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ABSTRACT

FACULTY OF ENGINEERING, SCIENCE AND MATHEMATICS

SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

OPTIMISATION OF THE COMPOUND HELICOPTER CONFIGURATION

by Matthew Noel Orchard

The addition of a wing and supplementary thrust to the helicopter has been mooted as a means of significantly enhancing its high-speed performance, due to the benefits it gains from rotor unloading. A comprehensive review of past flight test and theoretical investigations of the compound helicopter highlighted several aircraft types that demonstrated the technique to improve the airspeed, vibration levels, manoeuvrability and climb-rates over the conventional helicopter. The review also revealed the existence of few design guidelines to indicate the effect of configuration changes on performance.

To verify these performance benefits and develop guidelines for the effect of configuration changes, two performance analyses were developed. These take in a wide number of performance parameters, including vibration, power, airspeed, agility, range, endurance, productivity, initial cost and service ceiling to ensure that the full performance implications of each configuration change will be known. All the configuration parameters were investigated over a wide range of values to ensure that all maxima and minima were included.

To perform this investigation required modelling techniques that would include rotor-wing interference effects and yet allow computational efficiency. The initial study was based on a closed-form trim solution combined with biplane and momentum theory. To improve and widen the scope of the study a blade element rotor model, combined with flat horseshoe-vortex rotor-wake and lifting-line wing-wake models, was developed to estimate the rotor-wing mutual interference effects. Good correlation against experimental data was obtained.

Investigating the variation of the performance parameters demonstrated that certain compound helicopter configurations could better the conventional helicopter in velocity, productivity, vibration levels, service ceiling and manoeuvrability. The compound helicopter effectiveness in initial-cost, productivity, range and endurance, however, are dependent on the thrust compounding efficiency. A significant point was the isolation of rotor speed, blade design, wing area, wing-fuselage angle, supplementary thrust level and the supplementary propulsive efficiency as the primary performance influences. Other parameters such as wing aspect ratio, wing location and rotor size were found to be important, but of secondary influence. Significantly, no single configuration can optimise all the performance parameters simultaneously. A preferred configuration is one that utilizes supplementary thrust equal to the drag in level flight, a moderate wing-fuselage angle and low rotor speed, combined with a wing of the minimum area for the performance desired. Important developments to enhance the viability of the compound helicopter include the suppression of rotor overspeed and wing lift control.

To demonstrate the practicality of the analyses, a comparison between the tilt rotor and compound helicopter was performed. This showed the compound helicopter to be competitive both in productivity and against a rentability index, incorporating the velocity capability, and to have a lower sensitivity to low speed safety margins. The favourable result for the compound helicopter was primarily due to the development of the ability to size the wing area to a minimum, and the British Experimental Rotor Programmes' rotor capabilities. Overall the study shows that the compound helicopter, with careful design, is a viable alternative to both the conventional helicopter and tilt rotor.