RESEARCH ARTICLE OPEN ACCESS

Optimization of Conventional Type Landing Gear's Leg

Chinnam Akhil Teja[1], Dr.C.Govindarajulu[2]
[1]*PG Student, Department of Mechanical Engineering, Guntur Engineering College, Yanamadala, Guntur-522019, Andhra Pradesh, India.*
[2]*Professor and Head of Department, Mechanical Engineering, Guntur Engineering College, Yanamadala, Guntur-522019, Andhra Pradesh, India.*
Corresponding Author: Chinnam Akhil Teja

ABSTRACT:
Landing gear is a structural member that supports an aircraft on ground to bear the load of the aircraft and allows it to taxi, take-off, and land. In fact, landing gear design tends to have several interferences with the aircraft structural design. Now a day the weight of landing gear has become an important factor and efforts are being made to reduce the weight of the aircraft landing gear to consequently increase the payload. This thesis presents an approach to optimize the weight of conventional type landing gear’s leg made of aluminum ASM 7075-T6 material adopted from aerospace specification materials. First the structural behavior is tested using the structural analysis when subjected to behavior constraints. Optimization process is carried out iteratively to minimize thickness of landing gear’s leg which results in the minimum weight of landing gear. A new optimized landing gear’s leg with reduced weight is modeled with same material properties, boundary conditions and design loads. The behavior of component is checked using structural analysis which includes static and spectrum analysis.

Date Of Submission: 10-11-2019 Date Of Acceptance: 30-11-2019

I. INTRODUCTION:

Each type of aircraft needs a unique landing gear with a specific structural system, which can complete the demands described by unique characteristics associated with each air craft. The landing gear is the component that supports an aircraft and allows it to move on the ground. Conventional landing gear is one of the types among the landing gear where the gear legs are arraigned in tricycle fashion. The tricycle arrangement has one gear strut either back or front and two main gear legs. The main gear leg comprises a simple single piece of aluminum alloy spring leaf type which is bolted at the bottom of the fuselage.

A review of literature survey on different types of landing gears shows that landing gear is analyzed for safety of the structure and effort was made to identify the faults occurring in them. However there is limited literature available on conventional landing gear made of ASM7075-T6 material. The present study deals with the structural analysis and optimization of landing gear’s leg made of ASM7075-T6 material and the analysis was carried out using ANSYS.

II. GEOMETRICAL MODEL:

The undercarriage or landing gear in aviation is the component that supports an aircraft on the ground and allows it to land. Conventional landing gear consists of two wheels adjacent to the aircraft's centre of gravity and a third wheel at the tail. This type of landing gear is most often used in older generation aviation airplanes and now a day it is used in UAV.

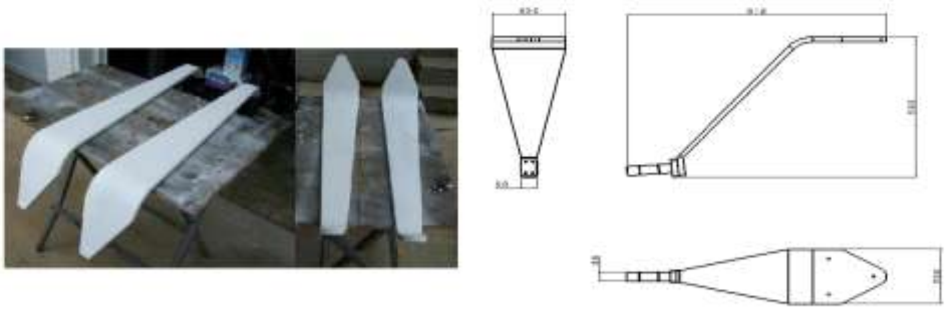


Figure 2.1: Landing gear legs

Figure 2.1 shows the model of gear legs chosen for analysis which have been used for Ceanna140, RV- 8 type vehicles. The weight of landing gear's leg considered for analysis was taken as 6 kg.

The data required for designing and weight of landing gear leg has been taken from "Grove Aircraft Landing Gear Systems Inc", which is a complete custom landing gear company manufactures ready to bolt component design for customer requirements to individual aircrafts.

2.1 MATERIAL PROPERTIES:

The main consideration when designing landing gear is to decide the type of material to be used. Aluminum alloys have played a dominant role in aircraft components for many decades. They offer good mechanical properties with low weight. Among the aluminum alloys, the 2024 alloy and 7075 alloy are perhaps the most used. 7075 alloys (7075-T6, T6510) have higher strength than the 2024 but lower fracture toughness. 2024-T3 alloy is used in the fuselage and lower wing skins, which are prone to fatigue due to applications of cyclic tensile stresses. For the upper wing skins, which are subjected to compressive stresses, fatigue is less of a problem, and 7075-T6 alloy is used. 7075 aluminum alloy's composition roughly includes 5.6-6.1% zinc, 2.1- 2.5% magnesium, 1.2-1.6% copper, and other materials like silicon, iron, manganese, titanium, chromium, and some other metals are used less than one percent.

2.2 LANDING GEAR LOADS:

The design loads applied on aircraft are lift load, drag load, side load and torsion load. Lift is the upward force created by the air flow as it passes over the wing, drag is the retarding force (back ward force) that limits the aircrafts speed, side load is the opposing acting in inward direction of gear leg and torsion load is applied when the air craft structure rotates. With the above all specifications the model was designed in CATIA, meshed in HYPERMESH and the results are viewed in ANSYS.

Figure 2.2: 3D-meshed model of landing gear's leg

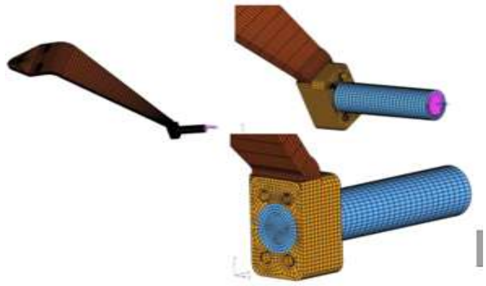


Figure 2.2 shows the 3D model of the landing gear's leg which is meshed in HYPERMESH and applied. The boundary conditions. The applied boundary conditions for the model are as follows,

- Fixing the gear leg at bolting portion in all directions.
- The loads such as lift, drag, side and torsion are applied in respective directions.
- Gear leg and axle component are glued to make a single component.

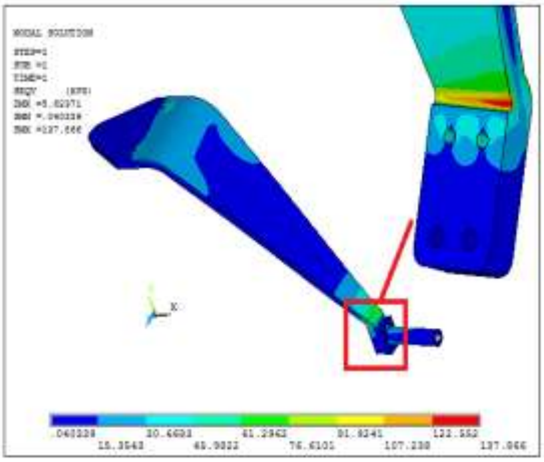
The maximum possible loads which are given as design loads are applied through RBE3 connection at the axle end spreading to wheel base. The units are taken in such a way that translational forces are in Newton and torsion moment is represented in Newton-millimeters. The colour code is used to represent the problem boundary conditions.

III. STRUCTURAL ANALYSIS:

There are several types of structural analysis which play an important role in finding the structural safety under stress and deformation. From that the basic structural safety of the component can be found by analyzing the structure for static and dynamic loading conditions.

3.1 STATIC ANALYSIS:

A static analysis is used to calculate the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. This analysis has been done by applying static loads and results are presented for the displacements and vonmises stresses, because vonmises stress theory is the main failure theory to find the failure of the components or factor of safety in the problem.



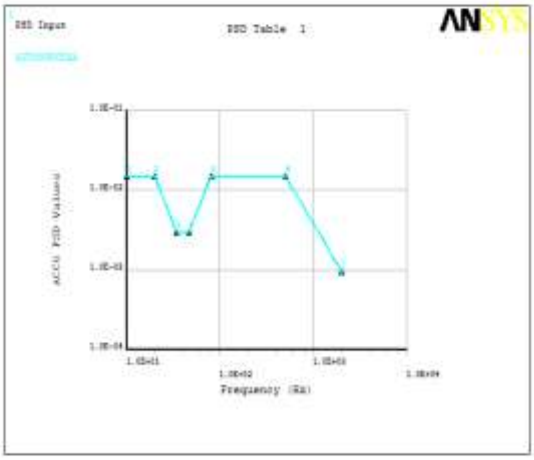


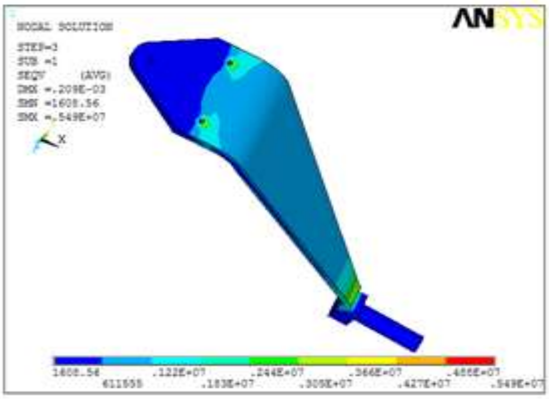
Figure 3.1: Vonmises Stress plot of the structure Figure 3.2: Modal analysis plot

Figure 3.1 shows developed vonmises stress in the structure. The maximum vonmises stress is 137.866 N/mm^2. The obtained stresses are less than yield stress of the material, so structure is safe for the given loads. The maximum displacement is 5.62371 mm. Maximum displacement is taking place at the loading region. This result of static analysis shows the maximum stresses are occuring at the connection region between the members. The stress obtained is much less the allowable stress of the structure. The maximum stress is observed near the curvature connecting to the wheel axle.

3.2 SPECTRUM ANALYSIS:

In number of instances (e.g. earthquakes, wave loading) dynamic loading is random in nature and static methods are used to represent them. One of such measure is response spectrum. This represents the response of an equivalent single degree of freedom system, to a prescribed random dynamic loading. The response is typically expressed as displacement across of range for a particular value of damping. The spectrum analysis is one in which the results of a modal analysis are used with a known spectrum to calculate displacements and stresses in the model. The landing gear leg is further analyzed for spectrum response. Initially modal analysis is carried out to find the dynamic stability of the structure. Spectrum analysis has been carried out at spectrum loading conditions.

Figure 3.2 shows Power Spectral Density (PSD) outputs in G^2/Hz for the landing gear vibration with change in frequency. It indicates random vibration loads on the landing gear. The modal frequencies are extracted up to the spectrum frequency and these are required to calculate the resultant effect of modal spectrum vibration. The initial frequency of 52.115 Hz is corresponding to a speed of 3126.9 rpm. This speed indicates resonance condition if the structure is excited with 3126.9 rpm of the air craft. The result of spectrum analysis using Single-Point Response Spectrum (SPRS) analysis shows maximum displacement of 0.209 mm which is due to combined modal and spectrum loads. Maximum displacement is observed at the axle end. This is due to cantilever nature of the support. The status bar indicates the varying displacements in the structure.



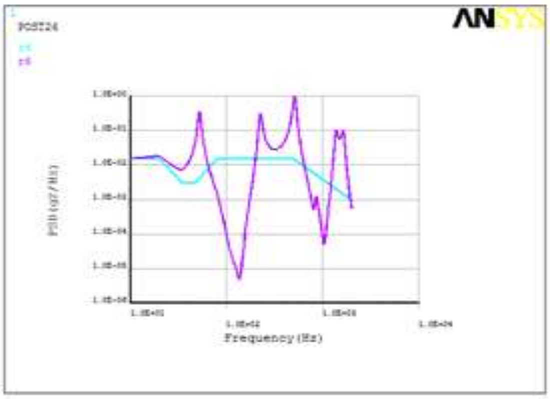


Figure 3.3: Vonmises stress plot Figure3.4: Response plot of spectrum analysis

Figure 3.3 shows spectrum response of the landing gear due to the given spectrum loads. Maximum stress of 5.49Mpa can be observed in the problem. The results viewed by ANSYS solver are 1σ or one standard deviation values. These results follow a Gaussian distribution. The interpretation is that 68.3% of the time the response will be less than the standard deviation value. We can scale the result by 2 times to get the 2σ value which gives 95.91% and 3σvalues 99.7% of the time. The default results are for maximum stress condition for 1σ value. By multiplying 3 times the 1σ values, 16.47 MPa stress is obtained. But this stress is much smaller than the allowable stress of the material; hence the structure is completely safe for the given loads.

Figure 3.4 shows dynamic amplification of the input to the output response of the systems. The uncontrolled vibration on gear leg lies between 100 to 750 Hz.

IV. WEIGHT OPTIMISATION OF THE LANDING GEAR'S LEG:

The static and spectrum results indicate that the obtained stresses are low when compared to allowable stresses of the material; here there is a possibility for optimization of the landing gear's legs thickness. The model with shell elements is considered for the analysis. Various regions are created by splitting and by varying thickness. The thicknesses are supplied as the real constants which can be easily optimized based on the optimization cycle satisfying the design requirements. Totally 11 regions were created with different thickness parameters for optimization. The analysis is limited to main landing gear part. Since the axle dimension depends on wheel diameter and suspension, so the axle part is not considered for optimization.

In ANSYS optimization the zero-order method which is an advanced method in sub problem approximation technique with random design generation type optimization tool performs multiple loops, with random design variable obtains values at each loop. A maximum number of loops with a desired number of feasible loops can be specified. This tool is useful for studying the overall design space, and for establishing feasible design sets for subsequent optimization analysis. A number of iterations were performed by varying the thickness of the component and the results are obtained with different sets of feasible thickness data. The lowest design thickness data obtained in iterative process is optimized for gear's leg.

At the beginning iterations the weight is not reduced and the reduction of weight can be observed at the end of the iteration cycles. It can be observed that the variation in vonmises stress is not much predominant for varying thickness. This is due to redistribution of loading region. Maximum vonmises stress is around 244.2 MPa as shown with red colour. The obtained stresses are minimum at top region and are increasing towards the connecting region between main landing gear to the wheel axle. Initial weight of 6 kg is reduced to 4.1538 kg by the final optimization cycle for the given loads. So reduction of 1.8462 kg can be observed.

V. ANALYSIS OF OPTIMISED LANDING GEAR'S LEG:

The goal of optimization is to minimize the weight of the component. After studying the results obtained from topology optimization and by considering the location of removing material from landing gear's leg. Static analysis is performed to determine the displacements, stresses and forces in structures or components caused by loads that do not induce significant inertia and damping effects. The maximum vonmises stress is 297.57 N/mm^2. The obtained stresses are less than yield stress of the material, so structure is safe for the given loads.

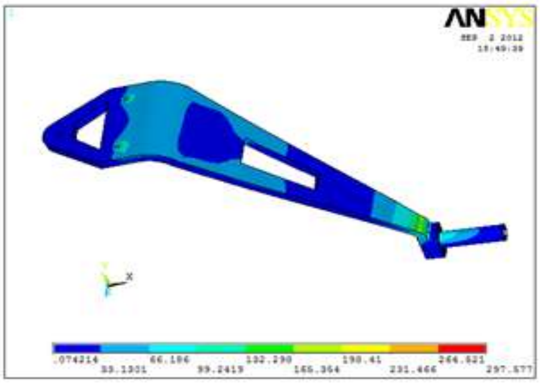


Figure 5.1: Vonmises Stress plot of the structure

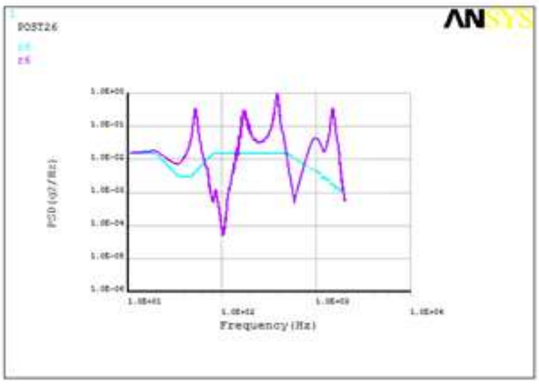


Figure 5.2: Response plot of spectrum analysis

The result of spectrum analysis using Response Spectrum analysis shows maximum displacement of 0.200 mm which is due to combined modal and spectrum loads. Maximum displacement is observed at the axle end. This is due to cantilever nature of the support. The status bar indicates the varying displacements in the structure. Figure 6.4 shows spectrum response of the optimized landing gear's leg due to the given spectrum loads. Maximum stress of 9.41 Mpa can be observed in the problem. The results viewed by ANSYS solver are 1σ or one standard deviation values. By multiplying 3 times the 1σ values, 28.23 MPa stress and 0.600 mm displacements are obtained. But this stress is much smaller than the allowable stress of the material, so the structure is completely safe for the given loads.
Figure 5.2 shows dynamic amplification of the input to the output response of the systems. The uncontrolled vibration on gear leg lies between 100 to 750 Hz.

VI. CONCLUSIONS

The following results are made from structural and optimized analysis on conventional type landing gear's leg for an unmanned aerial vehicle.

- Landing gear's leg model is drafted in CATIA, meshed in HYPERMESH and analyzed using ANSYS softwares.
- Static analysis is performed in ANSYS to determine maximum displacement and maximum vonmises stress.
- Spectrum analysis is carried out to obtain the frequency response.
- Optimization is carried out to identify the areas where material can be removed without affecting the safety of the design.
- Optimized model is tested for static and spectrum analysis to conform reduction of weight.

REFERENCES

[1]. Norman, S. C. "Aircraft Landing Gear Design: Principle and Practices", AIAA Education Series, AIAA, Washington, D.C., 1988.
[2]. Flugge W, "Landing Gear Impact", NACA, TN2743, 9016, 1952.
[3]. Fujimoto W.T, Gallagher J.P, "Summary of Landing Gear Initial Flaws", AFFDL-TR-77-125, 1977.
[4]. Derek Morrison, Gregory Neff and Mohammed Zahraee, "Aircraft landing gear simulation and analysis", American Society for Engineering Education Annual Conference, 1997.
[5]. James N. Daniels, "A Method for Landing Gear Modeling and Simulation with Experimental Validation" , NASA Contractor Report 201601, 1996.
[6]. Jocelyn I. Pritchard, "An Overview of Landing Gear Dynamics", NASA/TM-1999-209143 ARL-TR-1976.
[7]. Amit Goyal "Light Aircraft Main Landing Gear Design and Development", SAS Tech journals, page no: 45-50,2002.
[8]. Noam Eliaz, Haim Sheinkopf, Gil Shemesh and Hillel Artzi, "Cracking in cargo aircraft main landing gear truck beams due to abusive grinding following chromium plating", Elsevier -Engineering Failure Analysis, vol 12,page no: 337–347,2005.
[9]. Dave Briscoe,"ME 548 Aero structures Final Project ANSYS Analysis of Landing Gear", 2006.
[10]. Oraig Gellimore "Constrained layer damping treatment design for aircraft landing", 2007.
[11]. Jerzy Malachowski " Dyanamical analysis of Landing gear for critical work conditions ", 2010.
[12]. Essam Albahkali & Eng. Mohammed Alqahtani"Design of Light Landing Gear", 2011.

Chinnam Akhil Teja "Optimization of Conventional Type Landing Gear's Leg" International Journal of Engineering Research and Applications (IJERA), vol. 9, no. 11, 2019, pp 52-56