

## ABSTRACT

Title of dissertation:      **COMPREHENSIVE AEROELASTIC  
ANALYSIS OF HELICOPTER ROTOR WITH  
TRAILING-EDGE FLAP FOR PRIMARY  
CONTROL AND VIBRATION CONTROL**

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A comprehensive aeroelastic analytical model of helicopter rotors with trailing-edge flaps for primary and vibration controls has been developed. The derivation of system equations is based on Hamilton principles, and implemented with finite element method in space and time. The blade element consists of fifteen degrees of freedom representing blade flap, lag, torsional, and axial deformations. Three aerodynamic models of flapped airfoils were implemented in the present analysis, the unsteady Hariharan-Leishman model for trailing-edge flaps without aerodynamic balance, a quasi-steady Theodorsen theory for an aerodynamic balanced trailing-edge flap, and table lookup based on wind tunnel test data. The trailing-edge flap deflections may be modeled as a degree of freedom so that the actuator dynamics can be captured properly. The coupled trim

procedures for swashplateless rotor are solved in either wind tunnel trim or free flight condition. A multicyclic controller is also implemented to calculate the flap control inputs for minimization of vibratory rotor hub loads. The coupled blade equations of motion are linearized by using small perturbations about a steady trimmed solution. The aeroelastic stability characteristics of trailing-edge flap rotors is then determined from an eigenanalysis of the homogeneous equations using Floquet method.

The correlation studies of a typical bearingless rotor and an ultralight teetering rotor are respectively based on wind tunnel test data and simulations of another comprehensive analysis (CAMRAD II). Overall, good correlations are obtained. Parametric study identifies that the effect of actuator dynamics cannot be neglected, especially for a torsionally soft smart actuator system. Aeroelastic stability characteristics of a trailing-edge flap rotor system are shown to be sensitive to flap aerodynamic and mass balances. Key parameters of trailing-edge flap system for primary rotor control are identified as blade pitch index angle, torsional frequency, flap location, flap length, and overhang length. The swashplateless rotor is shown to achieve better rotor performance and overall more stable than the conventional configuration. Simulations of flaps performing both primary control and active vibration control are carried out, with the conclusion that trailing-edge flaps are capable of trimming the rotor and simultaneously minimizing vibratory rotor hub loads.