

# STATIC STRENGTH AND STABILITY ANALYSIS OF A LANDING GEAR STRUT

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**Abstract:** Landing gear strut is a dynamic structural unit element of an aircraft which allow to launch and land safely on the ground. A diversity of landing gear strut design are used depending on the compartment and size of an aircraft. The most frequent type is the oleo strut plan with one nose landing gear unit and two main landing gear units. Even during a standard landing brief heavy loads (equal to the weight of an aircraft) are to be taken up by the landing gear unit. In turn connection are to be provided such that such heavy concentrated loads are first majority by the airframe and after diffused to the circle areas. Average heavy concentrated loads are common through the struts. Therefore design of a strut element against failure under the static and dynamic load conditions assumes importance in the growth of an aircraft building. This project deals with the design and analysis of a normal landing gear strut characteristic of a landing gear attachment of a undersized transfer airplane. The design will give safety against 1) static failure of the landing strut, 2) Stability of the strut and 3) frequency analysis of a strut. The types of loadings consider here are axial loads. Aircraft design practices will be used. A FEA will be transport out to compare the design the calculations and to determine the stress absorption factor in order to evaluation the maximum local tensile stress which will be equate under limit and ultimate loading conditions. Also buckling load factor calculated for stability check.

**IndexTerms - Finite element analysis, frequency, Buckling analysis, Vonmises stress, Uni-Graphics, Nastran**

## I. INTRODUCTION

Landing gear is one of the most meaningful central structural member of the aircraft. Landing gear allow the airplane to launch and landing on the ground. Landing gears arrangement through are significantly different. A variety of landing gear framework and types are in use today aircrafts. The most common type being used are tri-cycle arrangement with a nose landing gear and the main landing gears. Impact loads during landing are the main plan loads for the landing gear design and analysis. Landing gears should also be agree for varied other ground handling loads in the expressive requirements. The landing gear resist the ground loads and take up the impact loads energy and diffuses the load to the environment building block attachment. Aircraft landing gears stay the total weight of an aircraft during landing and any ground assignment. These are inclined to central structural building block of the aircraft. Take the type of gear hinge on the aircraft plan and its intended usage. Most of the landing gears have wheels to smooth operation to and from hard surfaces paths, such as airport runways. Other landing gear foreground skids for this objective, such as those found on helicopters, balloons gondolas, and in tail area of few tail dragger aircraft. Figure 1 shows the assembly of landing gear.

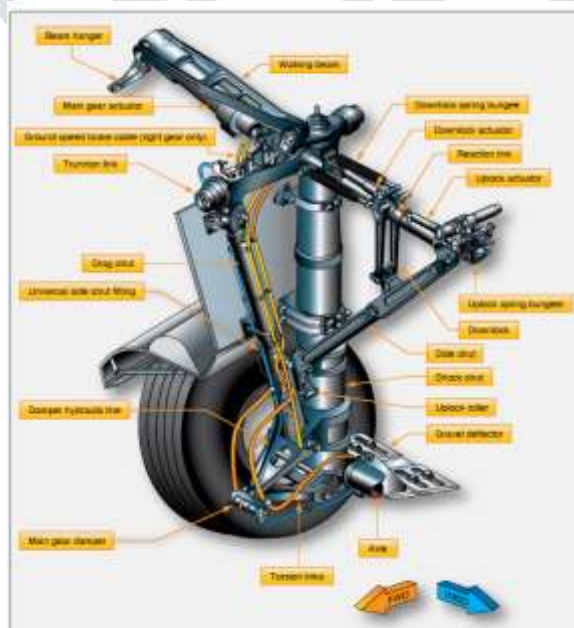


Figure 1 Landing Gear assembly

In the landing gear complex true shock attention occurs when the shock energy of float impact is converted into the heat energy, as in a shock strut float gear. It is the most common method of landing shock challenge in the aviation. This is used on

aircraft of all sizes. Impact loads struts are self-contained hydraulic units that stand up for an aircraft while on ground and cover the building during float. They must be check and serviced regularly to ensure correct brief before perform.

There is multiplicity of different plan of shock struts, but most familiar operates in a similar manner. The following discussion is general in overall. A typical pneumatic or hydraulic shock strut uses compressed air or nitrogen combined with hydraulic fluids to take up and free out shock loads form the ground. It is finally related to as an air or oil or oleo strut. An impact strut is construct of two telescoping cylinders that are closed on the external stop.



Figure 2 Strut 3D view

The upper cylinder is set to the aircraft building and does not move. The lower cylinder tube is called the piston and is free to slide in and out of the upper cylinder. Two chambers are formed. The lower chamber always filled with hydraulic fluids and the upper chamber is pack with compressed air or any nitrogen. An opening is purposeful between the two cylinders to deliver an approach for the fluid from the bottom take to enter the top cylinder chamber when the strut is compressed by the impact loads. Most impact struts are accept a metering pin alike to that shown in Figure 2.

## 1.2 Materials

Landing gear strut can be made out of several different types of material. The materials used for the camshaft depends on the quality and type of engine being manufactured. In this paper calculations compared with two materials.

### 1.2.1 300M steel

300M is a chromium-nickel-molybdenum is a equatorial alloy, vacuum melted a steel, parallel to 4340, but with the extension of vanadium and a richly silicon content And Also referred to as a "Modified 4340," 300M offers a mixture of toughness and ductility at a richly-strength levels. 300M is a profound hardening steel with an awesome torque properties, richly fatigue and creep feature, and conserve its energy at decline a richly temperature. Essentially it is a qualified AISI 4340 steel with a silicon, vanadium and put down greater through the carbon and molybdenum content than 4340. 300M has a very good mixture of strength (280 to 305 ksi), toughness, fatigue strength and nicely ductile. It is a through hardening alloy. 300M can be welded by fusion way or by flash opposition welding. Approve through the procedure must be used for the fusion of welding, including pre and post-heating practice, because the alloy will air harden due to heat input from welding. Following welding it is need to re-normalized or re-normalize and tempered priority to the final hardening heat treatment. The Table 1 shows the mechanical and material properties of 300M steel.

Table 1 steel 300M properties

300M steel		
Properties	Metric	English
Tensile Strength, Ultimate	1931 MPa	280 ksi
Tensile Strength, Yield	1586 MPa	230 ksi
Percent Elongation	7 %	
Thermal Expansion 20°C (68°F)	11.34µm/m-°C	6.300µin/in-°F
Specific Heat Capacity	0.448 J/kg-°K	0.107 BTU/lb-°F
Thermal Conductivity	37.49 W/m-°C	260.2 BTU-in/hr-ft2-°F

### 1.2.2 Titanium Alloy

The expensive strength, low weight ratio and payable corrosion resistance built-in to be titanium and its alloys has led to a exactly and diversified break down of successful applications which are demand richly levels of reliable interpretation in surgery and medicine as well as in aerospace, automotive, chemical plant, power generation, oil and gas extraction, sports, and other considerable industries. In the bulk of these and other engineering applications titanium has displace heavier, less applicable or less cost-effective materials. Cute with titanium taking all representative into account has result in a reliable, economic and more durable systems and building block, which are many status have significant exceeded account and service life expectance. Titanium is available in several dissimilar grades. Unmixed titanium is not as strong as the dissimilar titanium alloys. The following table 2 shows the mechanical properties of Titanium alloy.

Table 2 Titanium properties

Titanium alloy		
Property	value	Units
Tensile Strength MPa (ksi)	897 (130)	1000 (145)
0.2% Proof Stress MPa (ksi)	828 (120)	910 (132)
Elongation Over 2 Inches %	10	18
Reduction in Area %	20	
Elastic Modulus GPa (Msi)		114 (17)
Hardness Rockwell C		36
Tensile Strength MPa (ksi)	897 (130)	1000 (145)
0.2% Proof Stress MPa (ksi)	828 (120)	910 (132)

## 2. Finite Element modeling of a Landing Gear strut

In this chapter main focus is on design and analysis of Landing gear strut.UG is used for developing the Geometry and Hyper mesh is used for finite element modeling.

### 2.1 Procedure to develop strut in Uni-Graphics

Step:-1

Gateway application in uni-graphics:-

File → Select new on it → Select model click → Select name strut → Click ok

It is pre-request to all other application. Those applications such as modeling NX / sheet metal Shape studio, drafting, manufacturing, assembly, etc.

Step:-2

Menu → Select insert → Select sketch in task environment click on it → Select plane method in existing plane → Select xz plane of datum co-ordinate system → Click ok

Step:-3

Select menu → Select insert → Select curve → Select options line, arc, circle, etc. → Draw sketch → Click ok.

Step:-4

Select → Select insert → Select design feature → Select sketch option → Select extrude option → Click ok

Step:-5

Select menu → Select insert → Select curve → Select options circle → Draw sketch → Click ok

Step:-6

Select menu → Select insert → Select design features → Select sketch in circle option → Select extrude option → Click ok

Step:-7

Select menu → Select insert → Select curve → Select options circle → Draw sketch → Click ok

Step:-8

Select menu → Select insert → Select design features → Select sketch in circle option → Select extrude option → Click ok

Step:-9

Select menu → Select insert → Select design features → Select hole → Select extrude option → Click ok



Figure 3 3D Model strut

3D Cad model is ready for proceeding next step of computer aided analysis.

### 2.2 Finite Element modeling in Hypermesh

There are mainly 3 stages to complete the analysis in Hypermesh

- 1) Preprocessing
- 2) Solution
- 3) Post processing

#### 2.2.1 Meshing

The following steps provide the basic workflow for using the Meshing application as part of structural analysis.

1. Start the hyper mesh from program files and Select the appropriate solver in the profiles, such as Nastran.
2. Select file and choose import geometry from the menu bar and browse the geometry file from the directory then press ok. Now . You can see the geometry of strut as shown below. Initially it display in wire frame choose solid face icon for smooth shaded View
3. Create component name as strut and select the 3d mesh panel and choose tetra mesh tab from the tool bar panel and select the Component then select mesh icon.
4. Create RBE elements for constrains and loading positions.
5. Now you can see the meshed model of strut with tetrahedral elements in figure 4.

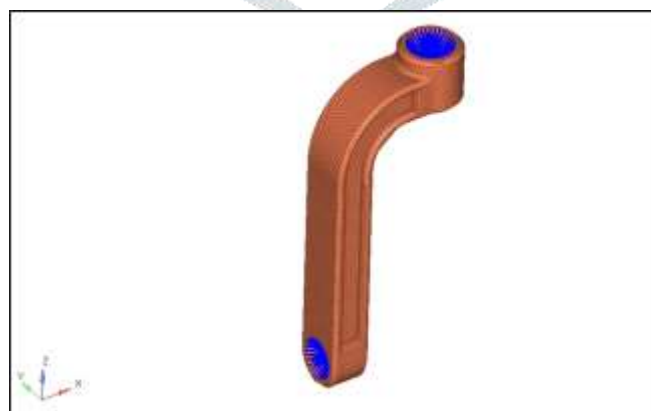


Figure 4 meshed model

#### 2.2.2 Materials and properties

Hypermesh has greatest advantage to create various material behaviors for different solutions and solvers.

1. Create material collector as 300M and titanium under collector group.
2. Select Mat1 card and enter the data as shown in the figure 5.

Name	Value
Solver Keyword	MAT1
Name	300M
ID	1
Color	
Include File	{Master Model}
Defined	
Card Image	MAT1
User Comments	Hide In Menu/Export
E	200000.0
G	
NU	0.20
RHO	7.87e-009
A	
TREF	
GE	
ST	
SC	
SS	

Figure 5 material and properties

### 2.2.3 Loads & Boundary conditions

For linear static analysis loads are assumed for the 60 passengers and each passenger Weight of 80kg. Also included approximately 2000N flight load. Total load on the flight from passenger mass plus is 48000N (60x80x10) and 2000N assumed flight load. Since this load shared by 3 landing gears and the total load on front landing gear approximately experiences 10000N. For the static analysis we need to provide constraints to overcome the free moments. In our problem strut is mounted on the axle of the landing wheel. So in finite element analysis we considered the center point is constrained in all the directions with the use of RBE elements. The shared flight loads of each wheel acts on the top of the wheel center with the help of struts. So the load will be applied on the face of the suspension zone of the strut. It is applied as force in hypermesh using rbe elements.

The following steps used in hyper mesh to create boundary conditions and loads.

1. Create constraints load collector and name it as fixed end for the reference. Then select constraints icon from the analysis Panel
2. Select the fixed end side center node and apply. The following figure shows the constraints at fixed end.
3. Create one more load collector and rename it as load and select forces tab from the analysis panel. You will get the following Application window .Enter force value as 10000 and direction is Z-axis.
4. Select the center node connected to top pressurized face of strut and creates. The following figure 6 shows both loads and Constraints.

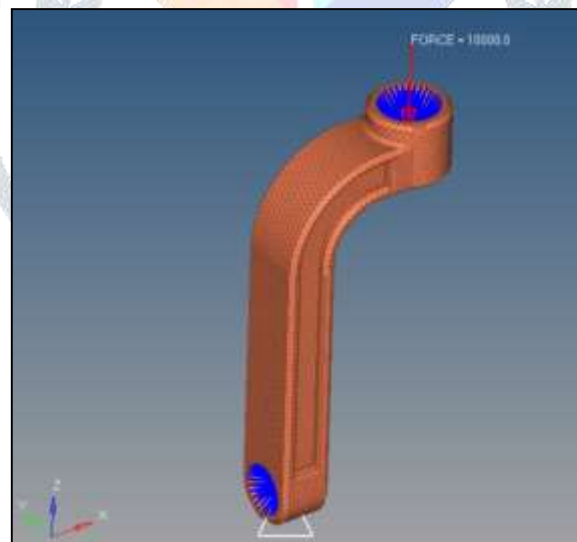


Figure 6 Apply load and fixed end

5. Create the load step for static analysis combining constraints and loads together. So that solve r will communicate with the given conditions.

### 3. Results and Discussion

Linear indicates a linear elastic behavior of the material. That is, the linear portion of the Stress Strain Curve a straight line following Hooke's Law:  $\sigma = \epsilon E$  which can be interpreted as the equation of a straight line ( $y = m x$ ) passing through the origin. "E", the Elastic Modulus, is the slope of the curve and is a constant.

When solving a static problem, all finite element solvers will solve the following equation:

$$[ \mathbf{K} ] \{ \mathbf{X} \} = \{ \mathbf{F} \}$$

Where:

K : It is the global stiffness matrix., X : It is the displacement vector response to be determined., F : It is the external forces vector applied to the structure.

**3.1 Reaction check**

The first step is to check whether the analysis is correct or not is reaction force check. It is shown reaction and applied forces are same. Hence analysis is perfect for static case. As shown in figure 7.

Residual energy ratio for static load case							1 = 1.088769E-10
Label	x-force	y-force	z-force	x-moment	y-moment	z-moment	
Sum-App.	0.000E+00	0.000E+00	-1.000E+04	-3.500E+05	1.472E+03	0.000E+00	
Sum-SPCF	-5.978E-07	-5.739E-09	1.000E+04	3.500E+05	-1.472E+03	5.462E-05	

Figure 7 Reaction force check

**3.2 Displacement results**

From figure 8 & 9 it is observed that maximum displacement 300m steel alloy is 0.653mm and for titanium alloy as 1.196mm.

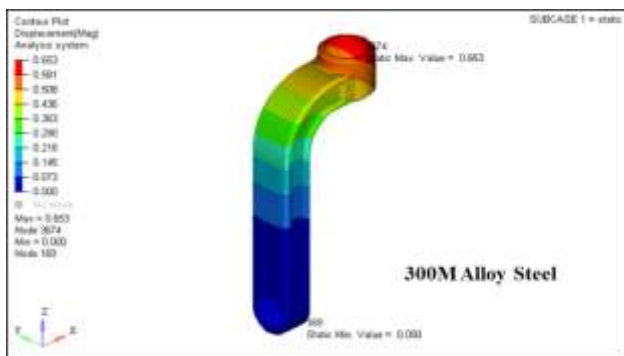


Figure 8 Displacement of 300M steel

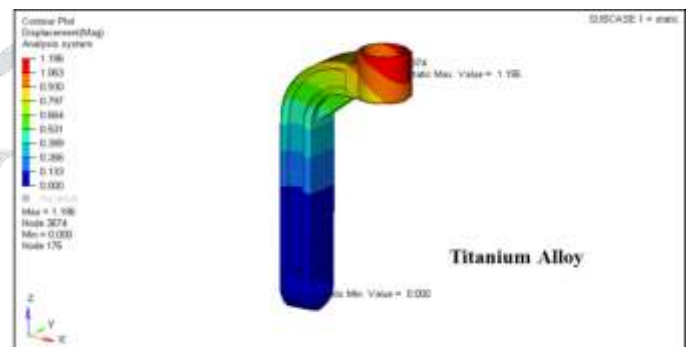


Figure 9 Displacement of Titanium alloy

**3.3 Vonmises stress results**

From figure 10 & 11 it is observed that maximum vonmises 300m steel alloy is 84.688Mpa and for titanium alloy as 81.560Mpa.

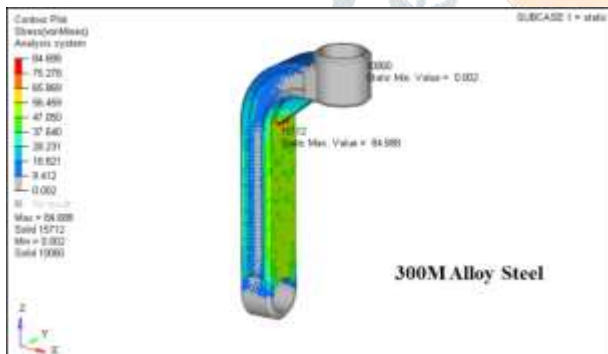


Figure 10 Maximum stress plot 300M steel

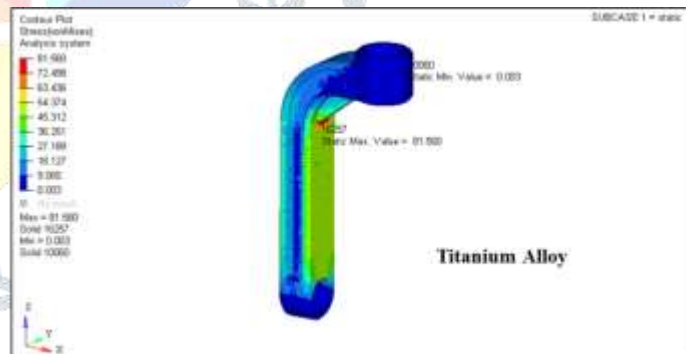


Figure 11 Maximum stress plot Titanium alloy

**3.4 Modal Analysis**

Normal Modes Analysis, also called eigenvalue analysis or eigenvalue extraction, is a manner used to work out the vibration shapes and take up with frequencies that a building will display. It is important to know these frequencies because if cyclic loads are applied at these frequencies, the structure can go into a resonance form that will lead to catastrophic neglect. It is also significant to know the shapes in order to make sure that loads are not applied at points that will cause the resonance condition.

$$(K-\lambda KG) x=0$$

The following figures 12 shows the Eigen frequencies and modes shapes of the strut for 300M steel material.

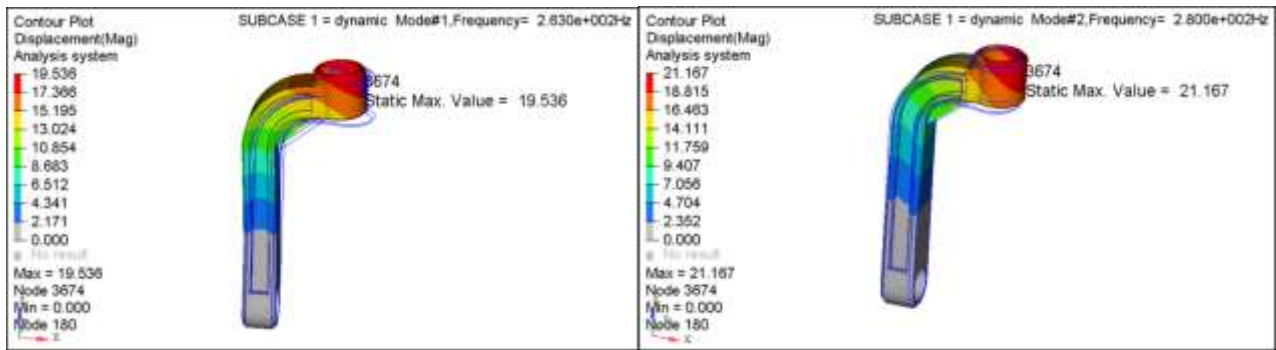


Figure 12 First two mode shapes of 300M steel

The following figures 13 shows the Eigen frequencies and modes shapes of the strut for Titanium alloy material.

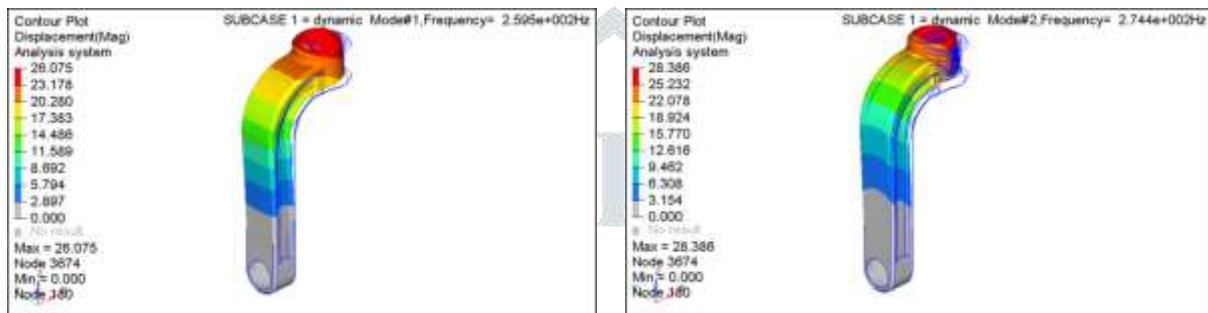


Figure 13 First two mode shapes of Titanium alloy

### 3.5 Buckling analysis

The problem of linear buckling in finite element analysis is work out by first applying a reference level of loading,  $F_{ref}$  the structure. This is perfectly a unit load,  $F$  that is applicable. The unit load and respective constraints, SPC, are referenced in the first load steps/subcase. A standard linear static analysis is then carried out to obtain stresses which are needed to form the geometric stiffness matrix  $K_G$ . The buckling loads are then calculated as part of the second load steps/subcase, by solving an eigenvalue problem:

The following results represent the behavior of a landing gear strut under buckling loads. Three buckling load factors and its shapes are extracted to study the behavior.

The following figures 14 shows buckling results for 300M steel alloy.

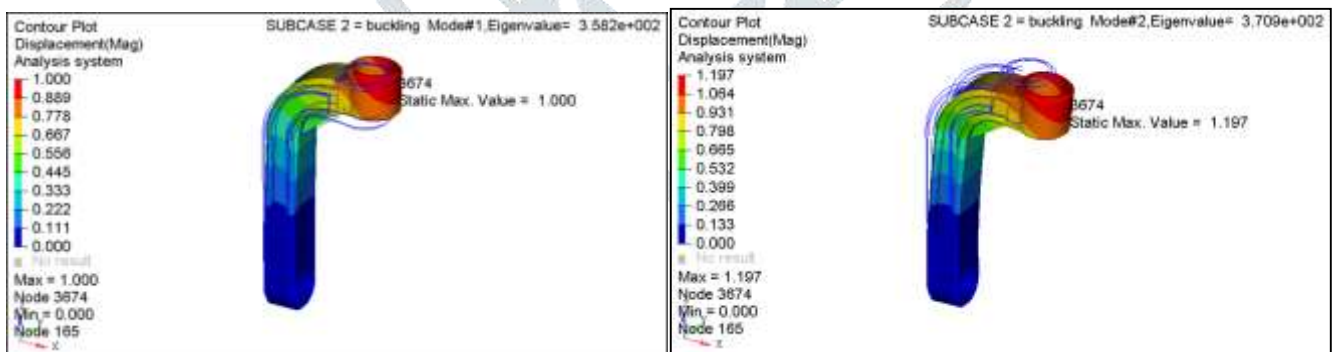


Figure 14 Buckling modes of Steel

The following figures 15 shows buckling results for Titanium alloy.

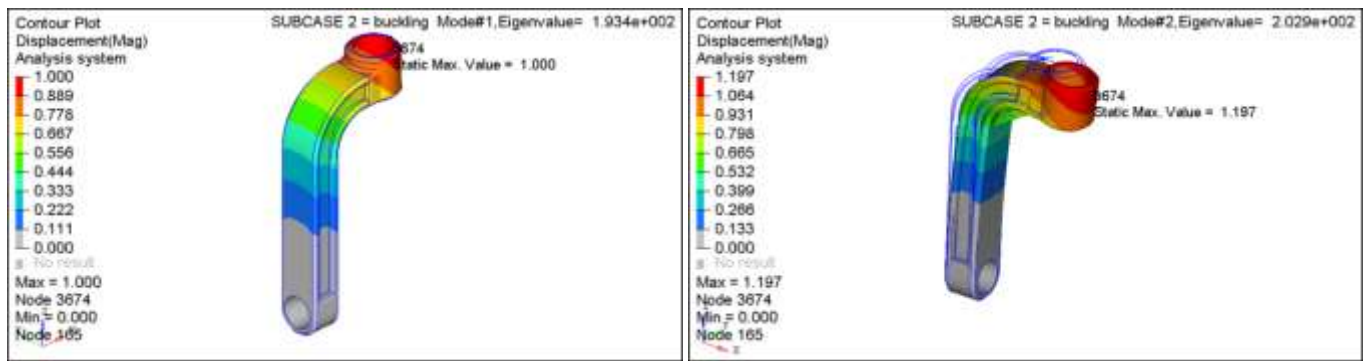


Figure 15 Buckling modes of Titanium

#### 4. CONCLUSION

Static analysis, Modal analysis and buckling analysis has been carried out to check the strength and stability of a landing gear strut component under the flight loads. The analysis techniques and knowledge presented here is most relevant for the design of landing gears and struts in aero structures.

The results showed a stress development of around 84.68 MPa which yields at a RF of 16.77 for 300M alloy steel and 81.56MPa which yields at a RF of 9.19 at the location of wedge on bottom side of the strut. Hence 300M alloy has more strength than the Titanium.

The results shown for Modal analysis has fundamental frequencies 263Hz and 259Hz for 300M alloy steel and Titanium respectively. Here we observed both materials nearby frequencies occurred.

The critical buckling load factors for 300M alloy and Titanium are 358 and 193. From this we can conclude that 300M Alloy Steel has more buckling strength than the Titanium.

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