STRUCTURAL ANALYSIS OF LANDING STRUT MADEUP OF CARBON FIBRE COMPOSITE MATERIAL

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Abstract: The landing strut is a structure that supports a helicopter on ground and allows it to take-off, and land. In fact, landing strut design tends to have several interferences with the helicopter structural design. Now a day the weight of landing strut has become an important factor. Efforts are being made to reduce the weight of the helicopter and consequently increase the payload. This paper presents an approach to optimize the design of landing strut of a Light Compact Helicopter (LCH) made of Carbon Fibre Composite Material adopted from Aerospace Specification Metals (ASM). 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 strut which results in the minimum weight of landing strut.

I. INTRODUCTION

Each type of helicopter needs a unique landing strut with a specific structural system, which can complete the demands described by unique characteristics associated with each helicopter. The landing strut is the component that supports a helicopter and allows it to move on the ground. Conventional landing strut is one of the types among the landing strut where the strut legs indeed of tricycle fashion. The tricycle arrangement has one strut either back or front and two main strut legs. The main strut leg comprises a simple single piece of carbon fibre composite material spring leaf type which is bolted at the bottom of the fuselage.

The design and development of a landing strut encompasses several engineering disciplines such as structures, mechanical systems, aerodynamics, material science, and so on. The conventional landing strut design [1] and development for aerospace vehicles is based on the availability of several critical components/systems such as forgings, machined parts, mechanisms, sheet metal parts, electrical systems, hydraulic systems, and a wide variety of materials such as carbon fibre composite materials, steel and titanium, beryllium, and polymer composites. As the science of materials is progressing continuously it is natural that the use of new materials will replace older designs with new ones. Energy absorption and crashworthy features are the primary design criteria that govern the development of landing struts. The impact force on landing strut has been discussed by Flugge [2] considering both the landing and taxiing impact forces and neglected the drag force acting on it. The crack generation in the landing strut components was observed by Fujimoto [3] and the basic causes of damage were found to be processing operations, latent material defects, mechanical damage and crack growth developed at corrosion pits. The helicopter landing strut simulation was analyzed by Derek Morrison et al. [4] by performing two types of analysis. The first is kinematic evaluation of front nose strut and other is the structural study of main landing strut for a light weight helicopter. The approach for modeling and simulating landing strut systems was proposed by James Daniels [5] devolved a nonlinear model of an A-6 intruder main strut, the simulation and validation was performed against the static and dynamic test data. A discussion has been done on problems facing by the helicopter community in landing strut dynamics, especially in shimmy and brake-induced vibration by Jocelyn Pritchard [6], experimentally validated and characterized the shimmy and brake-induced vibration of helicopter landing strut. The design analysis of Light Landing Strut was presented by Amit Goyal [7]. In the development phase, conducting a rigorous non-linear stress and buckling analysis was carried out and also conducting various experimentations on different combinations of loads and orientations. Noam Eliaz et al. [8] discussed failure of beams of landing strut during operation. During replacement of a wheel on the helicopter, a crack was found on the rear axle bore of the left-hand main landing strut truck beam. The aero structure analysis on ME 548 was analyzed by Dave Briscoe [9] verified that the vonmises and deflections of landing strut and also proved that results given by the ANSYS and SOLID WORKS software are not same because of improper meshing of components. The specific constrained layer damping applications for cantilever-loaded steel spring landing strut was investigated by Oraig Gellimore [10]. This work involves validation of the cost efficient design of traditional landing strut damping devices when used in constrained layer damping. The dynamic analysis of landing strut for critical work conditions by applying finite element analysis was analyzed by Jerzy Malachowski [11].The design of light landing strut by conducting structural analysis and design optimization was analyzed by Essam Albahkali and Mohammed Alqhtani [12] by conducting experiments on landing strut using impact analysis. Review of literature survey on different types of landing struts shows that landing strut 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 strut made of ASM7075-T6 material. The present study deals with the structural analysis and optimization of landing strut's leg made of ASM7075-T6 material and the analysis was carried out using ANSYS (Version 13).

II. GEOMETRICAL MODEL

The undercarriage or landing strut in aviation is the component that supports an aircraft on the ground and allows it to land. Conventional landing strut consists of horizontal struts connected with parallel struct which possess centre of gravity. This type of landing strut is most often used in older generation aviation airplanes and now a day, it is used in LCH.

The following are assumptions to be considered for analysis

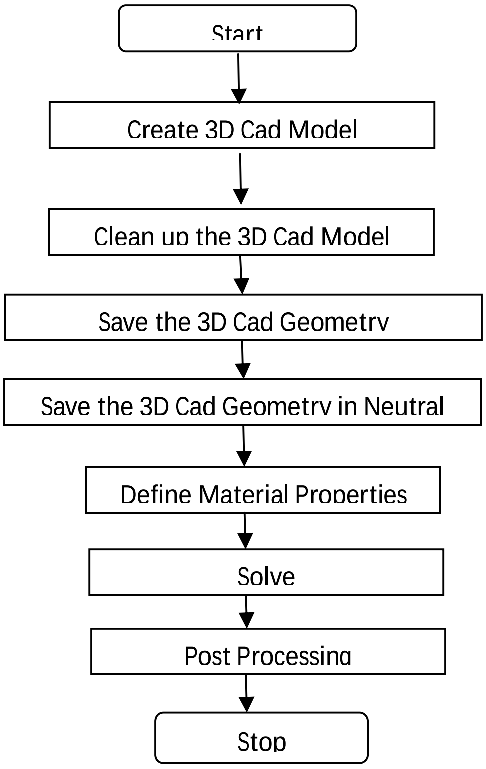
1. The material is assumed to elastic and homogenous.
2. The analysis has been carried out with in elastic limits.
3. Both Solid (pipe element) and shell elements are used for analysis.
4. Rigid Body Element (RBE3) connection is used for load transfer.

Figure 2.1: Landing Strut

Figure 2.1 shows the model of landing strut chosen for analysis which has been used for light compact helicopter and at present these are used in LCH. The weight of landing Strut considered for analysis was taken as 6 kg.

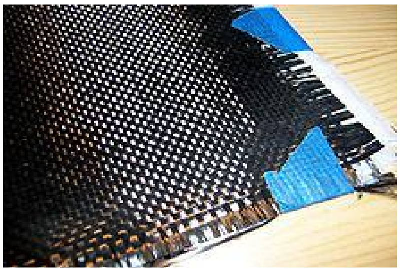
The data required for designing and weight of landing strut has been taken from "Grove Helicopter Landing Gear Systems Inc", which is a complete custom landing gear company manufactures ready to bolt component design for customer requirements to individual aircrafts and Helicopter.

III. FLOW CHAT



IV. MATERIAL PROPERTIES

Here we are using the materials for analysis of helicopter strut is Carbon fibre composite materials. It having density as 1.6 g/cm^3, Young's modulus as 70 Gpa and poissons ratio as 0.10. Carbon fiber, alternatively graphite fiber, carbon graphite or CF, is a material consisting of fibers about 5–10 µm in diameter and composed mostly of carbon atoms. The carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fiber. The crystal alignment gives the fiber high strength-to-volume ratio (makes it strong for its size). Several thousand carbon fibers are bundled together to form a tow, which may be used by itself or woven into a fabric. The properties of carbon fibers, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared to similar fibers, such as glass fibers or plastic fibers. Carbon fibers are usually combined with other materials to form a composite. When combined with a plastic resin and wound or molded it forms carbon fiber reinforced plastic (often referred to as carbon fiber) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. However, carbon fibers are also composed with other materials, such as with graphite to form carbon-carbon composites, which have a very high heat tolerance.



V. PROCEDURE

1. Define Geometry: First of all, we have to define the geometry and dimension for the helicopter strut. With the help of obtained geometry, we have to design 3D model of the landing strut with the help of CAD Package software's like Pro/E, Catia and NX CAD. After model has been designed, we have to save the modeled design in the common format like IGES or STEP.
2. For Analysis of landing strut, here we are using Ansys Workbench V12.0.1, this analysis can be also done with the help Nastran software too.
3. Meshing has been done for the designed model, here we used tetrahydral element type for dividing the model into small number of elements
4. We have defined the fixed support and force acting on the strut. Here we use force as 400N because the load acting on the landing strut during landing will be around 350N.
5. Then we have to select the result what are all we need for further studies like deformation, stress and strain

VI. 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. Table 2 shows general design loads considered to test the landing gear's leg.

Table 1: Landing Strut Loads (Design Loads)

Type of Load	Value
Landing Load	400 N

With the above all specifications the model was designed in CATIA (Ver-11), meshed in HYPERMESH (Ver-12) and the results are viewed in ANSYS (Ver-12).

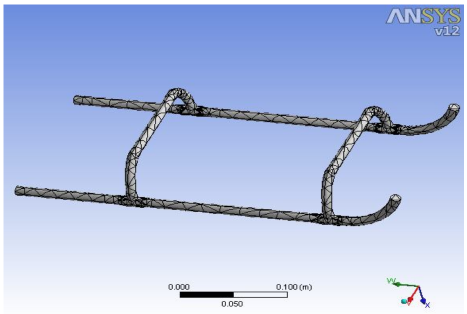


Figure 2.2: 3D-meshed model of landing gear's leg

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.

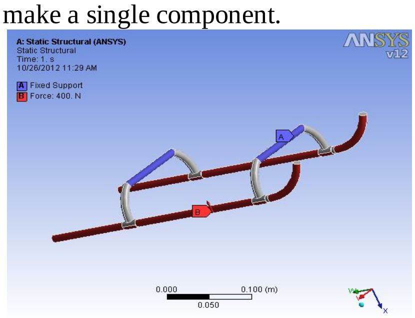


Figure 2.3: Loads applied on landing gear's leg

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.

VII. 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.

VIII. 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.

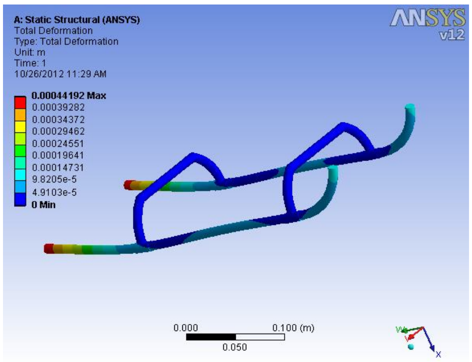


Fig 7.1 Total Deformation

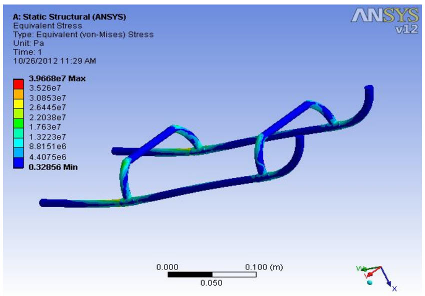


Fig 7.2 Equivalent Von-Mises Stress

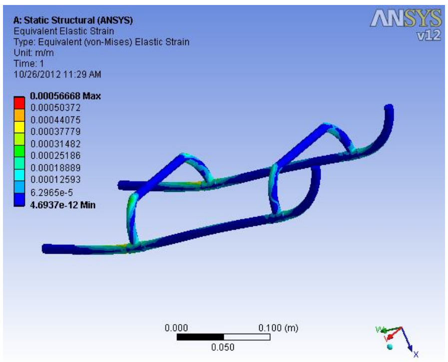


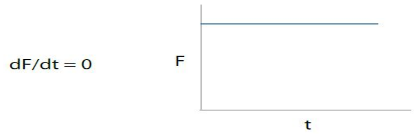
Fig 7.2 Equivalent Von-Mises Elastic Strain

From the above Contour Plots, we can able to find the place where the maximum stress, strain and deformation take place.

Results			
Plot	Deformation	Strain	Stress
Minimum	0. m	4.6937e-012 m/m	0.32856 Pa
Maximum	4.4192e-004 m	5.6668e-004 m/m	3.9668e+007 Pa

There are two conditions for static analysis:

1) The force is static i.e. there is no variation with respect to time (dead weight)



2) Equilibrium condition Σ forces (F_X,F_Y,F_Z) and Σ Moments $(M_X,M_Y,M_Z)=0$

The FE model must fulfill this condition at each and every node. The complete model summation of the external forces and moments is equal to the reaction forces and moments.

The complete equation to be solved in a linear static FE solver is **F = K * u.**

F is the vector of all applied external forces and moments.

K is the stiffness matrix of the model depending on material and geometric properties. In a linear analysis, **K** is constant.

u is the nodal displacement vector.

IX. 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; 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. 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.

X. OPTIMIZATION

Optimization is clearly one of the overall strengths of Altair and Hyper Works. You may distinguish optimization methods with respect to its position in the design phase i.e. concept design optimization such as topology, topography and free size optimization, and "fine" tuning optimization disciplines such as size or shape optimization. Alternatively, you can distinguish according to the design variable i.e. which variable of the system is modified/altered during the optimization. For instance, the design variable of a topology optimization is the elements density, whereas in size optimization the thickness of a sheet metal may be varied

Types of Optimization

1. Geometrical Parameters
2. Shape Optimization

Geometrical Parameters

- Optimization for geometry parameters, work well at the individual component level rather than with complicated assemblies.

- Software cannot add or remove geometry on its own but can only play with pre defined parameters within specified limits.

Shape Optimization

- Usually restricted to only linear static and normal mode dynamics.

- Good tool for innovative products (when the initial shape is not known or fixed).

- Software can give hints for the addition or removal of geometry.

XI. CRASH ANALYSIS

1. **Structural Crashworthiness Or Full Dynamic / Impact Simulations:**

   To find deformation, stress, and energy absorbing capacity of various structural components of a vehicle hitting a stationary or moving object. The component is said to be crashworthy (safe) if it meets the plastic strain and energy targets.

   Applications: Frontal, Side, Rear, Roof crush, car hitting a pole / wall etc.

2. **Drop Test Simulations:**

   Drop test is a free fall test carried out to check the structural integrity of the component.

   Applications: Black box of an aircraft, mobile phone, consumer goods such as TV, fridge etc

3. **Occupant Safety**

   To find the effects of crash on the human body and making the ride safe for the driver as well as the passengers. Several regulations exist in different countries to ensure a proper certification.

   e.g.: FMVSS (Federal Motor Vehicle Safety Standards) in the USA, ECE (Economic Commission of Europe) regulation in Europe. In India, the ARAI has set up standard procedures for the Automobile industry and called AIS (Automotive Industry Standards)

XII. ADVANTAGES OF FEA

- Visualization
- Design cycle time
- No. of prototypes
- Testing
- Optimum design

CONCLUSIONS

A CAD model of landing strut for LCH was made and discretized in to finite element mesh using HYPERMESH. Design loads were applied through RBE3 connection in respective directions. Static and spectrum response analysis were conducted in ANSYS. The 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 strut weight was reduced by iterative process using design optimization analysis in ANSYS from 6 kg to 4.1538kg for the given loading conditions. A reduction of 1.8462 kg can be observed which amounts to almost 30% reduction of weight.

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