Advanced Rotor Aerodynamics Concepts with Application to Large Rotorcraft

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A study was conducted using the comprehensive analysis CAMRAD II to explore performance enhancements to large rotorcraft. The aircraft considered were a 125 foot diameter six-bladed rotor helicopter and an 85 foot diameter four-bladed rotor tilt rotor. The objectives were to reduce power required and increase maximum lift. The effects of improved airfoils and active controls were investigated. Airfoils with higher maximum lift and with reduced drag were investigated. Results showed a moderate improvement in the maximum lift capability for the helicopter and a large improvement for the tilt rotor. For the helicopter, 2/rev individual blade control resulted in modest power savings in cruise flight, which increased with control amplitude and forward speed. The optimum phase for the individual blade control was relatively insensitive to both amplitude and forward speed. The influences of active twist, increased chord, increments in airfoil properties, and tilt rotor tip extensions were also investigated.

Introduction

One of the challenges likely to face the rotorcraft industry in the future is designing a new generation of transport rotorcraft that are significantly larger than current models. As rotor size increases, the scaling issues become more severe and the fraction of gross weight required for rotor and rotor controls increases. As a result, large rotorcraft use high disk loading to reduce rotor size and weight. However, high disk loading impacts both performance (high induced power) and operational suitability (high downwash velocity). The technology challenge is to enable large, low disk-loading rotors with affordable weight fractions.

One or several enabling rotor technologies will likely be required to produce the performance gains and weight savings necessary for a cost-effective large rotorcraft. Such technologies must provide greater maximum thrust from a given blade area and reduce the power required to achieve a given level of thrust. These performance improvements must be attained for the same or less weight for a given blade and disk area. This will result in less rotor and rotor controls weight to attain a given maximum thrust capability.

The purpose of the current study was to examine possibilities for rotor aeromechanics performance improvements and gain understanding of how these blade element level technologies interact to produce integrated rotor performance. This understanding will be used to guide future research.

Approach

The approach taken in this investigation was to design large rotorcraft (both helicopter and tilt rotor versions) based on advanced technology goals, and determine the rotor performance for these designs. The U.S. Army Rotary Wing Vehicle (RWV) Technology Development Approach (TDA) goals for FY05 were used for all rotorcraft components. This established targets for rotor performance using advanced technology. The second phase was to examine what performance enhancements might be achieved using specific advanced rotor concepts.

The design mission profile for these rotorcraft was a 20-ton load, 500 km mission radius, on an "Army hot day" (4000' MSL and 95° F). The vertical takeoff requirement was Hover Out of Ground Effect (HOGE) at 95% of Maximum Rated Power (MRP) on an "Army hot day." The cargo compartment of these rotorcraft had to be the same as that of a C-130 transport, 10 x 9 x 40 feet. Advanced technology rotorcraft designs