UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

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A FUNDAMENTAL STUDY INTO MAIN ROTOR DESIGN WITH THE AIM OF IMPROVING THE CONVENTIONAL HELICOPTER'S STABILITY AND CONTROL PROPERTIES

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The modern helicopter remains an unstable and asymmetric aircraft. Flying it requires practice and uninterrupted attention. The source of instability and cross-coupling is unwanted blade flapping. Eliminating this unwanted flapping will produce a helicopter with superior handling. A rotor which rejects disturbances, thereby flapping only when commanded by the pilot, is possibly the ideal rotor from a stability and control perspective. Such a rotor has been defined as the Ideal Rotor (IR) in this research. The IR is one that does not flap unless demanded by the pilot. This means that the rotor has to contain both Thrust and Moment demand. In a Thrust Demand Rotor (TDR), the pilot commands only thrust, with thrust (coning) perturbations suppressed. Conversely, in a Disc-tilt/Moment Demand Rotor (MDR), the pilot commands only disc-tilt (once/rev flapping). From the analysis conducted, a helicopter with an IR is found to be neutrally stable in all axes except the longitudinal, in which it has small positive stability. With this in mind, the research examines the use of rotor couplings to investigate if the conventional rotor without ASE can be improved and whether the Ideal Rotor concept can be achieved. The six degree of freedom quasi-steady rotor theory was used to construct the mathematical model of the single rotor helicopter. This enables the evaluation of analytic expressions for the flapping, control and stability derivatives. The nature of some of the couplings required incorporation of the blade torsion and lag degree of freedom. Their incorporation added blade feathering moments due to aircraft pitch or roll rates which do not occur in the conventional analysis because these degrees of freedom are not allowed. These were shown to reduce the magnitude of rate cross-coupling in conventional rotors and substantially increase rate damping in unconventional rotors. The addition of the pitch equation to conventional rotor analysis is therefore mandatory. The study has led to the description of rotor couplings within the quasi-steady rotor theory framework, thus facilitating the incorporation of the couplings into conventional analysis. The couplings that were studied were chosen because they represent the most common that occur, namely, phased pitch-flap, collective-cone, blade centre of gravity, aerodynamic centre offset and aeroelastic torsion-flap-lag. The research has resulted in the definition of a common framework for the analysis of rotors with couplings. The theory allows the full range of coupled or uncoupled rotors with prescribed flapping and torsional stiffness to be analysed. This is demonstrated by applying the theory to explaining the flapping, stability and control of two unique rotor systems namely the Bell-bar and the Kaman rotor.