Blade-Pitch Control for Quieting Tilt-Rotor Aircraft

Actively induced harmonic blade-pitch oscillations reduce BVI noise.

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A method of reducing the noise generated by a tilt-rotor aircraft during descent involves active control of the blade pitch of the rotors. This method is related to prior such noise-reduction methods, of a type denoted generally as higher-harmonic control (HHC), in which the blade pitch is made to oscillate at a harmonic of the frequency of rotation of the rotor.

A tilt-rotor aircraft is so named because mounted at its wing tips are motors that can be pivoted to enable the aircraft to take off and land like a helicopter or to fly like a propeller airplane. When the aircraft is operating in its helicopter mode, the rotors generate more thrust per unit rotor-disk area than helicopter rotors do, thus producing more blade-vortex interaction (BVI) noise. BVI is a major source of noise produced by helicopters and tilt-rotor aircraft during descent: When a rotor descends into its own wake, the interaction of each blade with the blade-tip vortices generated previously gives rise to large air-pressure fluctuations. These pressure fluctuations radiate as distinct, impulsive noise.

In general, the pitch angle of the rotor blades of a tilt-rotor aircraft is controlled by use of a swash plate connected to the rotor blades by pitch links. In both prior HHC methods and the present method, HHC control signals are fed as input to swash-plate control actuators, causing the rotor-blade pitch to oscillate. The amplitude, frequency, and phase of the control signal can be chosen to minimize BVI noise.

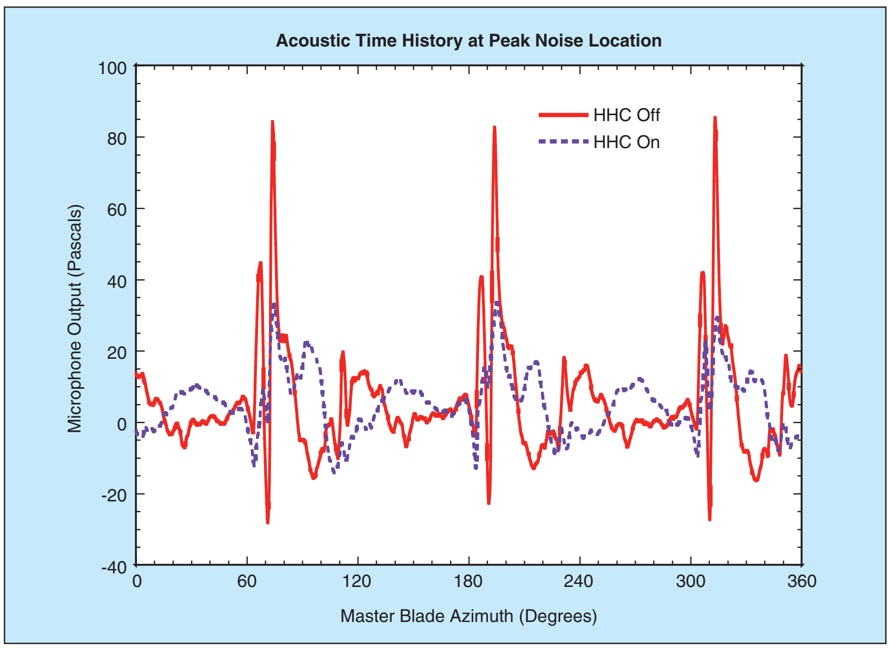
In the present method, one typically, chooses a control waveform that causes the blade pitch to oscillate sinusoidally at the N+1 harmonic of the rotation frequency (where N is the number of blades on each rotor). The phase of the oscillation is typically chosen such that the minimum pitch angle occurs at a fixed rotor-blade azimuth angle within the range from 60° to 90° (where 0° azimuth is defined as directly aft). The phase is critical, but the amplitude is not: It has been found that pitch-angle oscillation amplitudes up to approximately 0.7° can result in large reductions of noise. Larger pitch amplitudes can result in larger reductions of noise, but one might prefer to avoid them because they are accompanied by increases in control loads.

Prior efforts to exploit the HHC concept to reduce helicopter vibration and noise have been oriented toward the development of complex, closed-loop control systems that would utilize feedback from sensors and that would implement iterative control algorithms to adjust HHC settings to optimize responses over the full ranges of operating conditions. The development of such systems can be expensive and time-consuming. In contrast, a system according to the present method is relatively simple because it is an open-loop system. By selecting a single harmonic (the N+1) and fixing the amplitude, one can reduce the problem of choosing the control signal to one of selecting a single open-loop input signal (the phase signal), which can be optimized for several descending flight conditions. In other words, HHC phase values can be predetermined and scheduled for specific flight conditions. The schedule of phase values can be implemented by use of control software and hardware.

The pilot can turn the HHC system on or off by means of a switch (see figure). Ordinarily, the HHC system would be used only when reduction of noise was desired during descent in the helicopter mode. Because the time spent in use of the HHC system would ordinarily be a small fraction of the total operational time of the aircraft, the control loads associated with use of the HHC system could be expected to cause little, if any reduction, in the lifetime of the mechanical components of the pitch-control system. Because the HHC noise-reduction system is not needed for safe operation of the aircraft, it is a fail-safe system: The system can be switched off at any time without adversely affecting flight, the only penalty being an increase in noise.

This work was done by Mark D. Betzina and Khanh Q. Nguyen of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14606.



This **Graph Demonstrates the Effect of HHC** on acoustic time history at peak directivity.