Analysis of deformation and mode shape in the landing gear of light Unmanned Aerial Vehicle

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Abstract : During the landing of aircraft, the landing gear system absorbs energy through the impact of landing. Impact landing produces stress as well as deformation. The current study focuses on the numerical simulation of the landing gear system with the help of ANSYS software. Deformation is an important criterion to consider when testing a model under certain loading conditions which occurs along its span length. The majority of the deflections occur at free ends of the forks of the landing gear. The bottom plate being fixed has zero deflections in all directions. The deflections occur along the y-axis. As the impact loads were increased, the deformation increased gradually. Modal analysis has been performed to obtain the natural frequency of the model made of Aluminum Alloy Al 6061-T6. The maximum frequency was found to be 974 Hz causing a deflection of 403.59 mm. These Natural frequencies have help in calibrating the operating frequency to avoid resonance.

Keywords- Aircraft, landing gear, ANSYS, deflection, Aluminum alloy.

1. Introduction

The landing gear configuration of these light unmanned aerial vehicles (UAVs) is quite different from the conventional ones. Although conventional landing gear assembly can be used in the UAVs, using a leaf spring type landing gear is the most feasible. Aluminum alloys analysis can be used in aircraft parts that are susceptible to high energy absorption. Such parts include landing gear. Good property databases for landing gears of all magnitude are high energy absorption rate, elastic material, and high strength and should also have a lightweight and higher capacity to store strain energy. Considering all the properties it was found that aluminum alloys are the perfect choice for aircraft landing gears [1-5]. The cost-effective nature makes it suitable in the industry. The material that is used to determine studies consist of Al 6061-T6 as a suitable material for designing of such parts. To separate the effects on the other body parts, the fuselage was kept fixed, hence no displacement over it. Finally, the FEA model was used which provides static and dynamic loading conditions that were based on the Bernoulli's hypothesis. The resulting simulations revealed that the vibrations were due to the elastic properties which were maximum in the free ends of the landing gear model. And also the stresses generated were particularly higher in the adjoining section with the fixed fuselage [6-11]. During the landing phase of such a plane, at first, the main gears generally will touchdowns on two points and will then after several seconds, the tire of the nose gear touchdowns the ground. The ground specific reaction occurring on the landing gear is transmitted into the structure. When the aircraft lands, the force generated out of impact is transmitted via the tire to the main axle. In the paper, he discusses the methods that were used to perform the static analysis and also presents the mathematical model which shall allow determining the dynamic characteristics of the landing gear. The dynamic situation analysis is very important due to the shimmy vibration that occurs during the aircraft take-off which can prove devastating and cause the collapse of the aircraft [12-16]. The failure has been started by an impact shear load on a bolt resulting shear fracture which in turn leads to loosening of all the load bearings of the link of the landing gear. As a result, the entire vertical load was transferred to a lateral load on the left side landing gear causing the shear failure for the bolt and gradually mode I failure of linkage. For the failure in that way, the landing is supposed to be critical with the entire load to the right-sided landing gear. Therefore, accidents are occurred due to material defects. The cracks generally originated from the previously existing cracks in the surrounding areas. Along with the precipitation in the zones and impact loads, the material is failed to withstand crack propagation and the material is failed. Hence a material that can avoid catching up on precipitation is suitable for aerospace purposes. One made of aluminum alloy and the other made of composite materials. The landing gear's structural safety for each of the above-stated material was evaluated. It was found that composite material was much more favorable as it generates less stress than the conventional counterpart [17-20].

2. Materials and methods

2.1 Materials

The material considered here for the landing gear is Al 6061-T6, an Aluminum alloy. The material properties considered for the analysis are given in Table. 1.

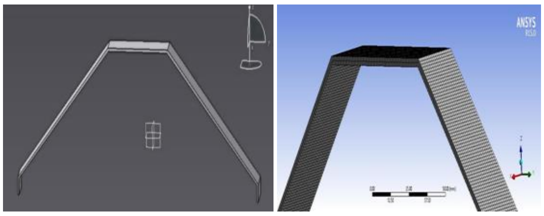
Young's Modulus (GPa)	Density (g/cc)	Poisson's ratio	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)
68.9	2.7	0.33	276	565

2.2 Modeling, meshing, and boundary conditions

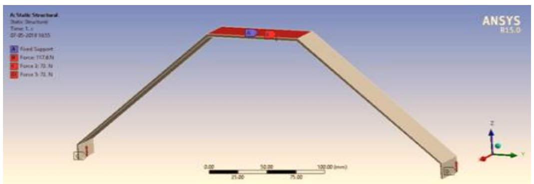
CATIA software is used for the modeling of the landing gear. The thickness provided to the model is 3mm. The 2D diagram was extruded using the padding feature to form a 3D model shown in Fig. 1. The accuracy of a simulation is governed by meshing. In ANSYS a wide array of meshing tools is available to allow flexible options to make a mesh that can give the final solution. Since the UAV landing gear is simple geometry, the hexahedral element also known as hex dominant mesh is chosen for this project work. Finite element analysis is the best tool to receive an approximated solution of the boundary condition. Sometimes it is also stated as field problems. The boundary conditions are specific to the boundaries of the field constraints. It is a critical part of simulations and analysis of problems. Boundary condition includes supports, forces and any type of constraints for the analysis. The landing gear is modeled using three-dimensional FE analysis. The maximum weight of the UAV is 12kg. The frictional force generated at the tire, the tangential force occurring by the inertia force, the moment that is developed by the vertical load, the distance from the center of gravity to the landing gear, the stiffness of the tire is all neglected. It is assumed that the UAV is landing with a speed between 2 and 6 m/s. Based on the given speed range the impact force can be calculated using the impulse-momentum equation.

$$F\Delta t = mV \qquad \text{-------} (1)$$

Where F is the Impact force, Δt is the impact time, m is the vehicle weight and V the considered velocity at impact.



(a) (b)



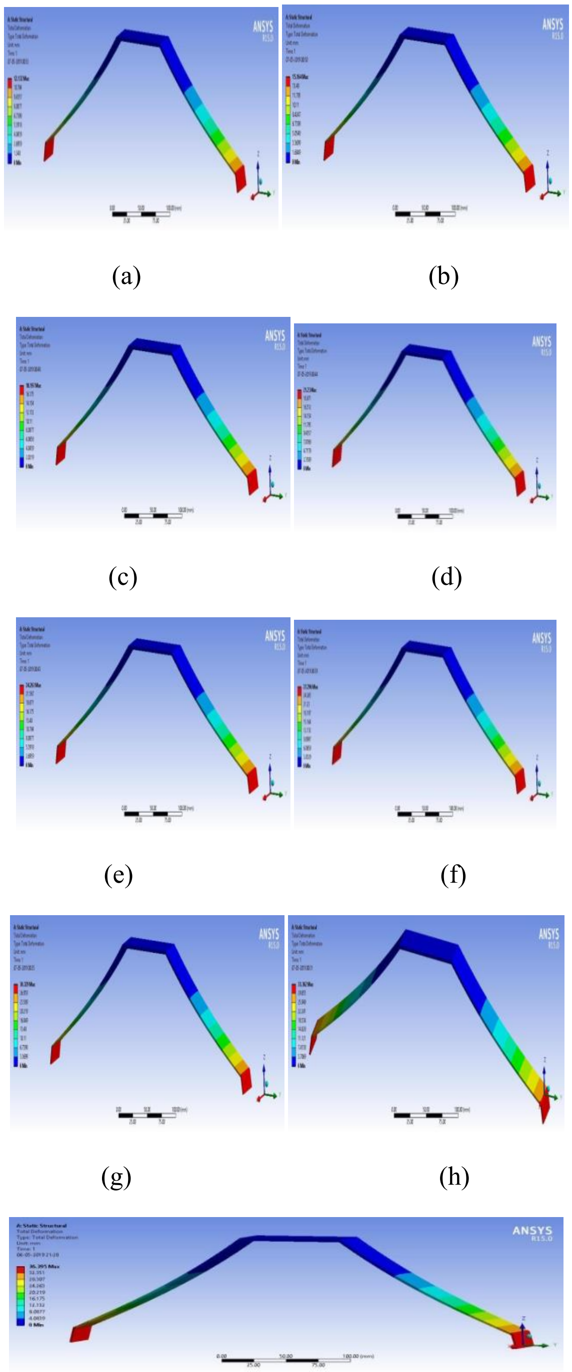
(c)

Fig.1. (a) 3D Model of the landing gear using CATIA (b) Hexahedral meshing of the part (c) The loads action on the landing gear

3. Results and discussions

3.1. Total deformation occurring on the application of impact forces

Deformation is an important criterion to consider when testing a model under certain loading conditions. Deformations in this model occurred along its span length. From Fig. 2 it can be seen that smaller deflections occur with a maximum of 18.19 mm. for a velocity of 3 m/sec. The majority of the deflections occur at free ends of the forks of the landing gear. The bottom plate being fixed has zero deflections in all directions. The Deflections occur along the y-axis. In Fig.2 deformations caused due to impact with a velocity range of 3.5 to 4.5 m/sec are shown. The maximum deformation is due to 4.5 m/sec with a magnitude of 27.29 mm. As the impact loads were increased, the deformation increased gradually.In Fig.2 it can be observed that the maximum deflection of 36.39 is caused due to the impact of 144N. When compared with the original span length of 300 mm, the observed deflection is considerably safe for operations.



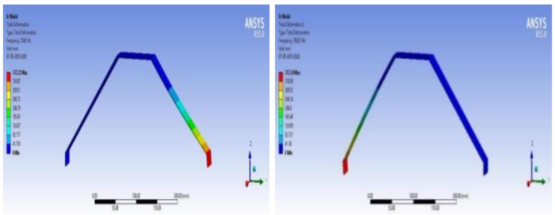
(a) (b) (c) (d) (e) (f) (g) (h) (i)

Fig.2. Deformation due to impact (a) load of 48N,(b) load of 60N,(c) load of 72N,(d) load of 84N,(e) load of 96N,(f) load of 108N,(g) load of 120N,(h) load of 132N,(i) load of 144N

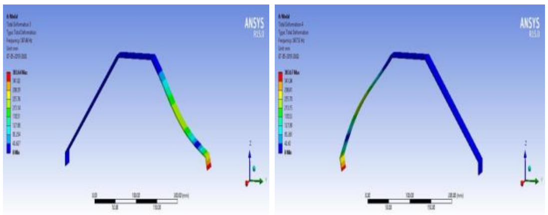
3.2. Modal Analysis Results

Modal analysis has been performed to obtain the natural frequency of the model made of Aluminum Alloy

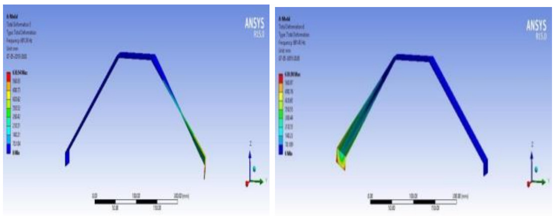
Al 6061-T6. It is very critical to know the natural frequency to avoid resonance. Natural frequency for different mode shapes and the maximum deflection caused due to that is shown in the following ANSYS analysis results. In figureNatural frequency of each mode, shapes have been shown. The Mode shapes are unique vibration patterns at specific frequencies. The maximum frequency was found to be 974 Hz causing a deflection of 403.59 mm. These Natural frequencies have help in calibrating the operating frequency to avoid resonance.



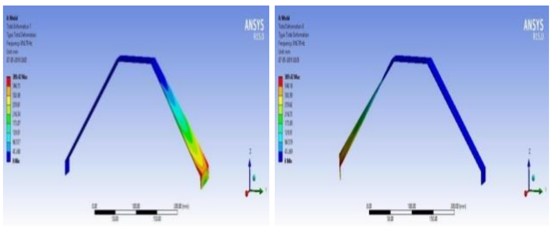
(a) (b)



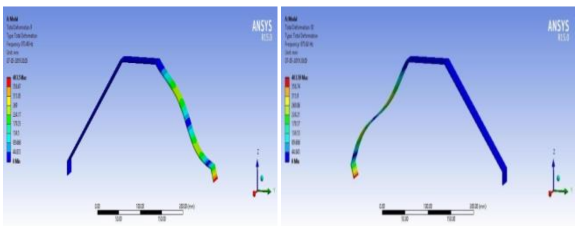
(c) (d)



(e) (f)



(g) (h)



(i) (j)

Fig.3. Mode shapes of landing gear (a) Mode shape 1,(b) Mode Shape 2,(c) Mode shape 3,(d) Mode shape 4,(e) Mode shape 5,(f) Mode shape 6,(g) Mode shape 7,(h)Mode shape 8,(i)Mode shape 9,(j)Mode shape 10

4. Conclusions

In the current work, the landing gear of light UAVs is simulated and maximum deformation is determined. The range of velocity has been taken as 2 m/sec to 6 m/sec. A greater range of velocity is taken to simulate an accident like situation. The stresses generated due to impact landing were well within the range of safety. But in Moderate landing speeds and above safety landing velocity, the design with the material Al 6061-T6 will work considerably well. The displacement at maximum landing velocity is 36.39 mm. considering the large span of the landing gear. At accidental speeds, this deflection is allowable owing to the high elastic nature of the material and the landing gear can withstand the obtained deflection. Hence with present work, it can be concluded that the design is stable and can be used to serve its purpose.

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