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TOPOLOGY OPTIMIZATION OF LANDING GEAR'S LEG FOR AERIAL VEHICLE USING ANSYS

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ABSTRACT

The landing gear is a structure that supports an aircraft on ground and allows it to taxi, take-off, and land. In fact, landing gear design tends to have several interferences with the aircraft structural design. Present research is going in 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 landing gear's leg for an Un-manned Aerial Vehicle (UAV) made of aluminum ASM 7075 material adopted from aerospace specification materials. Loads are applied through a rigid boundary condition & screw boundary connection.

1. INTRODUCTION

In recent years, there has been an increasing interest in development of light weighted components in aerospace applications. In that, landing gear plays a major role in its design and positioning which are determined by unique characteristics associated with each aircraft. The landing gear is one of the component that supports an aircraft and allows it to move on the ground. There are different kinds of landing gears. In conventional type landing gear, 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 metal alloy leaf spring type, which is bolted at the bottom of the fuselage

OBJECTIVES OF THE WORK

- To model the landing gear's leg is using CATIA software and mesh using HYPERMESH for good quality meshing.
- To perform structural analysis for examining the stresses and deflections developed in structure at design load conditions.
- To determine the response spectrum analysis for observing range of vibration developed in the structure
- To reduce the weight of the structure using optimization process.
- To carry out topology optimization for observing less stress concentration area in the structure.
- To perform structural analysis on optimized landing gear's leg.

LANDING GEAR

The landing gear is an aircraft component that supports weight of the aircraft on ground. The landing gear contains components that are necessary for taking off and landing the aircraft safely. Some of these components are landing gear struts that absorb landing and taxiing shocks, brakes that are used to stop and steer the aircraft. The most common sort of undercarriage consists of wheels, however aircrafts may be equipped with floats on water operations or skis for landing in snow. undercarriage is actually one dimension structure below serious compressive masses. Drag load and aspect load do act on undercarriage but. Landing gears enable the aircraft to land and take off from the ground.

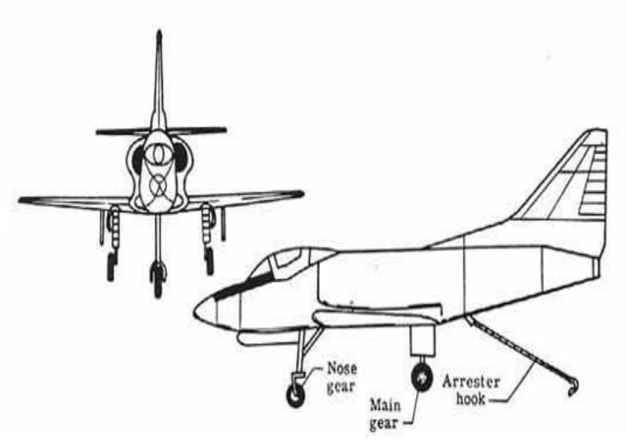


Figure 1.2 Tri cycle-nose wheel, two main wheels

AIRCRAFT MATERIALS:

Traditional metallic materials used in aircraft structures are Aluminum, Titanium and steel alloys. In the past three decades, applications of advanced fiber composites have rapidly gained momentum. Today, some modern military jet fighters already contain alloy materials up to 50% of their structural weight. The selection of aircraft materials depends on considerations, which are in general categorized as cost and structural performance. Cost includes initial material cost, manufacturing cost and maintenance cost. The key material properties that ar pertinent to maintenance price and structural performance ar rarely could be a single material ready to deliver all desired properties all told parts of the craft structure. A combination of various materials is often necessary to strengthen the existed materials. Generally, the following properties are to be checked when undertaking the material

- Density (weight)
- Stiffness (young's modulus)
- Strength (ultimate and yield strengths)
- Durability (fatigue)
- Damage tolerance (fracture toughness and crack growth)
- Corrosion resistant.

2. LITERATURE REVIEW

Flugge (1952)[2] discussed iMPact forces in landing gears. Both the landing iMPact and the taxiing iMPact have been considered, but drag forces have been excluded. The differential equations are developed and their numerical integration is shown, considering the nonlinear properties of the oleo shock strut

Fujimoto (1977)[3] observed the reasons for the crack generation in the landing gear components. The basic causes of initial harm area unit because of process operations, latent material defects, mechanical harm and crack growth from corrosion pits.

Norman (1988)1 rumored on style and development of a undercarriage encoMPasses many engineering disciplines corresponding to structures, mechanical systems, aeromechanics, material science and then on. the traditional undercarriage style and development for part vehicles relies on the provision of many vital components/systems corresponding to forgings, machined elements, mechanisms, flat solid elements, electrical systems, hydraulic systems and a wide variety of materials such as aluminum alloys, steel and titanium, beryllium and polymer composites

James Daniels (1996)[5] proposed an approach for modeling and simulating landing gear systems. Specifically, a nonlinear model of AN A-6 trespasser main gear is developed, simulated and valid against static and dynamic check information. This model includes nonlinear effects reminiscent of a polytropic gas law, speed sq. damping, a mathematics dominated model for the discharge coefficients, stick-slip friction effects and a nonlinear tire spring and damping model. AN adams-moulton predictor corrector methodology was accustomed integrate the equations of motion till a separation caused by a stick-slip friction model and Runga-Kutta routine models were integrated past the continuity and returned the problem solution back to the predictor corrector.

3. STRUCTURAL ANALYSIS AND OPTIMIZATION

STRUCTURAL ANALYSIS

The seven types of structural analyses plays important role in finding the structural safe under stress and deformation. The primary unknowns (nodal degrees of freedom) calculated during a structural analysis square measure displacements. different quantities equivalent to strains, stresses and reaction forces square measure then derived from the nodal displacements.

DESIGN OPTIMIZATION:

The optimization problem is classified on the basis of nature of equations with respect to design variables. If the objective function and the constraints involving the design variable are linear then the optimization is termed as linear optimization problem. If even one of them is nonlinear it is classified as the non-linear optimization problem. In general the design variables are real but sometimes they could be integers for example, number of layers, orientation angle, etc. The behaviour constraints could be equality constraints or inequality constraints depending on the nature of the problem.

OPTIMIZATION DATA FLOW

The analysis file must exist as a separate entity. The database for optimization is not a part of the ANSYS model database. The approach of ANSYS optimization is in two ways as a batch run or interactively via Graphical User Interface (GUI). The approach will depend on analyzers ANSYS expertise and the preference for interacting with the ANSYS program. The optimization is initialized by creating an ANSYS command input file and submitting it as a batch job.

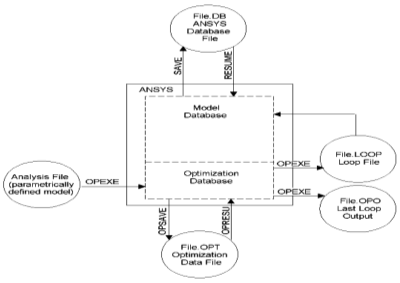


Figure 3.3 Design optimization flow chart

TOPOLOGY OPTIMIZATION

Topological optimization is a form of shape optimization analysis, sometimes referred as layout optimization. The purpose of topological optimization is to find the best use of material for a structure such that an objective criterion takes on a maximum or minimum value subject to given constraints such as volume reduction.

4. ANALYSIS OF LANDING GEAR’S LEG

GEOMETRICAL MODEL

The analysis of landing gear’s leg requires few assumptions that are to be considered while performing the analysis and they are as follows

- The material is assumed to elastic and same.
- The analysis has been meted out with in elastic limits.
- Both Solid (pipe element) and shell elements are used for analysis.
- Rigid Body Element (RBE3) connection is used for load transfer.

Figure 4.1 Landing gear legs

MATERIAL PROPERTIES

The main thought once coming up with undercarriage is to determine the sort of fabric to be used. atomic number 13 alloys have compete a dominant role in craft parts for several 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 have higher strength than the 2024 alloy 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. The initial weight of the landing gear is considered for analysis which is given by grove Aircraft CoMPany is taken as 6 kg and the Table 5.1 shows material properties of T7075-T6 alloy.

LOADS ON LANDING GEAR’S LEG

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. The Table 5.2 shows general design loads to test the landing gear’s leg.

Lift force $F_L = C_L * A * \frac{\rho u^2}{2}$
Drag force $F_D = C_D * A * \frac{\rho u^2}{2}$
C_D= 0.15, C_L=0.75
Density of air ρ=1.15kg/m^3
Velocity of landing gear = 500Km/hr = 139m/s
Area of landing gear = 603*230 mm^2 = 0.1387m^2
Note: - Area of landing gear is measured using CATIA software.
Lift force = 1154 N
Drag force =540 N
Momentum lode = 20000 N-mm
Side Thrust lode = 230 N

1. Meshed in ANSYS workbench mesh tool (Ver-16).

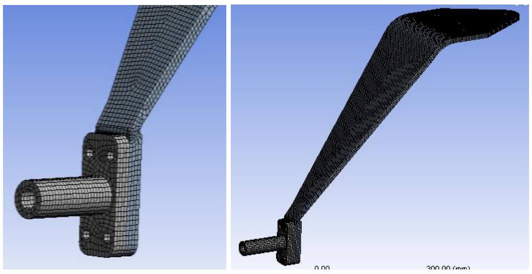


Figure 4.3 3D-Meshed model of landing gear’s leg

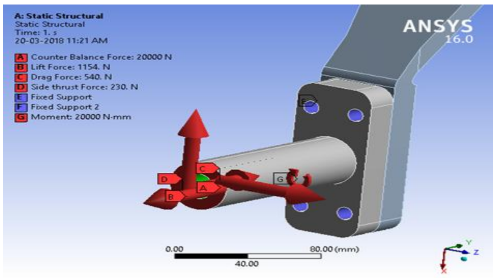


Figure4.4 Applied loads on landing gear’s leg

STATIC ANALYSIS ON LANDING GEAR’S LEG:

Static analysis is employed to calculate the results of steady loading conditions on a structure, whereas ignoring inertia and damping effects, resembling those caused by time-varying hundreds. This analysis has been done by applying static hundreds and results ar conferred for the displacements and vonmises stresses, as a result of vonmises stress theory is that the main failure theory to find the failure of the components or factor of safety in the problem.

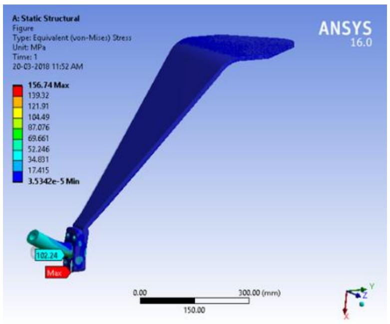


Figure4.5 Vonmises Stress plot of the structure

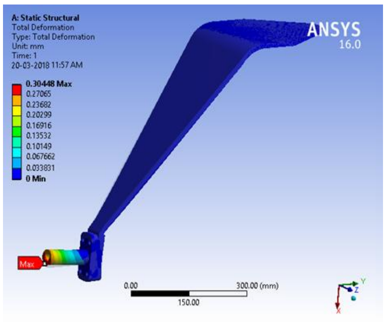


Figure 4.6 Displacement plot of the structure

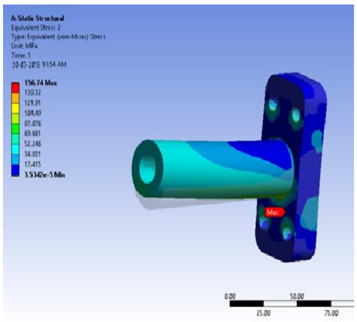
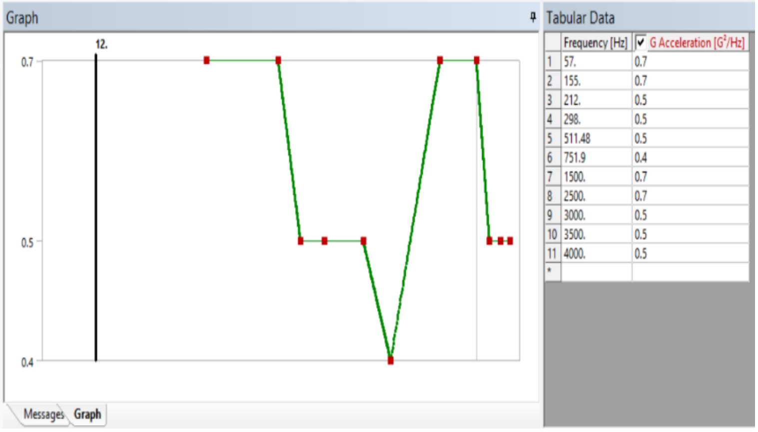


Figure 4.7 Vonmises stress plot of axle component

RANDOM ANALYSIS ON LANDING GEAR'S LEG:

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. Random is a graph of spectral value verses frequency that captures the intensity and frequency content of time-history loads. The random vibration analysis uses Power Spectral Density (PSD) to qualify the loading and is a statistical measure which is defined as the limiting mean-square value of a random variable. Generally PSD analysis used in random vibration analysis in which instantaneous magnitude of the response can be specified only by probability distribution of the magnitude by taking a particular value.



Tabular Data

	Frequency [Hz]	☑ G Acceleration [G²/Hz]
1	57.	0.7
2	155.	0.7
3	212.	0.5
4	298.	0.5
5	511.48	0.5
6	751.9	0.4
7	1500.	0.7
8	2500.	0.7
9	3000.	0.5
10	3500.	0.5
11	4000.	0.5
*		

Figure 4.8 Input PSD plot of landing gear's leg

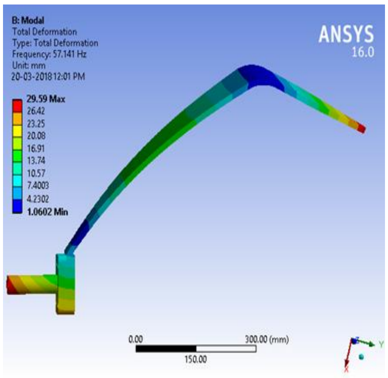


Figure Mode shape (1) at 57.141 Hz

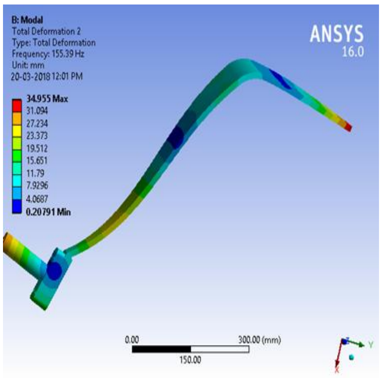


Figure Mode shape (2) at 155.39 Hz

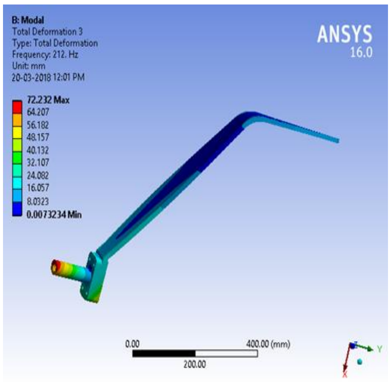


Figure Mode shape (3) at 212 Hz

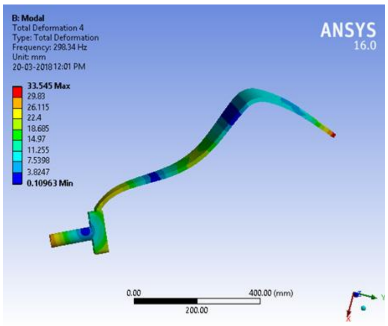


Figure Mode shape (4) at 298.34 Hz

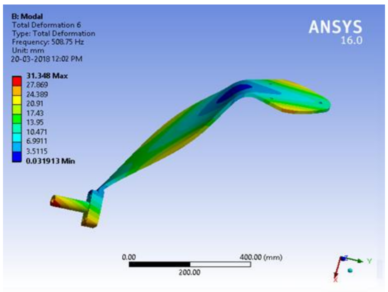


Fig Mode shape (6) at 508.75 Hz

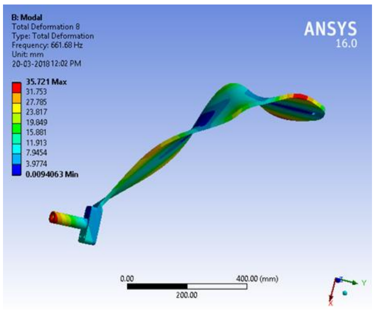


Figure Mode Shape (8) at 661.68 Hz

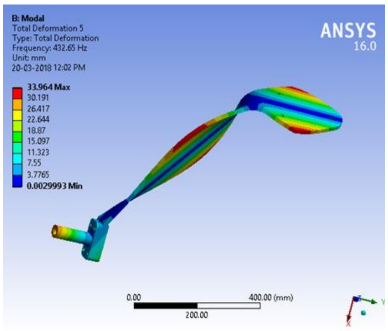


Figure Mode shape (5) at 432.65 Hz

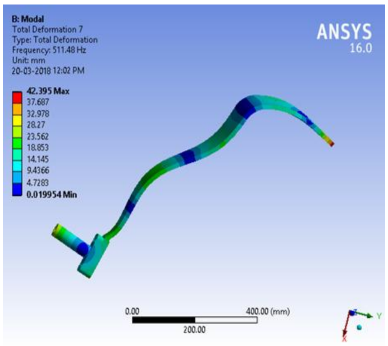
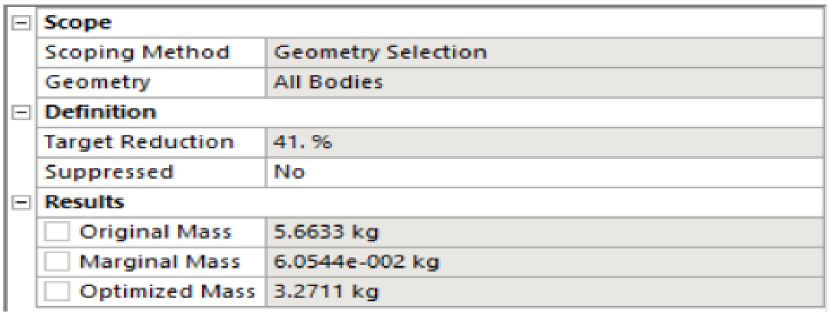


Figure Mode shape (7) at 511.48 Hz

WEIGHT OPTIMIZATION OF THE LANDING GEAR’S LEG:

The static and random results indicate that the obtained stresses are low when compared to allowable stresses of the material, hence 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. The analysis is proscribed to main undercarriage half. Since the shaft dimension depends on wheel diameter and suspension, therefore the shaft half isn't thought of for improvement.



Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Target Reduction	41. %
Suppressed	No
Results	
☐ Original Mass	5.6633 kg
☐ Marginal Mass	6.0544e-002 kg
☐ Optimized Mass	3.2711 kg

Figure 4.14 Variation of weight of the structure with iterations

TOPOLOGY OPTIMIZATION:

Topology improvement is also a mathematical commence that optimizes material layout among a given vogue house, for a given tons of and boundary conditions specific the following layout meets a prescribed set of performance targets. mistreatment topology improvement, the simplest conception style that meets the planning necessities will be familiar. Topology improvement had enforced through the utilization of finite component strategies for the analysis, and improvement techniques supported the tactic of moving asymptotes, genetic algorithms, optimality criteria methodology, level sets and topological derivatives. In some cases, proposals from a topology improvement, though optimum, could also be pricey or impossible to manufacture. These challenges will be overcome through the utilization of producing constraints within the topology improvement drawback formulation. mistreatment producing constraints, the improvement yields engineering styles that might satisfy sensible producing necessities.

5. RESULTS AND DISCUSSIONS

Shape optimization is a form of optimization, sometimes referred as layout optimization. The goal of Shape optimization is to find the best use of material for a body that is subject to either a single load or multiple load distributions. The goal of Shape optimization is to minimize the weight of structural component by satisfying the constraints which are applied on the structure.

STATIC ANALYSIS ON OPTIMIZED LANDING GEAR'S LEG

Static analysis is utilized to examine the displacements, stresses and forces in structures or elements caused by a whole bunch that do not induce very important inertia and damping effects. Steady loading and response conditions ar assumed; that is, the plenty and additionally the structure's response ar assumed to vary slowly with relevancy time.

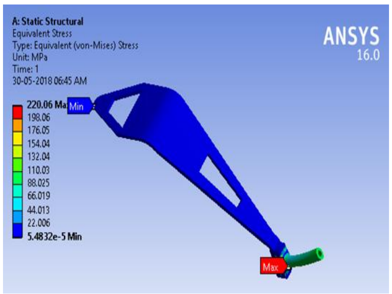


Figure 5.1 Von-Mises Stress plot of the structure

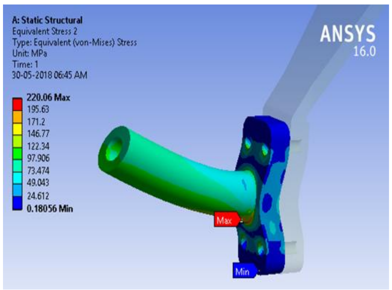


Figure 5.2 Von-Mises Stress plot of the structure

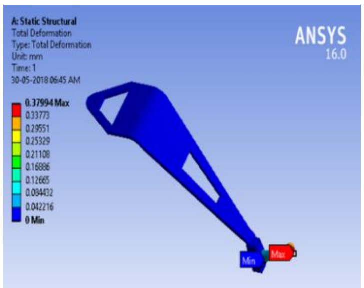


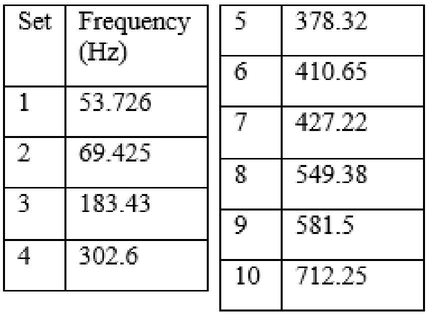
Figure 5.3 Total Deformation plot of the structure

Figure 5.1 shows developed vonmises stress in the structure. The maximum von-mises stress is 220.06 N/mm^2. The obtained stresses are less than yield stress of the material, so structure is safe for the given loads. By observing the vonmises stress plot of static analysis the stress levels throughout the structure is almost equal and a small portion at bottom corner of the component has highest stress concentration. The maximum displacement obtained by conducting static analysis is 0.3799 mm.

RANDOM ANALYSIS ON OPTIMIZED LANDING GEAR'S LEG:

The extension of modal analysis used to calculate the modal frequencies in the model. Random analysis has been carried out at Random loading conditions. The resultant plot and stresses are viewed by combining the mode frequencies. The modal frequencies which are obtained by base excitations are listed in Table 5.1.

Table **Error! No text of specified style in document.**.1 Modal frequencies from optimized modal analysis



Set	Frequency (Hz)
1	53.726
2	69.425
3	183.43
4	302.6
5	378.32
6	410.65
7	427.22
8	549.38
9	581.5
10	712.25

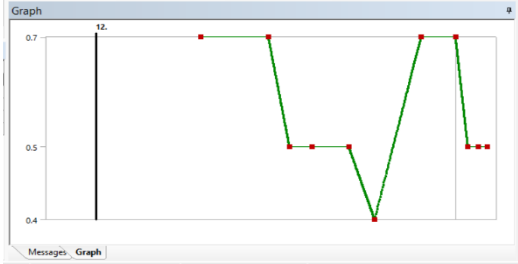
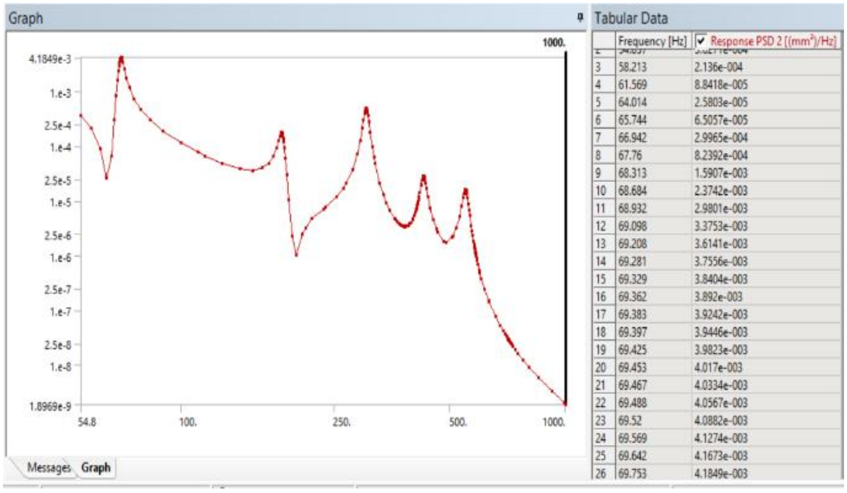


Figure **Error! No text of specified style in document.**.1 Input PSD plot of optimized landing gear's leg

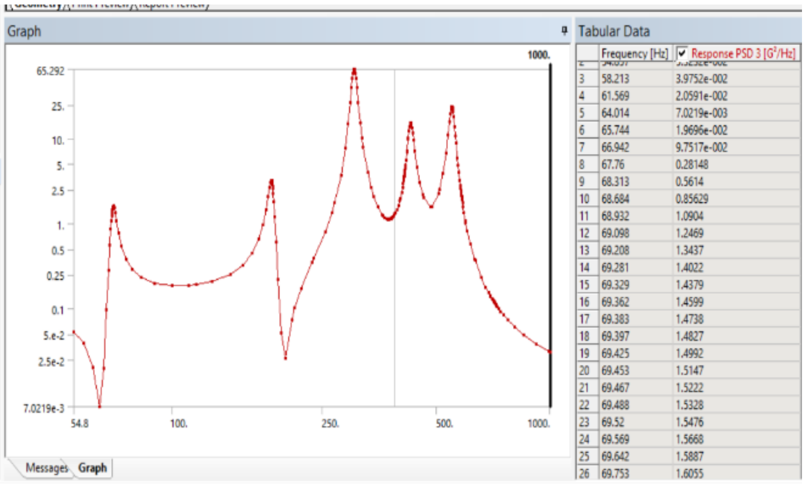
Figure 5.4 shows Power Spectral Density (PSD) outputs in G²/Hz for the landing gear vibration with change in frequency. It indicates random vibration loads on the landing gear. The modal frequencies are extracted up to the Random frequency and these are required to calculate the resultant effect of modal Random vibration. The initial frequency of 50.354 Hz is corresponding to a speed of 3026.9rpm. This speed indicates resonance condition if the structure is excited with 3026.9 rpm of the air craft.

The result of Random analysis using Response Spectrum analysis shows maximum displacement of 0.8029 mm which is due to combined modal and Random 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 6.8 shows Random response of the optimized landing gear's leg due to the given Random loads. Maximum stress of 128.19 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, 280.23 MPa stress and 2.4 mm displacements are obtained. But this stress is much smaller than the allowable stress of the material, hence the structure is completely safe for the given loads.



	Frequency [Hz]	☑ Response PSD 2 [(mm^2)/Hz]
3	58.213	2.136e-004
4	61.569	8.8418e-005
5	64.014	2.5803e-005
6	65.744	6.5057e-005
7	66.942	2.9965e-004
8	67.76	8.2392e-004
9	68.313	1.5907e-003
10	68.684	2.3742e-003
11	68.932	2.9801e-003
12	69.098	3.3753e-003
13	69.208	3.6141e-003
14	69.281	3.7556e-003
15	69.329	3.8404e-003
16	69.362	3.892e-003
17	69.383	3.9242e-003
18	69.397	3.9446e-003
19	69.425	3.9823e-003
20	69.453	4.017e-003
21	69.467	4.0334e-003
22	69.488	4.0567e-003
23	69.52	4.0882e-003
24	69.569	4.1274e-003
25	69.642	4.1673e-003
26	69.753	4.1849e-003

Figure **Error! No text of specified style in document.**.2 Displacement Response plot of Random analysis



	Frequency [Hz]	☑ Response PSD 3 [G^2/Hz]
3	58.213	3.9752e-002
4	61.569	2.0591e-002
5	64.014	7.0219e-003
6	65.744	1.9696e-002
7	66.942	9.7517e-002
8	67.76	0.28148
9	68.313	0.5614
10	68.684	0.85629
11	68.932	1.0904
12	69.098	1.2469
13	69.208	1.3437
14	69.281	1.4022
15	69.329	1.4379
16	69.362	1.4599
17	69.383	1.4738
18	69.397	1.4827
19	69.425	1.4992
20	69.453	1.5147
21	69.467	1.5222
22	69.488	1.5328
23	69.52	1.5476
24	69.569	1.5668
25	69.642	1.5887
26	69.753	1.6055

Figure **Error! No text of specified style in document.**.3 Acceleration Response plot of Random analysis

Figure 5.8 -5.9 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.

6. CONCLUSIONS AND SCOPE FOR FUTURE WORK

CONCLUSIONS

A CAD model of landing gear's leg for unmanned aerial vehicle was made and discretized in to finite element mesh using ANSYS. The following results are made from structural and optimized analysis on conventional type landing gear's leg.

1. Landing gear's leg model is drafted in CATIA, meshed in ANSYS workbench 16 and analyzed using ANSYS software's.
2. Static analysis is performed in ANSYS to determine maximum displacement and maximum von-mises stress.
3. Random analysis is carried out to obtain the frequency response of the landing gear's leg.
4. Optimization is carried out to identify the areas where material can be removed without affecting the safety of the design.
5. Optimized model is tested for static and spectrum analysis to conform reduction of landing gear's leg weight.

From the above analysis they obtained stresses are much lesser than the allowable stresses of the material. So design optimization is carried out to reduce the weight of the component. The landing gear's leg weight was reduced by repetitious method exploitation style optimisation analysis in ANSYS from vi kilogram to four.1538kg for the given loading conditions. a discount of one.8462 kilogram are often ascertained that amounts to nearly half-hour reduction of weight.

SCOPE FOR FUTURE WORK

- The landing gear 's leg can be analysed for impact loads
- Possible interference effect can be considered for fatigue life of the landing gear.

REFERENCES

1. Norman, S. C. "Aircraft undercarriage 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 undercarriage Initial Flaws", AFFDL-TR-77-125, 1977.
4. Derek Morrison, Gregory Neff and Mohammed Zahraee, "Aircraft undercarriage simulation and analysis", yankee Society for Engineering Education Annual Conference, 1997.
5. James N. Daniels, "A technique for frame Modelling and Simulation with Experimental Validation", independent agency Contractor Report 201601, 1996.
6. Jocelyn I. Pritchard, "An outline of frame Dynamics", NASA/TM-1999-209143 ARL-TR-1976
7. Amit Goyal "Light craft Main undercarriage style and Development", SAS school journals, page no.: 45-50, 2002.
8. Wurzba and Trez "A undercarriage FEM Analysis mistreatment Master of Science Patran/Nastran", 2004.
9. Noam Eliaz, Haim Sheinkopf, Gil Shemesh and Hillel Artzi, "Cracking in wares craft main undercarriage truck beams because of abusive grinding following metal plating", Elsevier -Engineering Failure Analysis, vol.12,page no: 337–347,2005.
10. Dave Briscoe,"ME 548 Aero structures Final Project ANSYS Analysis of Landing Gear", 2006.
11. OraigGellimore "Constrained layer damping treatment style for craft landing", 2007.
12. Jerzy Malachowski "Dynamical analysis of undercarriage for vital work conditions", 2010.
13. EssamAlbahkali& Eng. Mohammed Alqahtani"Design of sunshine Landing Gear", 2011.