Optimization of the UAV Landing Gear to Minimize the Weight

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Abstract

UAV-Unmanned aerial vehicles are extensively being used these years. These are commonly known as drones. Today drones are used in various applications like military, commercial, cargo, transport and for agricultural purposes. The present aircraft has weight which is more than estimated ones. The objective of this project is to reduce the weight of the UAV by modifying the landing gear design. The obtained results will be compared to the weight changes of the UAV before and after the modification. ANSYS software is used for analysis and CATIA software is used for part modeling of the UAV.

Keywords: UAV, Optimization, Landing gear, Weight.

1. Introduction

An Unmanned Aerial Vehicle (UAV) is an aircraft that can be controlled by a pilot on ground station or autonomously by pre-programmed flight plans. The UAV generally has a droppable payload. In case of agricultural UAV’s the aircraft will unload the payload. The main advantage of UAV is that they can be developed, produced and operated at lower costs. In terms of saving in engines, airframes, fuel consumption, pilot training, logistic and maintenance it is high. The use of UAV’s in the agriculture industry can be a Crop field scanning with compact multispectral imaging sensors, GPS map creation through onboard cameras, Heavy payload transportation, Livestock monitoring with camera.

Topology optimization extensively used in industrial optimization tasks. The definitions of objective, constraints and the specifications of allowable design space are required. A Parameterization is not necessary as topology optimization will not distinguish between geometry and analysis model. The end result of this optimization determines the material distribution in the optimal design space.

The landing gear is the main component which supports an aircraft and allows it to move on the ground. Conventional landing gear is one of the type of the landing gear where the legs of gear are presented in a tricycle form. The tricycle arrangement has a gear strut either back or front and two main gear legs. The features such as Energy absorption and crashworthy are the primary design criterion that govern the development of landing gears. The tricycle form landing gear comprises of a layout with one wheel in front, called the nose wheel and two or more wheels at the back. These wheels improve stability and also provide safety in the case of malfunction of one wheel. The nose wheel allows the UAV to change directions during ground operations.

The landing gear attachment is placed under the fuselage of an aircraft. The forces borne by the landing gear during landing when will have a contact to the ground are transferred to the fuselage by the attachment. The structure for attaching the landing gear to the fuselage should be capable of supporting the load borne by the landing gear.

2. Problem Statement

Weight of the UAV was more than estimated weight. Before flight test the UAV weighed about 13kg and the expected weight is 12kg without payload. Due to this payload capacity is reduced.
1. About 70% takeoff can be achieved with no payload condition. The liftoff could not be achieved with payload condition.

2. Without payload condition, the thrust required to fly was high and is similar to the with payload, so endurance of the UAV was low.

3. **Objective**

   The main objective is to reduce weight of the UAV by optimizing various components of the UAV like landing gear, landing gear attachment without reducing the structural strength of the UAV.

4. **Methodology**

   **Weight optimization**

   1. Modeling of landing gear and landing gear attachment of UAV is from CATIA software.
   2. The static and impact loads are to be calculated on landing gear.
   3. Structural analysis of landing gear and landing gear attachment is done using ANSYS software for landing condition.
   4. Topology optimization on main landing gear and landing gear attachment is performed static and impact loadings will be analyzed and must check that the maximum stress is less than critical stress.

5. **Results & Discussion**

5.1 Landing Gear Analysis

   ➢ **PRIOR OPTIMIZATION:** For static structural analysis of landing gear, we used ANSYS software.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Dimension(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>50</td>
</tr>
<tr>
<td>Height</td>
<td>265</td>
</tr>
<tr>
<td>Thickness</td>
<td>11</td>
</tr>
<tr>
<td>Length between wheels</td>
<td>666</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Young’s modulus</th>
<th>Density</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>115GPa</td>
<td>1422 kg/m³</td>
<td>0.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Boundary condition</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact load</td>
<td>502.7N</td>
</tr>
<tr>
<td>Static load</td>
<td>136N</td>
</tr>
<tr>
<td>Displacement</td>
<td>0mm at red portion indicate in figure</td>
</tr>
</tbody>
</table>
Table 4: Landing Gear Load Analysis results

<table>
<thead>
<tr>
<th>Loading condition</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Von Mises stress distribution for static loading(Pa)</td>
<td>1.5896</td>
<td>2.9945e7</td>
</tr>
<tr>
<td>Deformation of the structure for static loading(m)</td>
<td>0</td>
<td>0.0021883</td>
</tr>
<tr>
<td>Von Mises stress distribution for impact loading(Pa)</td>
<td>342.7</td>
<td>4.0608e7</td>
</tr>
<tr>
<td>Deformation of the structure for impact loading(m)</td>
<td>0</td>
<td>0.0020895</td>
</tr>
</tbody>
</table>

- **STATIC LOAD ANALYSIS**

Static equivalent von-misses stresses and the deflection of landing gear components are determined with the given load data and constraints by satisfying equilibrium equations. Both material and geometrical linearity is considered in the analysis. A static structural analysis determines the displacements, stresses, strains, and forces in structures.

The maximum Von-Mises maximum stress is 30 N/mm². The obtained stresses are less than yield stress of the material, so structure is safe for the given loads.
The Maximum displacement is 2.2 mm which can observe at the loading region which is at the wheel base of the axle component

IMPACT LOAD ANALYSIS

During landing condition impact load acting on the landing gear is considered because, during landing condition only aircraft encounter a maximum load so, landing gear should have good strength enough to sustain impact load.

The maximum Von-Mises maximum stress is 55N/mm². The obtained stresses are less than yield stress of the material, so structure is safe for the given loads.

The Maximum displacement is 4 mm which can observe at the loading region which is at the wheel base of the axle component.
LANDING GEAR ANALYSIS POST OPTIMIZATION

Completing structural analysis of landing gear in ANSYS, after that model is tested for topology optimization in that process we got clear view of changing the design structure so, weight of the landing gear can be reduced to certain extent. The static and impact load analysis indicates that, The obtained stresses are low compared to allowable stresses of the material, hence there is a possibility for optimization of the landing gear. The landing gear can be optimized where the stress is low, so model shape is changed along the length of the landing gear as shown in below figure and it is imported to the ANSYS software for further analysis is to carried out.

Fig. 5 Optimized Plot of structure

Fig. 6 Views of optimizes landing gear

Topology optimization for the landing gear is done using Ansys and the design can be modified so as to curb excess weight upto a certain limit without compromising strength.

Fig.7 Von Misses Stress distribution

The Von-Mises stress distribution with maximum stress as indicated is 68MPa which is at fixed region of landing gear which is not greater than ultimate strength. So, landing gear can withhold the loading condition.
The deformation plot of the landing gear during landing condition i.e. maximum deformation of 4 mm is obtained near the wheel axle component.

**LANDING GEAR RESULTS**

After optimizing the landing gear for slight change in design, weight is being reduced from 850g to 550g, resulting in reduce of 300g in landing gear attachment.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Initial model</th>
<th>Optimized model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight(grams)</td>
<td>850</td>
<td>550</td>
</tr>
<tr>
<td>Width(mm)</td>
<td>50</td>
<td>45</td>
</tr>
</tbody>
</table>
5.2 Landing Gear attachment analysis

- **PRIOR OPTIMIZATION**

  The main purpose of landing gear attachment fitted to aircraft is to distribute the aircraft load during ground travel like the taxiing, taking off and landing. The details of the design and material properties of the landing gear attachment is given below.

![Initial Landing Gear attachment dimensions](image)

Fig. 9 Initial Landing Gear attachment dimensions (mm)

The landing gear attachment was analyzed for an impact loading of 350N. The results of this loading case is tabulated below:

<table>
<thead>
<tr>
<th>Loading condition</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Von Mises stress distribution for static loading (Pa)</td>
<td>1094</td>
<td>2.342e7</td>
</tr>
</tbody>
</table>

- **POST OPTIMIZATION**

![Optimized Landing Gear attachment dimensions](image)

Fig. 10 Optimized Landing Gear attachment dimensions

![Optimized Landing Gear attachment dimensions](image)
The Fig. 1.11 shows Von-Mises stress distribution of the optimized landing gear. The maximum stress being 30.3MPa acting at the fixed bolt region as indicated by red color while the minimum stress being 206.6Pa acting as indicated by blue color.

**RESULT OF LANDING GEAR ATTACHMENT**

After optimizing the landing gear support for impact loads, the low stress region is removed, hence weight is being reduced from 220g to 107g, resulting in reduce of 113g in landing gear attachment.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Initial model</th>
<th>Optimized model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Stresses (MPa)</td>
<td>23.4</td>
<td>30.3</td>
</tr>
<tr>
<td>Weight (grams)</td>
<td>220</td>
<td>107</td>
</tr>
</tbody>
</table>

6. Conclusion

1. Landing gear weight is reduced by 40%. The landing gear mass prior to optimization was 885 grams and after the optimization is reduced to 529 grams, i.e. 356 grams is removed.
2. The landing gear attachment weight is reduced by 51%. Weight is reduced from 220 grams initially to 107 grams finally, i.e. 113 grams has been removed.

**References**


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