Pre-Design of the Tiltrotor UAV

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Contents

1 Requirements

- The UAV shall be able to take off and land vertically.
- The UAV shall be able to transition from the vertical flight to the horizontal flight and vice versa.
- The UAV shall fit into the Category C0 (privately built) [1]:
  - The UAV shall have a MTOW of less than 250 g.
  - The UAV shall have a maximum speed of less than $19\,\mathrm{m\,s^{-1}}$.
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1.1 Vertical Flight

- Vertical flight only necessary for take-off and landing
- No fast manoeuvres necessary

1.2 Horizontal Flight

- The UAV shall be optimized for efficient flight at slow speed.
- The manoeuvrability shall suffice for basic manoeuvres. The ability to perform acrobatics is not necessary.

2 Overall Design

- The basic design is a conventional layout with a high wing with a high aspect ratio and a conventional tailplane.
- The motors are situated in front and in the back of the wing.
- The motors can be turned to perform the transition between vertical and horizontal flight.
- The UAV is controlled using a rudder and an elevator. There are no ailerons.

3 Wing Design

- Wing properties:
  - High aspect ratio for good efficiency.
  - Rectangular planform with tapered tips. Reason:

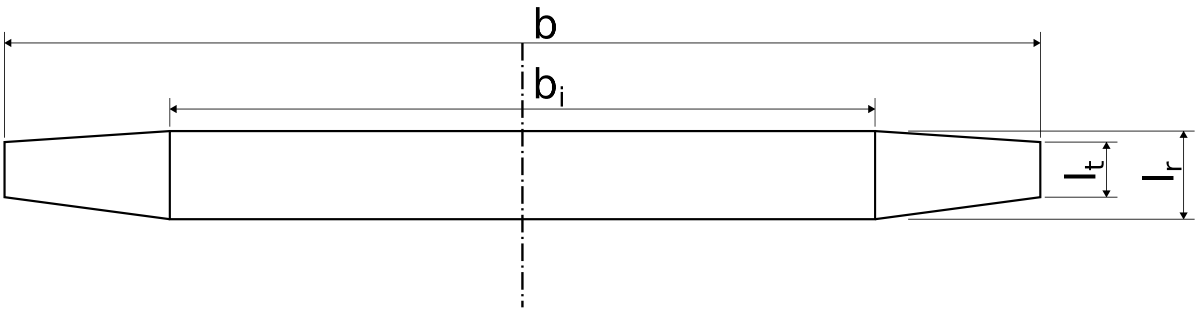

Figure 1: Wing planform

  - The main part of the wing has no dihedral. Only the wing tips have a moderate dihedral as needed for stability.

- Wing surface:

$$S = b_i \cdot l_r + \frac{b - b_i}{2} \cdot \frac{l_r + l_t}{2}$$

- Wing aspect ratio:

$$\Lambda = \frac{b^2}{S}$$

- Relative mean chord:

$$l_\mu = l_r$$

  This is only correct if the wing tips have no sweep.

4 Empennage Design

- The initial sizing of the empennage is done with the formulas given by Raymer [2, p. 112].
- Both the vertical and horizontal tailplanes have a swept back leading edge and a straight trailing edge.
- Length of the mean aerodynamic chord with $\lambda_i = \frac{L_{t,i}}{L_{r,i}}$:

$$L_{\mu,i} = \frac{2}{3} \cdot L_{r,i} \cdot \frac{1 + \lambda_i + \lambda_i^2}{1 + \lambda_i}$$

- y-position of the mean aerodynamic chord:

$$y_{l_{mu},i} = \frac{b_i}{6} \cdot \left(\frac{1 + 2 \cdot \lambda_i}{1 + \lambda_i} \right)$$

4.1 Vertical Tail

$$S_{VT} = \frac{c_{VT} \cdot b \cdot S}{L_{VT}}$$

- The volume coefficient for the vertical tail is chosen as the one of a sailplane ($c_{VT} = 0.02$).

4.2 Horizontal Tail

$$S_{HT} = \frac{c_{HT} \cdot l_{\mu} \cdot S}{L_{VT}}$$

- The volume coefficient for the horizontal tail is chosen as the one of a sailplane ($c_{VT} = 0.50$).
- L_{VT} is the distance of the $\frac{1}{4}$-point of the mean aerodynamic chord of the horizontal tailplane to the centre of gravity.
- l_{mu} is the length of the mean aerodynamic chord of the horizontal tailplane.

References

[1] Luftfahrt-Bundesamt. (). "Fragen und antworten zum eu-drohnenführerschein," [Online]. Available: `https://www.lba.de/DE/Betrieb/Unbemannte_Luftfahrtsysteme/FAQ/02_EU_Drohnenfuehrerschein/FAQ_node.html;jsessionid=3AB85C850216B1BFEEDFD691C` `live21304` (visited on 17/07/2021).

[2] D. P. Raymer, *Aircraft Design: A Conceptual Approach*. Washington, DC: American Institute of Aeronautics ans Astronautics, Inc., 1992.