

Stress analysis of Landing gear of light Unmanned Aerial Vehicle

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Abstract : The landing gear system of an aircraft absorbs energy from the impact of landing. Numerical simulation has become a great tool for the assessment of the landing gear dynamics as well as for aircraft structure and landing gear interaction. This paper basically describes the normal structural behavior of a simple landing gear structure model system and accurately simulates the energy absorbed by the gear system without adding substantial complexity with the model. It carries the structure aircraft weight at all required ground operations including landing, take off, taxiing and towing. The stress results obtained from the finite element analysis is used to calculate the factor of safety. This work also focuses on landing gear of small unmanned aerial vehicles, where the landing gears used are of leaf spring type. It has been seen that the stresses are very high during greater impact speeds, which resulted in less factor of safety.

Keywords- Landing gear, aircraft, finite element method, stress, factor of safety

1. Introduction

Aircrafts have made of multiple configurations of landing gear such as the tricycle gear where the nose gear is at the front or conventional gear where there is one tail wheel and two main front gears. The different load paths and stress behaviors will result in different configuration while supporting the aircraft during landing, take-off, taxiing and operations on the ground. This thesis focuses on the new generation of Unmanned Aerial Vehicles, also known as UAV. The landing gear configuration of these light UAVs are quite different from the conventional ones. Although conventional landing gear assembly can be used in the UAVs but using a leaf spring type landing gear is the most feasible. As this does its job without adding much complexity to the system [1-5]. The primary focus of the present analysis work is study about landing moment. However, the model used in this work can also be used to test other cases of loads. More than a hundred records of landing gears were found in the 2009 U.S. Service difficulty report. The difficulties vary between a nose gear and a main gear and a tail gear. Although Richard Courant first introduced the Finite Element Analysis theory in 1943, the study of the UAV landing gear using FEA is not heavily done and published [6-12]. In order to do FEA, it is necessary to complete many steps in order to procure accurate results, including appropriate assumptions. Owing to the UAVs small size and lesser weight, the weight of the landing gear assembly should be less as compared to the size. Since UAV are used for specific purpose the landing gears must be of high performance and also must adhere to the UAV principles. With present developments and studies it is found that the leaf spring type landing gears are most suitable. They require less volume and are very light weight. These landing gears have a portion fixed to the fuselage known as the bottom plate. And two forks emerge at an angle from the base plate. The fixed part can be bolted with the fuselage or welded depending upon the requirement [13-19].

In the present work all the components that are making up gear must go through modeling in 3D computer-aided design (CAD) Package. In this specific study, the CATIA software is used. When the 3D model is done, calculations are to be executed to understand the loads acting on the landing gear during landing. Then the kinematic analysis is done and the models justification is done on how to apply the loadings in the finite element model (FEM). Then FEM is used in obtaining the stress and displacement behavior during landing. The FEA package used in this work is ANSYS 14.5.



2. Materials and methodology

2.1. Materials

Aluminium alloy and steel alloy are most commonly preferred in landing gear assembly. Aluminium's high corrosion resistance property helps in retaining the structural integrity for aircraft support. In conventional landing gear assembly, some parts are forged before being machined. For this unmanned aerial vehicle, the whole of the element is casted and then machined. The material considered here for the landing gear is Al 6061-T6. The material properties considered for the analysis are given in the Table. 1

Table.1. Material Properties

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 Methodology

The landing gear model was generated in CAD modeling software (CATIA) and then converted to stp file format. The stp file formats were imported to ANSYS for carrying out different analysis such as equivalent stress. The Factor of safety with respect to the landing speeds and impact loads were calculated and tabulated.

2.3 Solid modeling of landing gear

Software used for modeling the landing gear is CATIA. The 2D model of the landing gear with appropriate dimensions were drawn and then extruded for the required face width of the part. The procedure for the making of the landing gear is given here. At first the top part of the gear that is to be fixed with fuselage is drawn. The two forks of the model are generated at an angle of 139.7° with the fixed part. The part that attaches the wheel is generated vertically from the free end of the forks. The thickness provided to the model is 3mm. The following 2D diagram was extruded using the padding feature to form a 3D model shown in Figure.1.



Fig.1. 3D Model of the landing gear using CATIA

2.4 Mesh, element type and boundary conditions

Meshing is an important part in a computer simulation. Accuracy of a simulation is governed by meshing. In ANSYS a wide array of meshing tools are available to allow flexible options to make mesh, that can give final solution. Since the UAV landing gear is a simple geometry, hexahedral element also known as hex dominant mesh is chosen for this project work. This unique type of meshing gives the solution higher accuracy and efficiency. DOF is greater in hex dominant as it provides smooth nodal distribution along with high accuracy.



Fig.2. Hexahedral meshing of the landing gear part

For 3D FEA the hexahedral elements are SOLID 186. It is an upper order 20 node solid element that shows displacement of a quadratic. The element is categorized by 20 nodes which exhibit 3 DOF per node shown in Fig. 2. Finite element analysis is the best tool to receive an approximated solution pertaining to the boundary condition or field problems. Differential equations govern the field problems basically. The boundary conditions are specific to the boundaries of the field constraints. It is a critical part of simulations and analysis to problems. Boundary condition includes supports, forces and any type of constraints for the analysis. For Equivalent stress (von-mises) analysis following boundary conditions are applied in ANSYS 14.5, Fixed support is applied to the gear, due to the fixed support the displacement along all the axis will become nil, A load of 117.6N has been applied on the fixed support, Impact loads of several speeds as tabulated has been applied on the free ends of the landing gear shown in Fig.3.



Fig.3. Loads action on the landing gear along positive and negative z-axis

2.5 Landing condition

The following general assumptions are applied. 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 centre of gravity to the landing gear, the stiffness of the tire are all neglected. It is assumed that the UAV is landing with a speed between 2 and 6 m/s. In addition, the UAV is landing at normal glide angle between 3 to 10 degrees. The glide angle is also measured from the ground. Based on the given speed range the impact force can be calculated using the impulse-momentum equation.

$$= mV_f \dots(1)$$

- Where, F is considered as the Impact force
- Δt is considered the impact time
- m is vehicle weight
- V_f is considered as the velocity at impact

The time of impact is considered to be 0.5 seconds. Impact loads for different velocities are recorded in Table.2.

Table.2. Impact loads corresponding to different landing speeds

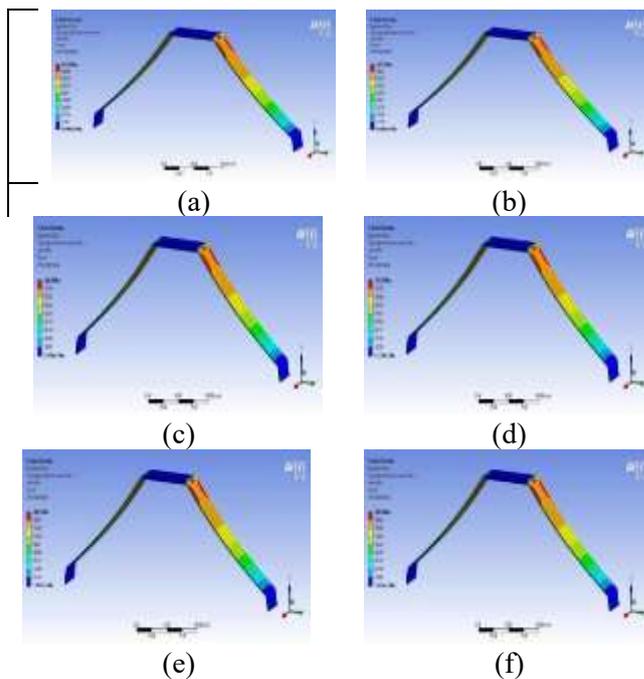
Case	Velocity at impact (m/s)	Force (N)
1	2	48
2	2.5	60

3	3	72
4	3.5	84
5	4	96
6	4.5	108
7	5	120
8	5.5	132
9	6	144

3. Results and discussions

3.1 Equivalent stress developed on application of loads

With the given boundary conditions, simulations were carried out to check for the equivalent stress developed when making an impact landing within a velocity range of 2 to 6 m/sec. With landing velocities of 2 to 3 m/sec, from the ANSYS reports it is seen in Fig.4. that the stresses generated are maximum of 126.39 MPa. The bottom plate of the landing gear which is attached to the fuselage or the body of the aircraft is having zero displacement. Hence, there is no stress generation in the clamped region. Maximum stresses occur in the fork region. In Fig.4.a maximum stress of 189.58 MPa is seen on the landing gear when the landing velocity is 4.5 m/sec. Impact load of 108N is responsible for this stress generation. The junction of the bottom plate and the beginning of the fork is the zone of maximum stress concentration. Thus, to avoid the stress concentration cracks, any attachment of holes must be avoided in this region since stress concentration in holes are maximum resulting in failure of the body. In Fig. 4.it can be seen that higher stress close to yield strength of the material has been generated. Higher impact velocities in the range of 5 to 6 m/sec produced higher stress in the body, due to higher impact loads. Any further increase in speed may lead to the failure of the body. Although UAVs land in the velocity range of 1 to 2 m/sec, the simulations carried here describes an aggressive landing situation. Hence, higher range of landing velocity is considered, with 6 m/sec to be categorized as crash landing. Despite an aggressive velocity consideration, the maximum stress generated is desirably less than the yield strength limit.



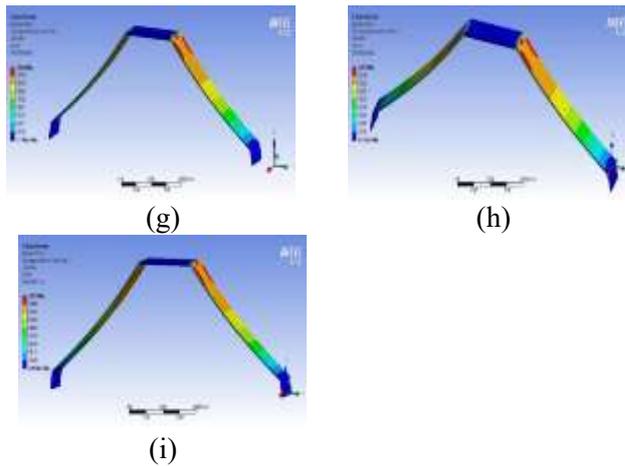


Fig. 4. Stress developed due to (a) load of 48N, (b) load of 60N, (c) load of 72N, (d) load of 84N, (e) load of 96N, (f) load of 108N, (g) load of 120N, (h) load of 132N, (i) load of 144N

3.2 Factor of safety calculation

Impact load (N)	Deflection (mm)	Von-Mises stress (MPa)	FOS
48	12.13	84.26	3.7
60	15.16	105.32	2.9
72	18.19	126.39	2.5
84	21.23	147.45	2.1
96	24.26	168.52	1.9
108	27.29	189.58	1.6
120	30.32	210.64	1.5
132	33.36	231.71	1.3
144	36.39	252.77	1.2

The FOS can be calculated as the ratio between the Ultimate tensile strength and the maximum allowable stress generated in the landing gear. Table 3 represents the tabulated data. The variation in impact velocity, factor of safety and equivalent stress is shown in Fig.5.

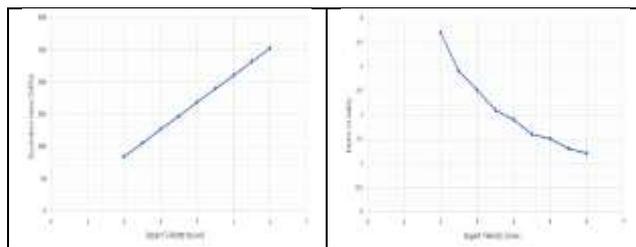


Fig. 5. Variation in equivalent stress and factor of safety with respect to impact velocity

4. Conclusions

In the present work, landing gear of a light unmanned aerial vehicle is simulated to determine the maximum equivalent stress under impact loads for certain velocity range. In the present work, landing gear of a light unmanned aerial vehicle is simulated to determine the maximum equivalent stress and displacement generated, when under impact loads for certain velocity range. The velocity range has been taken in the range of 2 m/sec to 6 m/sec, although the real time data shows a UAV lands within the speed of 1.5 to 2.5 m/sec. But the UAVs are also very prone to accidents, and most of the time it is during landing activity. So 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, as the yield strength of the material is 276 MPa and the maximum stress generated is 252.7

MPa. Also, the factor of safety has been calculated, It is well suitable for design. The factor of safety ranges from 3.7 to 1.2. Although it is well within the range, but at higher landing speeds, the landing gear is prone to failure after repeated use. But in Moderate landing speeds and above safety landing velocity, the design with the material Al 6061-T6 will work considerably well.

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