DESIGN AND OPTIMIZATION OF A TANDEM WING AIRCRAFT

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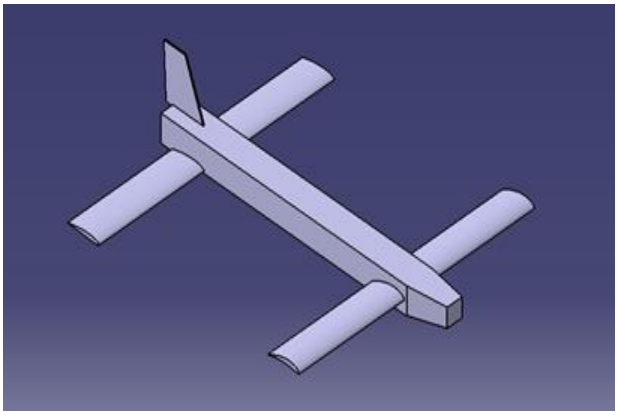
Introduction:

A tandem wing is a type of configuration of an aircraft, which has two main wings with one placed behind the other. While a biplane has two wings stacked vertically, the wings in a tandem wing configuration are placed such that one of the wings is behind the other along the fuselage. Both the wings are used to produce lift in the aircraft. The rear wing acts as both a horizontal stabilizer and lift generator.

Tandem wings produce high lift due to their surface area, and unconventional stability while also having the benefit of larger CG limits. The tandem wing can be used to reduce the wingspan of an aircraft which is helpful in airports with compact ramp size, and can be implemented on flying cars in the future. In some challenging terrains, runways are shorter than usual because of which the aircraft cannot gain enough lift before it overruns. The tandem wing configuration can be used to generate higher lift and is suitable in these conditions.



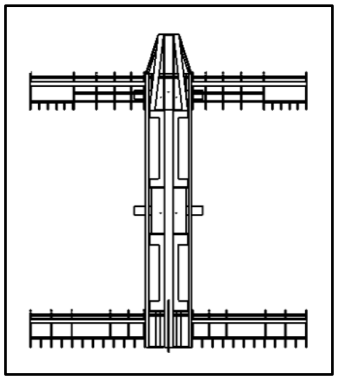
Tandem wing concept has not been well researched upon like a conventional fixed wing aircraft. To start a design process of a tandem wing aircraft, the ratios for sizing the aircraft are not available unlike a normal conventional aircraft. This is one of the aspects that was considered by the team before choosing this topic, and it is stated in the objectives that the goal of the project is to provide sizing ratios for future designers of tandem wing aircraft. We had to start our design process by having a wing-span constraint of 1 meter appropriate for

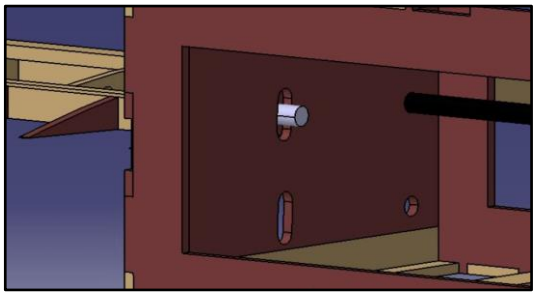
the given class of weight and carry on with the design process using hand calculations for sizing the aircraft.

Objectives:

- To understand flight characteristics of a tandem wing aircraft; size and provide a conceptual CAD design of the same.
- To vary the moment arm and height between the wings and manipulate the CG of the aircraft to find the optimum design configuration by performing several iterations on these parameters
- To design a modular tandem wing aircraft with sufficient structural integrity for a particular all up weight and verify the results with engineering simulations.
- Perform flight tests on the model with the previously obtained theoretical flight configurations and verify the results obtained.

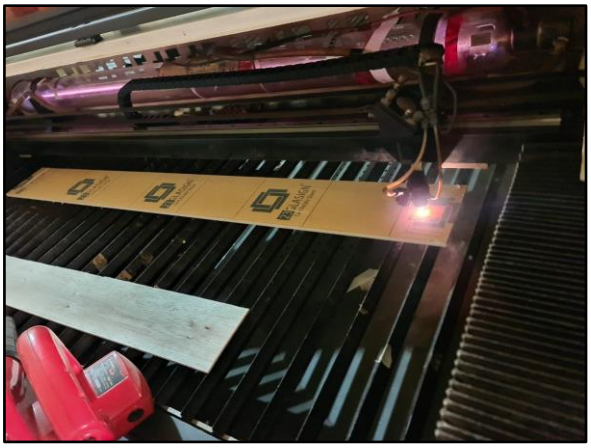
Methodology:
The tandem wing aircraft would be sized and a solid model of the same would be developed which would help analyze the aerodynamic performance.

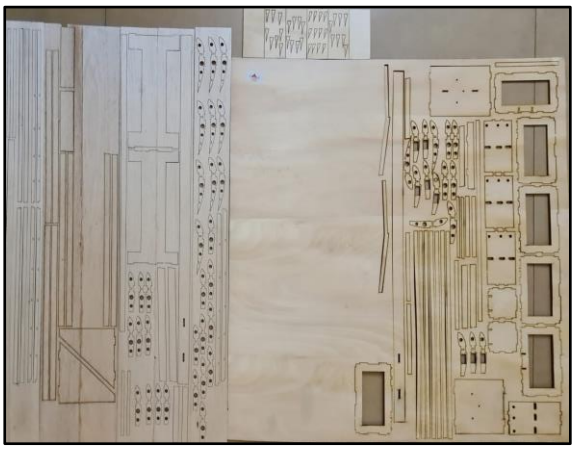




Three important parameters which govern the flight characteristics of a tandem wing aircraft are: distance between the wings, the height between the wings and the angle of incidence of each wing. We would perform iterations and build a model such that these parameters can be varied and thereby the most optimum aircraft configuration could be found by performing flight simulation.The aerodynamics and design of the model would be analyzed and achieved through XFLR5, CATIA V5 and ANSYS, while the stability and performance would be evaluated using hand calculations and verified through XFLR5.

Materials: Balsa and Aeroply were the main materials used for the construction. Balsa has a density of 150kg/m^3 while aeroply, also known as hobby grade ply has a density of 700kg/m^3. In the construction of the airplane, aeroply is mostly used as a structural member, while balsa wood is used to maintain aerodynamic profile and frame. The whole plane is covered in a thin transparent plastic film as the skin. To build an aircraft, raw materials must be processed and fabricated accurately. For this reason, aeroply and balsa wood sheets are laser cut. The CAD model of the aircraft was drafted into individual 2D part drafts, and then processed for laser cutting.





3mm aluminum was used for the landing gear, with 2.5in rubber PU wheels. The reason for these big wheels is that the tarmac is not a fine surface and is filled with small stones. Table on the left below shows the performance values, on the right are the stability and control surface values.

C_{Lmax}	2.7
W (lbs)	6.61
V_{stall} (ft/s)	26.15
C_{D0}	0.04
V_{cruise} (ft/s)	82.02
$C_{lcriuse}$	0.7
L/D_{criuse}	29.57
Rate of climb (ft/s)	30.58
Power required (watts)	24.84
V_{TO} (ft/s)	28.81
V_{ro} (ft/s)	28.74

$C_{m\alpha}$	-0.561
$C_{l\beta}$	-0.086
$C_{n\beta}$	0.149
$C_{l\delta e}$	0.3311
$C_{l\delta a}$	0.02
$C_{l\delta r}$	0.002

Results and Conclusion:

To compare the performance of our tandem wing design with conventional aircraft, an airplane with the conventional configuration was designed. It maintained the same wing aspect ratio, same forward airfoil (E423), same MTOW, and was sized using the same initial conditions, except for the span limit of 1m. It also used the same propulsion system. The wing area for our tandem wing design is 0.284m^2 (combined wing area) while the conventional plane had a wing area of 0.191m^2. From the wing area, we can understand that

more lift has to be produced from a conventional plane's wing area, which means that the conventional plane has higher induced drag, while the tandem plane has higher skin friction drag.

The following were the advantages of tandem wing aircraft over conventional design:

- 13.5% shorter wingspan, making it ideal for tight ramps.
- 40% less take-off roll. Shorter runway is required for take-off due to the higher lift produced by tandem wing aircraft.
- Approximately 3 times more static margin. Having a large static margin allows for a wide Center of Gravity range, which means the plane can be loaded with heavy cargo anywhere in that range of the fuselage.

The drawback of tandem wing aircraft is the additional structural weight, due to the additional wing. From our CAD design, the tandem wing aircraft is 23% heavier than the conventional plane.

Scope for future work:

The tandem wing aircraft marks the base structure for the future of air travel. Aviation is booming world-wide and the development of flying cars is already in the process, which is the biggest application of tandem wing aircraft. The following parameters achieved by a tandem wing aircraft makes the perfect foundation for flying cars:

- Low wing span
- High Lift Coefficient
- Short Take off & Landing
- Wide CG range (Large Static Margin)

As stated in the previous section, the tandem wing aircraft possess larger static margin compared to conventional aircraft design, which signifies its use in military cargo aircraft, carrying main battle tanks, armored vehicles and other types of commercial cargo. The wide range of CG available can be used to load cargo without having to bother about CG shift due to the large static margin of the tandem wing configuration.