Flight Dynamics Simulation & Mission Analysis of Integrated Helicopter–Engine Systems Using a Comprehensive Aeroelastic Rotor Model

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An integrated approach, targeting the comprehensive assessment of combined helicopter–engine designs in terms of flight dynamics and mission performance, is presented. The developed methodology comprises a series of fundamental modeling theories, applicable to the analysis of natural vibration characteristics of rotor blades, treatment of rotor blade flexibility, rotor–fuselage aerodynamic interaction, three-dimensional flight path definition, aeroelasticity and engine performance. The individual mathematical methods are elaborately integrated within an overall simulation framework encompassing the corresponding nonlinear numerical procedures solving for trim, stability, control response and mission analysis.

The developed methodology is applied to the analysis of a twin-engine light helicopter, modeled after the popular MBB Bo105. Flight dynamics results are presented in terms of main rotor trim parameters, linearized stability derivatives, fuselage dynamic response to pre-defined control input schedules and unsteady blade structural loads during flight. Extensive comparisons with flight test data are included for validation purposes. Mission analysis is carried out based on two generic, three-dimensional, twin-engine light helicopter missions, compiled in collaboration with the European Helicopter Operator's Committee (EHOC). Results are presented in terms of engine performance parameters as functions of time, during the course of both operations.

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The simulations carried out suggest that, with respect to the typical range of operating conditions encountered by modern twin-engine light civil helicopters, the influence of operational altitude on fuel consumption is predominantly determined by the corresponding effects induced on the engine, rather than on airframe–rotor performance. The implications associated with the implicit coupling between aircraft and engine performance, through the aircraft's time-dependent All-Up Mass (AUM), are thoroughly discussed in the context of mission analysis. The capability to comprehensively evaluate integrated helicopter–engine systems within realistically defined three-dimensional operations, using modeling fidelity designated for main rotor design applications, is demonstrated. The proposed methodology can essentially be regarded as an enabling technology in terms of focusing the overall system design process on designated operation types, rather than on specific sets of flight conditions.