A Computational Study on Improving the Performance of a Small Unmanned Helicopter by Modifying Its Main Rotor

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Abstract:

The research presented aimed to evaluate the possibility of modifying the main rotor of a small-unmanned helicopter so that the modified rotor could lift the helicopter heavier by 67% compared to the baseline. The baseline configuration was a helicopter equipped with a two-blade teetering rotor with rectangular, untwisted blades with an aspect ratio of 15. Within a frame of the presented study, a sensitivity analysis of changes in the rotor thrust (T) and the power (P) necessary to drive the rotor was carried out, depending on changes in the following rotor design parameters:

- number of blades,
- rotor radius,
- blade chord,
- blade-tip planform,
- blade geometric twist,
- shape of the blade cross-section (blade airfoil)

To calculate the performance of various variants of the main rotor, the Virtual Blade Model (VBM) methodology was used, developed in the form of an original software package extending the computational capabilities of the ANSYS FLUENT program. The methodology is based on the coupling of the Blade Element Theory with the U/RANS (Unsteady/Reynolds Averaged Navier-Stokes) solver. The applied computational methodology, thanks to the simplifications used, allows you to quickly determine the aerodynamic characteristics of the main rotor while maintaining relatively high reliability of the results.

The research focused on searching for a rotor configuration that would require minimal power, necessary to drive the rotor to achieve the required lift generated by the rotor. During the research, the aerodynamic characteristics of several dozen rotor variants were analysed in various helicopter flight conditions. Ultimately, as the most promising solution, a two-blade teetering rotor with rectangular, untwisted blades whose radius was increased by 30% compared to the baseline rotor blades was recommended to the helicopter designers. Figure 1 presents the dependence of the power (P) vs flight speed (V), determined computationally for the base variant of the rotor (BASELINE) and the finally selected variant (FINAL DESIGN). The aerodynamic characteristics of both rotors were calculated for the conditions of balanced helicopter flight, i.e. where the collective pitch angle of the rotor blades and the helicopter pitch angle were determined so that the vertical and horizontal components of the rotor thrust vector balanced the weight and drag force of the helicopter, respectively. As seen in Figure 1, compared to the baseline, the modified rotor

characterises itself by a decrease of necessary power of up to 17% in the range of low-speed flight and hover. In the range of higher-speed flight (above 130 km/h), the differences in necessary power for both rotors disappear. Figure 2 compares the dependences of thrust (T) vs power (P) calculated in hover for two compared rotors, for two hovering altitudes of 50 and 6000 masl. As one can see, the modified rotor, in this case also has better aerodynamic and performance properties than the baseline rotor.

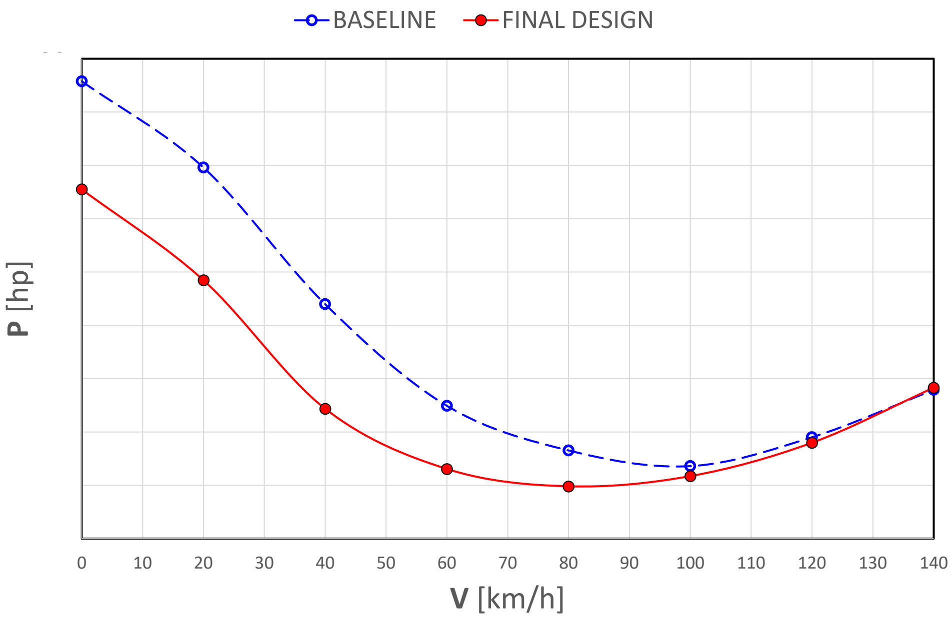

Figure 1 Comparison of the dependence of the power (P) vs flight speed (V), determined computationally for the base variant of the rotor (BASELINE) and the finally selected optimized variant (FINAL DESIGN), in a balanced flight of a helicopter.

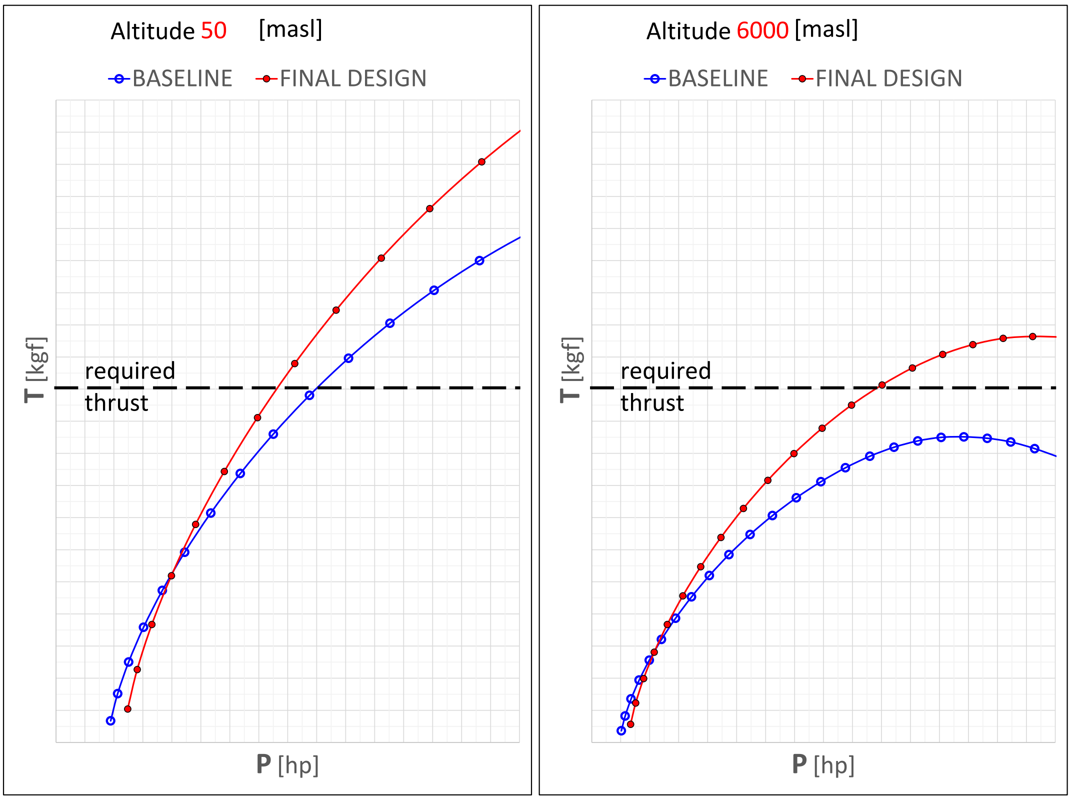

Figure 2 Dependences of thrust (T) vs power (P), calculated in hover for two compared rotors, for a hovering altitude of 50 masl (left) and 6000 masl (right).