundary conditions and load.

2.1 Material

Titanium alloys have high specific strength among all the metallic materials below 400°C. Though they are light weight, they provide strength and resistance to corrosion [2]. Ti-6Al-4V is the most commonly used material in aerospace industries. The study of different titanium alloys is carried out and two titanium alloys (Ti-7Al-4Mo and TIMETAL 834) are selected for landing gear assembly and are tested for same load and boundary conditions.

Table 1. Material specifications for landing gear (Source: MatWeb, July 2019)

Material specifications				
Properties	Ti-6Al-4V	Ti-7Al-4Mo	TIMETAL 834	Units
Density	4.43	4.48	4.55	g/cm^3
Young's Modulus	113.8	116	120	GPa
Poisson's Ratio	0.342	0.32	0.32	-
Tensile Yield Strength	880	827	930	MPa
Tensile Ultimate Strength	950	896	1050	MPa
Coefficient of Thermal Expansion	8.6	9.50	10.6	µC^{-1}

2.2 Geometry

The model of landing gear is made in CREO 3.0 as a part file. Then the model is imported into ANSYS after converting PART file into IGS format.

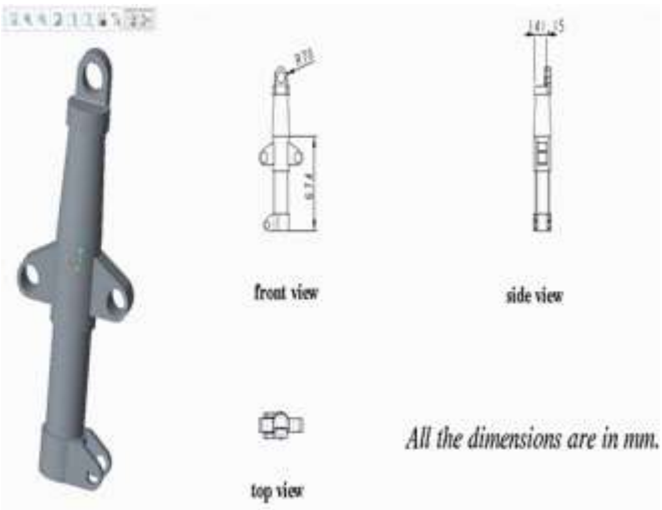

Figure 1. CAD model (left) and Oleo cylinder detailed drawing (right)

2.3 Meshing

In order to get accurate results, it is required to have smaller aspect ratios and hence tetrahedron meshing is used for outer cylinder as it provides aspect ratio close to unity. It provides a greater number of elements in the mesh. Therefore, a patch conforming method is utilized to generate Tetrahedron meshing to carry out the calculations. An element size of 12mm is used for generating mesh elements. A total of 31699 Nodes and 17538 elements were generated.

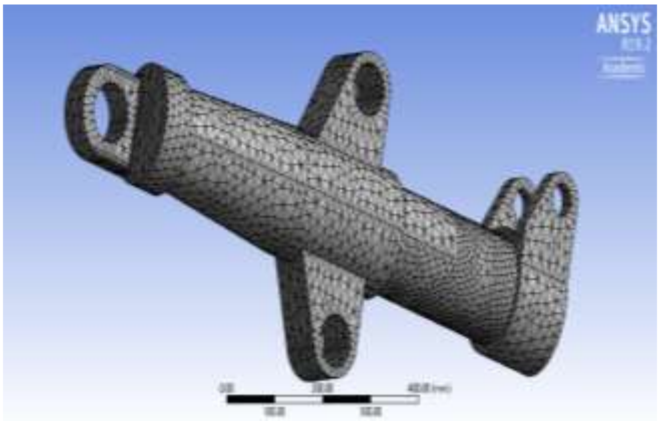

Figure 2. Tetrahedron meshing for Oleo cylinder with 12mm element size

2.4 Boundary Conditions

Two boundary conditions are applied. First, fixed support at the top end of the component. Second, a force of 15KN at face at bottom end.

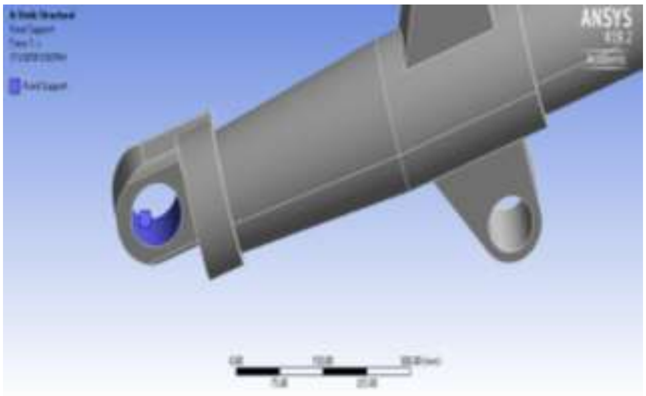

Figure 3. Fixed support at top

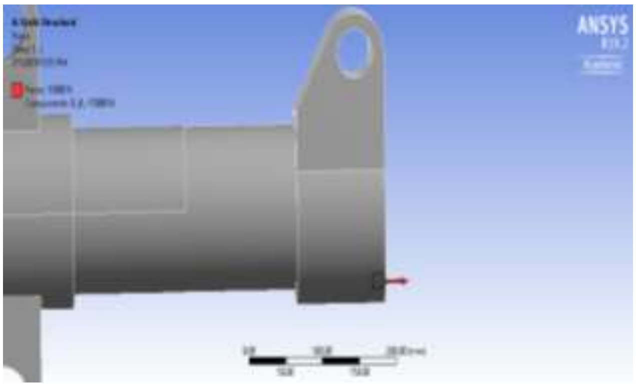

Figure 4. Force at bottom end

The landing gear is subjected to a very large magnitude of fluctuating load which generates stress in the component. This is approximated to a static load to ease the calculations. Total deformation, maximum principal stress, strain is calculated by using ANSYS solver. Details are provided in Table 2.

3. RESULTS

The structural behaviour of Oleo cylinder has been studied for three different Titanium alloys. The results are tabulated and compared. The potential of Ti-6Al-4V material for parts requiring more strength in airframes and other aerospace applications has been an area of interest to researchers.

TIMETAL 834 is a near alpha titanium alloy offering increased tensile strength and creep resistance up to 600°C along with increased fatigue strength. Figure 5, 6, 7 compares the total deformation for the three alloys. TIMETAL 834 holds higher yield value than other two materials. So, for given boundary conditions as stated above, TIMETAL 834 shows least total deformation and maximum principal stress. Hence, TIMETAL 834 holds a good performance.

Figure 8, 9, 10 compares the maximum principal stress for the three alloys. Maximum principal stress contour clearly shows that principal stress is high for Ti-6Al-4V compared to other Titanium alloys analysed.

Deformation

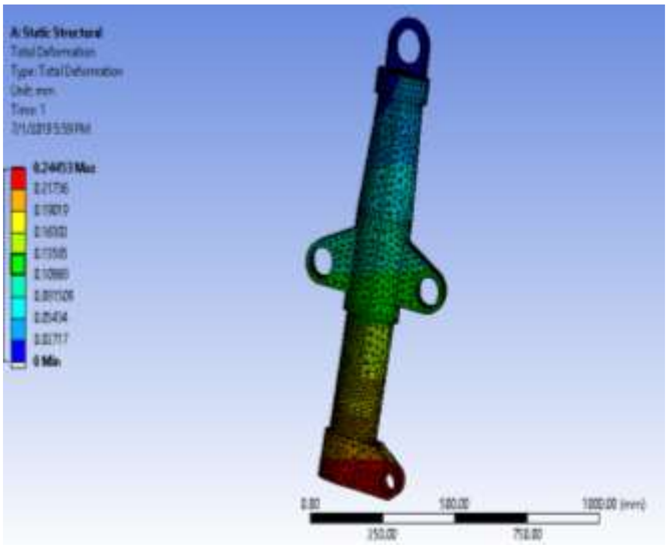

Figure 5. Deformation for Ti-6Al-4V

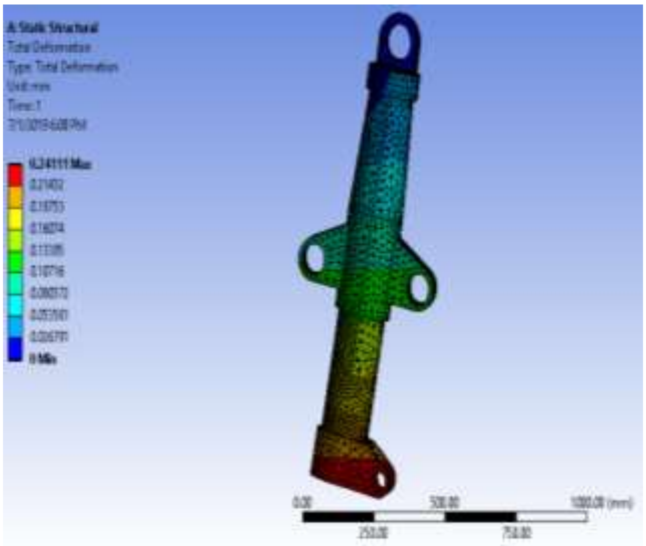

Figure 6. Deformation for Ti-7Al-4Mo

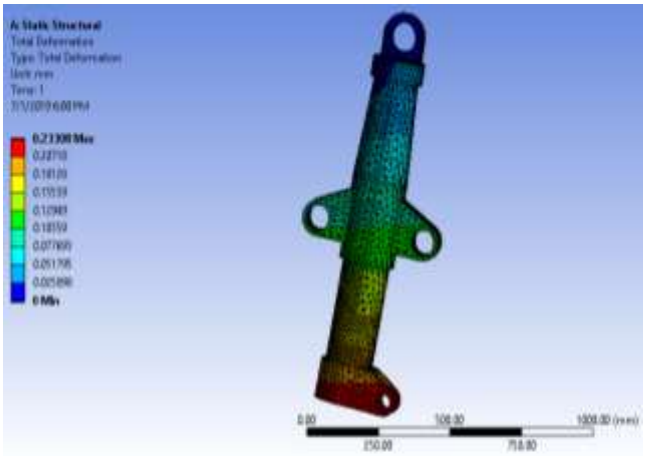

Figure 7. Deformation for TIMETAL 834

Maximum principal stress

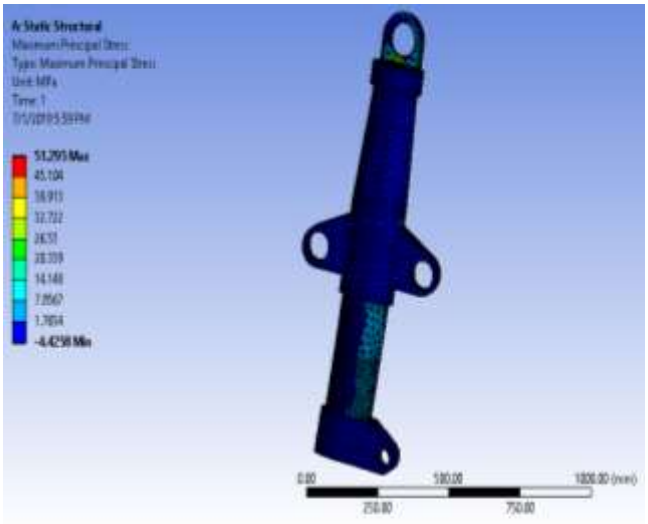

Figure 8. Maximum principal stress for Ti-6Al-4V

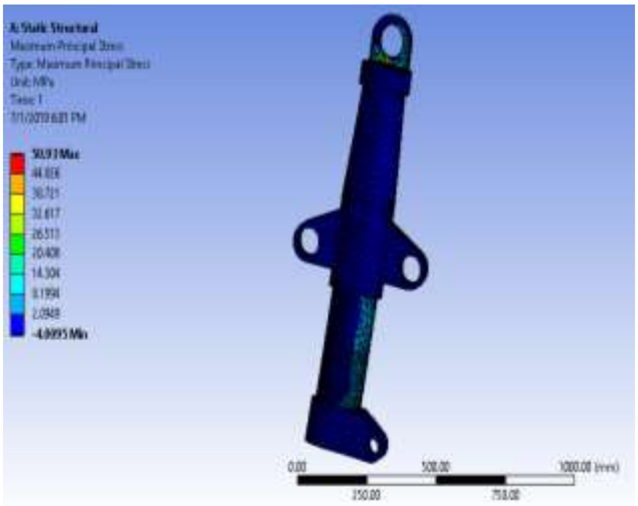

Figure 9. Maximum principal stress for Ti-7Al-4Mo

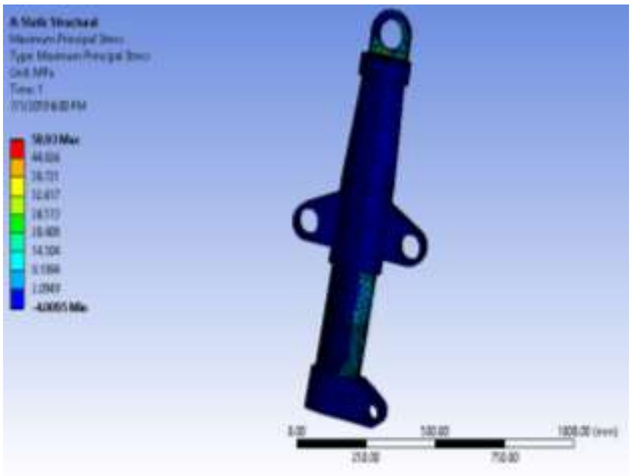

Figure 10. Maximum principal stress TIMETAL 834

Equivalent elastic strain

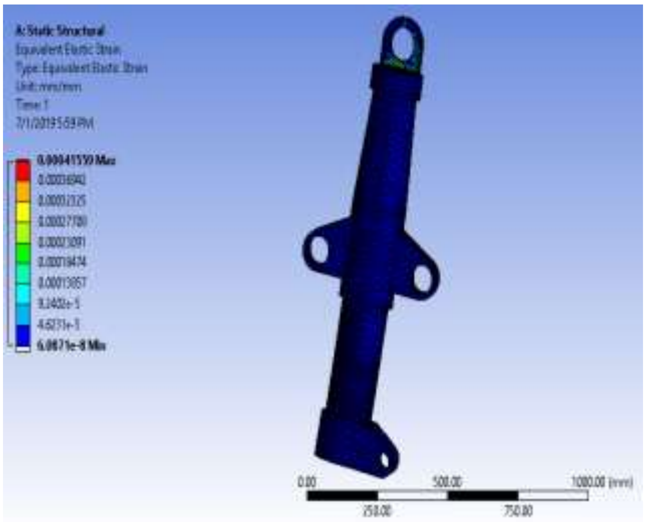

Figure 11. Equivalent elastic strain for Ti-6Al-4V

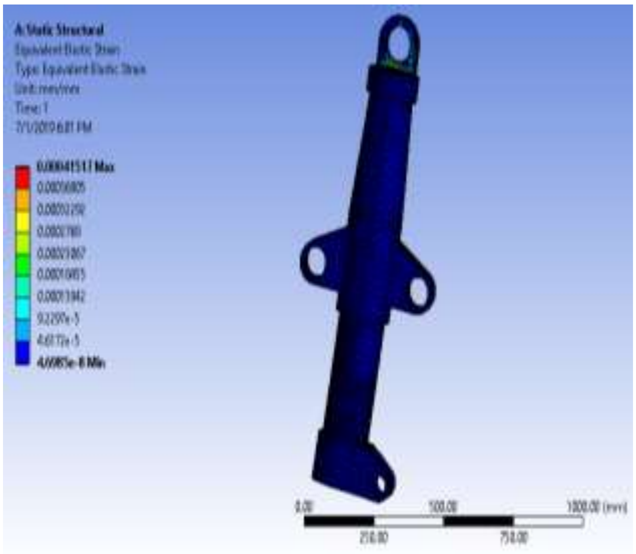

Figure 12. Equivalent elastic strain for Ti-7Al-4Mo

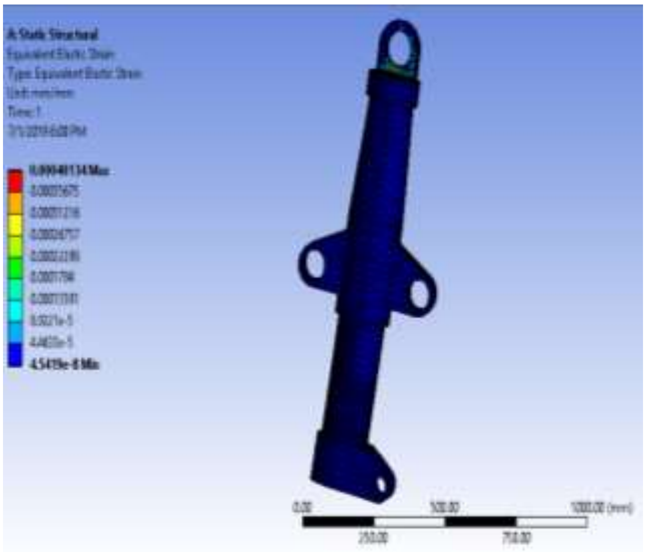

Figure 13. Equivalent elastic strain for TIMETAL 834

Table 2. ANSYS results

Properties	Ti-6Al-4V	Ti-7Al-4Mo	TIMETAL 834
Total deformation	0.244	0.241	0.233
Maximum principal stress	51.295	50.93	50.93
Equivalent elastic strain	0.00041	0.00041	0.00041

4. DISCUSSION

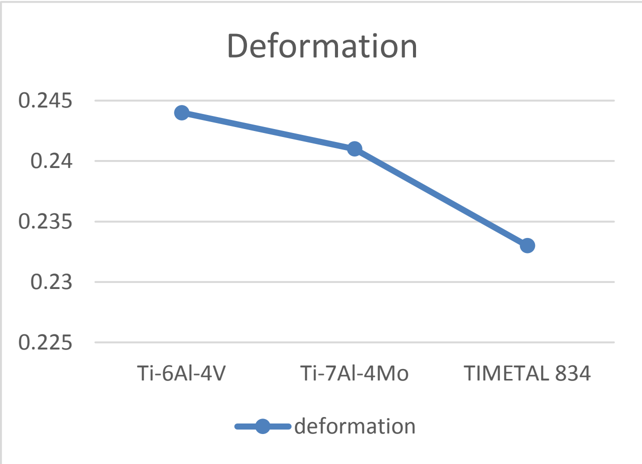

Figure 14. Deformation plot

The landing gear is required bear loads without any permanent deformation and the stresses should be below critical yield point to meet FFA regulations.

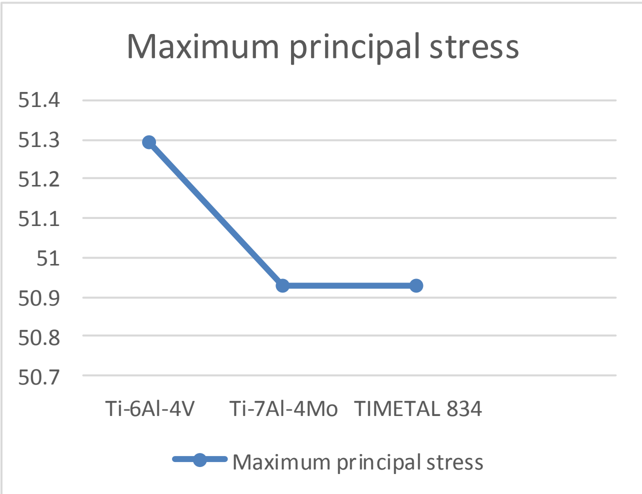

Figure 15. Maximum principal stress plot

The maximum value of normal stress is called maximum principal stress. It basically combines both normal stresses and shear stresses. All structural members of an aircraft are subjected to one or more alternate stresses. Therefore, the strength of aircraft materials must be great enough to withstand force of varying stresses.

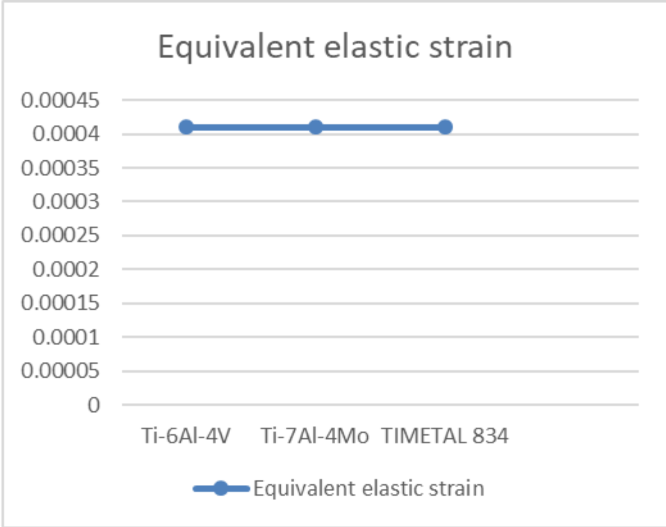

Figure16. Equivalent elastic strain plot

Elastic strain is a type of strain in which a distorted body can return to its original shape and size when distorting force is removed. Elastic strain can be understood as distortion of crystal lattice and not a dislocation in lattice. The materials used for aircraft components should be tough enough to withstand the elastic strains induced due to alternating stresses.

5. CONCLUSIONS

The Oleo cylinder is modelled in CREO 3.0 and analysed in ANSYS 19.2 using static structural analysis as the accuracy of solutions depend upon quality of mesh. A tetrahedron mesh has been used to ensure accurate solution. Then the results have been compared for three different materials Ti-6Al-4V, Ti-7Al-4Mo and TIMETAL 834. The results have been compared on the basis of parameters namely total deformation, maximum principal stress and equivalent elastic strain.

Material Ti-7Al-4Mo and TIMETAL 834 shows lesser total deformation and stress than Ti-6Al-4V under similar conditions. The deformation and stress plot show that TIMETAL 834 has better results compared to other two materials analysed. The deformation of oleo strut for same loading condition has reduced by 4.508 percent for TIMETAL 834 compared to the commonly used Ti-6Al-4V. Also, the stress for same load conditions has reduced by 0.711 percent. So, application of TIMETAL 834 will help improve the life the strut and avoid landing gear damage.

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