Optimization of the Unmanned Aerial Vehicle Wing Planform to Maximize Flight Endurance

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Abstract:

This work presents a comprehensive approach to optimizing the wing planform of an unmanned aerial vehicle (UAV) in a flying wing configuration, with the objective of maximizing flight endurance. The study focuses on the aerodynamic design process and its optimization, integrating various multidisciplinary elements to address both the challenges and potential solutions in UAV performance.

The motivation behind this study arises from the need to overcome limitations imposed by the low energy density of current power sources, which restricts the operational duration of UAVs. This research introduces a multi-criteria optimization method that targets the geometric parameters of the UAV's wing, such as wingspan, aspect ratio, sweep angle, and taper ratio, using these as decision variables in the optimization process. The objective function is the inverse of the flight duration, which depends on the decision variables.

$$F_{obj} = \frac{1}{t}$$
$$t = f(b, AR, TR, \Lambda, E)$$

The optimization model is developed in several stages, starting with the definition of the UAV's mission profile and the relationship between endurance and wing geometry. Based on decision variables the geometry and mass model of the aircraft is created. In each iteration of the optimization process, the masses of the motor and battery are calculated based on predifined criterions, whereas airframe mass is upadated depending on the bending moment that loads the wing structure. The aerodynamic analysis is conducted dynamically for each configuration using AVL software, which provides aerodynamic derivatives. A genetic algorithm is employed to efficiently explore the problem space and optimize the wing's parameters, focusing on minimizing aerodynamic drag to improve endurance.

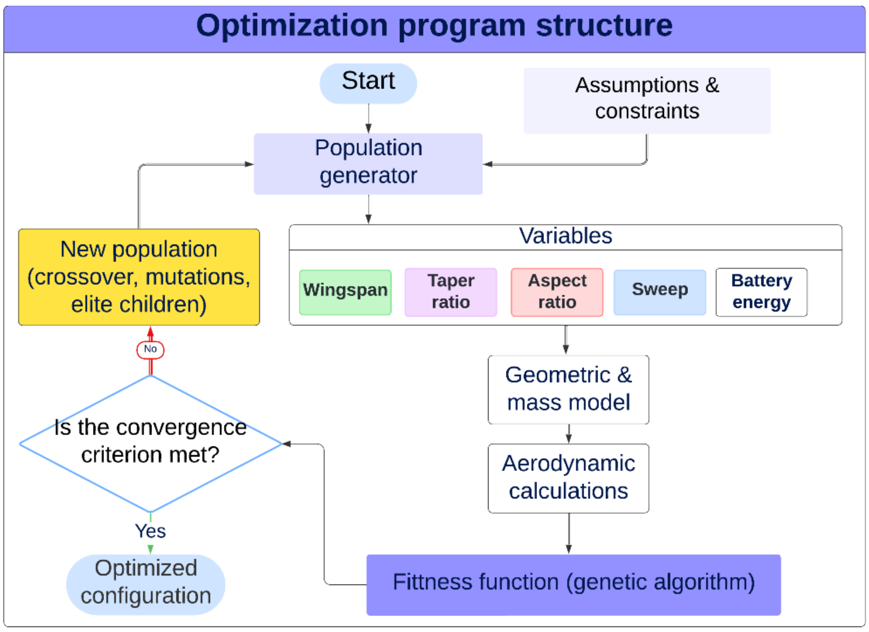

Figure 1 Optimization program structure

In addition to aerodynamic optimization, the study investigates the dynamic stability of the optimized UAV using the PANUKL and SDSA software tools. The results confirm that the flying wing configuration presents unique challenges, particularly in maintaining stability and control without conventional tail surfaces. The dynamic stability analysis led to an improvement in the Dutch roll characteristics by adding vertical surfaces to the design, enhancing overall flight stability. These modifications were crucial in maintaining control of the flying wing configuration, which lacks traditional stabilizing surfaces.

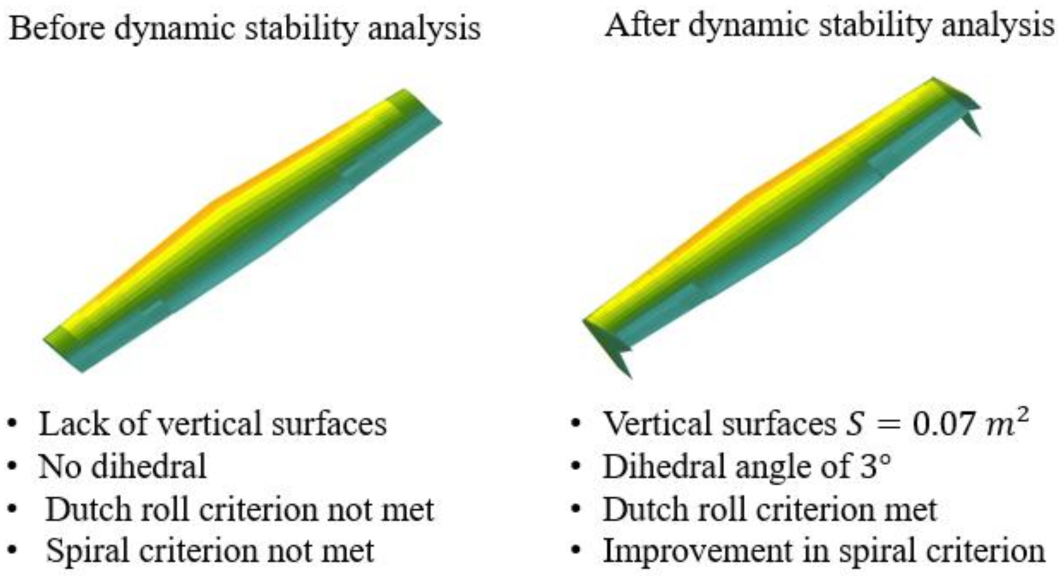

Figure 2 Dynamic stability analysis results

The optimization approach presented in this study significantly improves the aerodynamic efficiency and stability of the UAV, resulting in a 23% performance gain compared to the initial configuration. These findings demonstrate the potential for further advancements in UAV design, specifically for long-endurance missions where aerodynamic efficiency and stability are critical.

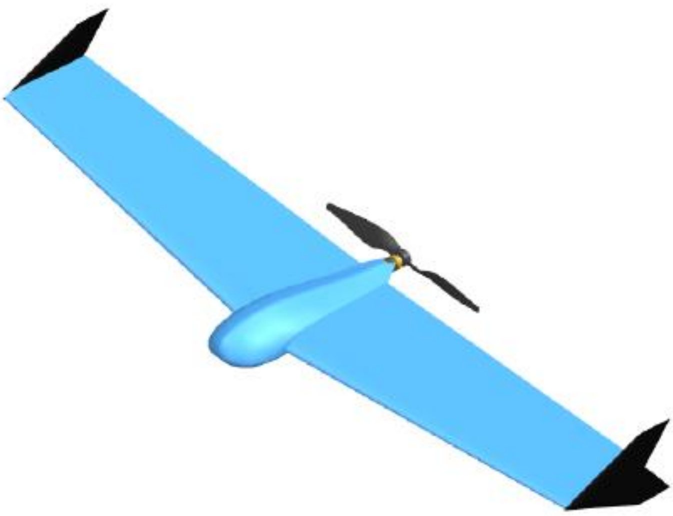

Figure 3 Final configuration proposal