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Design of a Coaxial Counter-Rotating Rotor for an Emergency Drone

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Abstract

The design and optimization of coaxial rotors are crucial for enhancing the performance and efficiency of aerial vehicles, particularly in applications requiring high thrust-to-weight ratios and precise control. This thesis aimed to optimize the aerodynamic performance of coaxial rotor blades by refining their geometry, focusing on the modification of twist and chord distributions.

Initially, in this research, ROTARE, a BEMT code developed by PhD candidate Thomas Lambert, was validated for single-rotor analysis, forming a strong foundation for the validation of the coaxial rotor case and confirming the reliability of ROTARE for the optimization process. The study then progressed through two main optimization phases. In the first phase, the optimal operating conditions—specifically the combination of RPM and collective pitch of the upper and lower rotors—were identified to achieve a target thrust of 6 kg and a thrust to power ratio T/P of approximately 12.5 g/W without altering the blade geometry. This phase involved systematic sweeps and iterative adjustments to maximize rotor efficiency.

The second phase focused on geometry optimization, where both the twist and chord distributions were independently optimized. The twist optimization led to a 4% improvement in the thrust-to-power ratio, but this gain was not considered significant. Similarly, the chord optimization alone did not yield significant performance improvements. The detailed analysis revealed that these strategies, when applied in isolation, were insufficient to achieve major gains in efficiency.

The study was conducted on four real-life blades, SAB280, ALZRC325, ALZRC380, and BL450, which are usually used for drone applications, with the ALZRC380mm blade emerging as the most efficient. The ALZRC380mm blade achieved a thrust-to-power ratio of approximately 15 g/W at a thrust of 6 kg, outperforming the other blades, which achieved T/P between 11 g/W and 12.5 g/W. This superior performance is attributed to the ALZRC380mm blade's larger chord length and increased overall blade length, enhancing lift generation and improving the lift-to-drag ratio.

The analysis was applied in detail to the SAB280 blade, covering upper rotor rotational speeds ranging from 500 to 6000 RPM and collective pitches between 1° and 17°. The optimal configuration of the SAB280mm blade, which achieves a thrust of 6 kg and a T/P of 11 g/W

that is below the target value, was determined at an upper rotor rotation speed of 3000 RPM and a collective pitch of 13°, paired with a lower rotor rotation speed of approximately 2600 RPM and a collective pitch of approximately 18.5°. It turned too that all blades achieved their c_T/cP ratio and T/P peak at upper collective pitch angle values approximately between 4° and 5°.

It turned out that while the twist and chord optimizations provided small improvements, their combination would ensure significant performance gains. This approach, particularly when aligned with a well-defined thrust distribution strategy could lead to an optimal chord distribution that, when combined with an optimized twist, enhances overall rotor performance. This research opens avenues for further exploration, including integrating multiple airfoil profiles along the blade span and developing simpler, more cost-effective manufacturing approaches.

Keywords: Coaxial rotors, ROTARE, optimization, blade geometry, twist distribution, chord distribution, thrust efficiency, airfoil profiles, rotor performance.