AN ACCELEROMETER-BASED INSTRUMENTATION SYSTEM
FOR MEASUREMENT OF HELICOPTER ROTOR
MOTION AND LOADS

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ABSTRACT

Results from a recent Navy-sponsored study directed at an accelerometer-based instrumentation system for the measurement of helicopter rotor motion and loads are described. Background into the requirements and needs of the measurement system are provided, and then consideration is given to a novel scheme that incorporates blade-mounted accelerometer sensors with a simplified signal processing scheme to extract both rotor motion measurements, and to a limited extent, blade loading information. Issues regarding sensitivity of the system to modeling errors, nonlinearities and sensor bias errors are examined through detailed simulation and analysis. Finally, a demonstration of the system performance for reconstructing flapping motion measurements is provided using Froude-scaled model rotor test results. Conclusions from this work and some preliminary implementation issues leading to prototype development for this new system are presented.

INTRODUCTION AND BACKGROUND

U.S. Navy rotary-wing flight training and operational evaluation requirements have been aided through extensive use of manned flight simulators. These simulations can provide sufficient realism to reduce the number of operational flight hours required for flight and weapons system training, as well as provide scenarios and environmental factors that would be difficult or impossible to achieve on an as-needed basis (Ref. 1). With the ever-increasing computational capability in modern simulators, it has become possible to add additional realism by including more complicated physical models for the systems represented by the simulator's computers. However, if the added physics does not properly represent reality, the benefits of manned simulation may be lost due to having pilots interact with a representation that does not properly mimic the experience of actual flight trials. In such a situation, the personnel are being trained to operate the simulator and not the desired aircraft. In order to avoid this problem, high-fidelity flight simulators must be correlated against actual rotary-wing aircraft flight data. The ultimate goal of the effort described here would result in a simplified means of acquiring rotor motion and loads data, using a combination of accelerometer sensors and a Kinematic Observer processing structure, that would help the Navy to support this correlation exercise.

Rotorcraft simulation has progressed from simple adaptation of fixed-wing maneuvering flight models through early stability-derivative models and rotor map models, to models that include both individual rotor blade motion and structural modes. While this added modeling capability has been made easier by the steady improvement of computational performance, correspondingly significant advances have not been realized in the acquisition of supporting data across all rotary-wing platforms to aid in the validation of this simulation software. This deficiency is primarily due to the difficulty in acquiring sensor data from helicopter rotor systems in general and isolated rotor blades in particular. Rotor blade instrumentation systems must operate in a severe dynamic environment, where centrifugal loads may range up to 900 g's at the rotor blade tip, and vibratory load spectra can extend out past 60 Hz on the main rotor. In addition, acquiring rotating-frame data necessitates the use of either on-blade telemetry or a slipring assembly for transmitting sensor input power and signal output to the fuselage or ground station for archiving. And finally, accommodating the particular geometric constraints of the rotor hub system may preclude convenient location of traditional motion sensing instrumentation.

While rotor motion and loads data has been collected for flight tests of helicopters for some time (see Ref. 2 for a good summary of NASA efforts), most of the instrumentation has required specialized blades, mounting hardware, or other significant modifications to the test aircraft. Although such compromises in implementation flexibility may be acceptable on a research aircraft, a truly useful helicopter rotor data acquisition system would avoid as many airframe-specific components as possible, thus allowing it to be used as a standardized piece of test equipment, much like an ordinary oscilloscope. The proposed instrumentation system investigated in this effort would combine the convenience of using miniature accelerometer sensors, coupled to a Kinematic Observer signal processor, to provide rotor blade motion and loads

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