SELECTION AND ANALYSIS OF THE LANDING GEAR FOR UNMANNED AERIAL VEHICLE FOR SAE AERO DESIGN SERIES

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ABSTRACT

UAV-Unmanned Aerial Vehicle commonly known as Drones are extensively being used these years. Today drones are used in various applications like Military, Commercial Cargo Transport, and 3-D Mapping etc. For supporting the weight of the plane, and shock absorption functions, landing gear design is highly essential.

Society of Automotive Engineers (SAE) conducts ‘Aero Design Series’ competition annually in the United States of America (USA). This papers explains and gives details about the landing gears and significance of selecting the optimum one for the respective plane required to compete in the challenge. The gears were selected on various factors and methods depending upon the design and the load bearing capacity of the UAV.

Keywords: Aero, Analysis, Landing gear, SAE, UAV
I. INTRODUCTION

SAE International conducts “Aero Design Series” competition annually in USA. Depending upon the event objectives there are three classes in the competition-Advanced, Regular and Micro class. The objective of the Advanced Class of SAE Aero Design Series was to design the most efficient aircraft capable of accurately dropping a three pound (3 lb) humanitarian aid package from a minimum of 100 feet off the ground.

As the build UAV was approximately 29 pounds, a strong and efficient landing gear was to be designed.

Landing gear is a very major component in any UAV. The landing gear provides a stable support for the aircraft at rest on the ground. During landing, it acts as shock absorbent mechanical structure to absorb and transmit these loads to the stronger part of the UAV (fuselage) so that a majority of impact energy is dissipated. Landing gears also act as brakes during the motion of the UAV on the runway.

For building the most efficient UAV for the competition a high strength, light weight coupled with techno economic feasibility of the landing gear was to be designed and fabricated.

The types of landing gear are as follows:

- Tail Wheel Type (Tail- Dragger)
- Tandem Type (Bicycle Type layout)
- Tricycle Type

II. LANDING GEAR

A. Tail Wheel-Type

Tail Wheel-type landing gear is an arrangement in which the main gear is attached to the UAV slightly forward to the center of gravity and so another gear is required to support the UAV at the tail portion. This type of design is also called the conventional gear or Tail-dragger gear. This kind of landing gear results in giving the angle of the fuselage as such, which allows the use of long propellers to recompense for the underpowered engines. Figure below shows the layout of the Tail-wheel type landing gear.

![Figure 2.1 Tail Wheel Configuration](image-url)
B. Tandem Type

Tandem landing gear is the arrangement in which the main gear and the tail gear are aligned on the longitudinal axis of the UAV. Most UAVs have only the main gear forward with the tail having a skid under it. Usually it is arranged in a bicycle type layout and sometimes the wings may have small wheels attached to them to ensure optimum balance and stability. This type of landing gear allows high flexibility of the wings. Figure 2.2(a) and 2.2(b) shows the layout of tandem landing gear.

![Figure 2.2 (a) Front View of Tandem Type Layout](image)

![Figure 2.2 (b) Top View of Tandem type layout](image)

C. Tricycle-Type

The Tricycle-type landing gear comprises of a tricycle like layout with one wheel in front, called the nose wheel and two or more wheels at the back. The basic arrangement of this type of system is shown in the figure2.3. The main wheels are usually joined to a wing structure or fuselage of the UAV. They can vary in number and location. The 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 Tricycle-type landing gear is the most commonly used landing gear due to the ease at which ground operations can take place when implemented in a UAV.
III. DETAILS

A. Tail Wheel-Type

In the tail-wheel Configuration the main landing gear usually consists of two wheels which support most part of the UAV and are usually larger in size. The gear mounted to the tail helps in controlling direction and supports the latter half of the UAV. This type is usually used in UAVs having large propeller diameter and need higher ground clearance. This type of an arrangement has its advantages and disadvantages as follows:

Advantages:
- This type of configuration reduces the overall weight of the UAV.
- It Increases the directional stability of the UAV.
- The damages due to ground operations on unpaved and rough runways are reduced.
- The overall parasitic drag is reduced as it has an inclined configuration.

Disadvantages:
- Difficulty in steering the UAV latter half of fuselage.

B. Tandem type

This type of landing gear arrangement is similar to that of a bicycle with the main landing gear on the fuselage aligned on the central axis of the UAV to support its weight. It usually has wheels attached to the wings to maintain stability. It is specially used in case of UAVs which have slender and long fuselages which cannot support Tricycle type and Tail-wheel type landing gear. Its advantages and disadvantages are mentioned below.

Advantages:
- The overall Weight of the UAV is considerably reduced.
- The induced drag on the UAV is reduced.
- It Allows the UAV to have high aspect ratio wings with low angles of attack where high lift is created.

Disadvantages:
- Take-off and landing operations of the UAV becomes difficult and unstable.
- UAV might get damaged if airstrip is uneven while landing.

Figure 2.3 Tricycle-Type Configuration
C. Tricycle-type

The tricycle type landing gear arrangement works just as a tricycle. The main landing gear that is located at the latter half of the UAV usually supports most of the weight of the UAV and the nose landing gear located at the nose of the UAV is used to steer the UAV in the required direction. This is a very frequently used landing gear arrangement as it helps in easy maneuvering of the UAV. Some of its advantages and disadvantages have been mentioned below:

Advantages:

- It allows the UAV to brake faster without the UAV nosing over.
- Ground-Looping of UAV is prevented due to optimum location of center of gravity.
- Evenly distributed weight of UAV increases stability and ensures safety.
- Cross winds do not affect the UAV.
- Easy maneuvering.

Disadvantages:

- The drag is significantly increased.
- Weight of the UAV is slightly more.
- The nose gear is damage-prone as stresses induced on it are high.

IV. Practical Setup

A. Geometrical Model

The Mechanical Analysis was done on Finite Element Software Ansys Workbench 14.5 Module. Several models were considered for the landing gear and the model selected for the UAV is shown below, it has straight ends.

![Model Selected](image)

**Figure 4.1 Model Selected**
B. General Assumptions
Assumptions made during the Analysis for the gear are as follows: The frictional force developed between the contact of the wheel and the ground surface was neglected, as the rolling resistance of the wheels which we used was negligible. The tangential force developed by the inertia force, the moment produced by the vertical load times the horizontal distance from the center of gravity to the gear was neglected as the wheels were placed equidistance from the center of gravity of the gear. The weight of the UAV was considered to be 12kgs (29 pounds).

C. Landing conditions
The landing gear was analyzed assuming that the UAV would land between 3 to 6m/sec. As the Impact force is a function of vertical velocity, the impulse momentum equation is given by,

\[ F \Delta t = \frac{m}{g} \]

Where, \( F = \) Impact Force in Newton
\( \Delta t = \) Impact time
\( m = \) weight of the UAV
\( V_f = \) vertical velocity

Assuming the impact time to be 0.5 seconds, range of impact load with respect to the velocity are tabulated below,

<table>
<thead>
<tr>
<th>Velocity(m/sec)</th>
<th>Impact Force(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>72</td>
</tr>
<tr>
<td>3.5</td>
<td>84</td>
</tr>
<tr>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>4.5</td>
<td>108</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>5.5</td>
<td>132</td>
</tr>
<tr>
<td>6</td>
<td>144</td>
</tr>
</tbody>
</table>

D. Boundary Conditions and Constraints
The material assigned to the landing gear was a grade of 6061-T6 Aluminum. Material properties are shown in below table,

E. Material Properties

<table>
<thead>
<tr>
<th>Table 2: Material Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
</tr>
<tr>
<td>Yield tensile Strength</td>
</tr>
<tr>
<td>Ultimate tensile Strength</td>
</tr>
<tr>
<td>Break Elongation</td>
</tr>
</tbody>
</table>

Fine meshing done on the structure gave 5948 Elements and 12548 Nodes.
F. Mechanical Constraints and Loads
The top surface of the landing gear, a fixed support was imposed, between the landing gear and fuselage (shown in blue color). Thus the displacement of the top surface in all the directions becomes null.

The UAV weight in Newton was put in vertically downward direction at the top surface of the gear from its center. The impact load was applied at the bottom of the gear along the positive y-direction.

![Figure 4.2 Loading Constraints on Ansys](image)

V. RESULTS

The model was solved according to the respective loading conditions. The total deformation and the Von Mises Equivalent stress is shown in the following table for the different values of impact loading. Factor of Safety was calculated as,

\[
\text{Factor of Safety} = \frac{\text{Ultimate Strength}}{\text{Allowable Strength}}
\]

Calculated values of factor safety compared to the Ultimate Strength of the material is also shown.

<table>
<thead>
<tr>
<th>Impact Force (N)</th>
<th>Total Deformation (mm)</th>
<th>Von-Mises Equivalent (MPa)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>9.36</td>
<td>73.4</td>
<td>4.2</td>
</tr>
<tr>
<td>84</td>
<td>10.9</td>
<td>85.6</td>
<td>3.6</td>
</tr>
<tr>
<td>96</td>
<td>12.4</td>
<td>97.9</td>
<td>3.1</td>
</tr>
<tr>
<td>108</td>
<td>14.0</td>
<td>110.1</td>
<td>2.8</td>
</tr>
<tr>
<td>120</td>
<td>15.6</td>
<td>122.4</td>
<td>2.5</td>
</tr>
<tr>
<td>132</td>
<td>17.16</td>
<td>134.6</td>
<td>2.3</td>
</tr>
<tr>
<td>144</td>
<td>18.7</td>
<td>146.8</td>
<td>2.1</td>
</tr>
</tbody>
</table>
VI. CONCLUSION

The landing gear configuration was analyzed in Ansys Workbench 14.5 Module. Different landing conditions were considered using various landing speeds. The factor of safety rendered for all impact loads were above 1, implying the material selected was acceptable to manufacture the model. The factor of Safety ranges from 2.1 to 4.2 leading to more conservative and safe design.

The gear was chosen considering various parameters. As the weight of the UAV including the payload bay was over 29 Pounds, tandem wheel type was rejected. As the build UAV was a high...
winger and covered with MonoKote, mounting wheels on the wings wasn’t feasible. The configuration chosen was conventional gear or the tail-dagger type over the tri-cycle type, the following table shows the comparison,

<table>
<thead>
<tr>
<th></th>
<th>Tail-Dragger</th>
<th>Tri-Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drag</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Propeller Clearance</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>Overall Weight</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Stresses Induced</td>
<td>Moderate</td>
<td>More</td>
</tr>
<tr>
<td>Ground Looping Tendency</td>
<td>More</td>
<td>Less</td>
</tr>
</tbody>
</table>

A complete model of the gear was designed and fabricated for the UAV. Apart from conforming to the design requirements of ‘SAE Aero Design Series’, the landing gear is a reliable, lightweight and high strength unit which can be mounted easily on the UAV. It proves to be an invaluable tool for assisting the flight and mission requirements of the UAV.

VII. ACKNOWLEDGMENT

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