

Harmonic Acoustic Pneumatic Source (HAPS) as a Narrow Bandwidth Acoustic Loudspeaker

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ABSTRACT

During takeoff, the harmonic noise of the turbofan is the main acoustic nuisance for people near airports. Much research has been done to achieve active noise control of turbofans with loudspeakers or piezo actuators as noise suppression sources. However, the required fragility, and weight and volume penalty make them unsuitable for engine nacelle applications. On the other hand, electro-pneumatic sound sources (sirens or air modulators) are good candidates for generating the required high noise control sound pressure level, but they are not designed for active noise control applications. Therefore, an alternative solution, called the Harmonic Acoustic Pneumatic Source (HAPS), has been designed to generate a high harmonic noise level controllable in amplitude, phase and frequency. The specificity of the HAPS is to use a flow chopper to generate a pulsed jet at a given frequency and a servo-valve to control its amplitude.

This study presents the HAPS composed of a high-pressure pneumatic air source, a flow chopper using a rotating perforated cage and a dedicated exhaust. The fundamental equation of the pneumatic speaker is used to define the time-varying orifice as the generator of a periodic pressure source with a built-in internal impedance. To implement phase control of the generated sound, a phase-locked loop (PLL) controls the instantaneous angle of the rotating cage. Thus, control of the HAPS requires 2 slow-time signals: one for amplitude (position of the servo-valve) and the second for phase (via the PLL). However, for active noise control, the HAPS control is presented as a mechanical modulator driven by two slowly varying signals (the real and imaginary parts of the complex value envelope of the command). The mechanical time responses of the servo valve and the rotating cage motor imply a narrow bandwidth centered on the modulation frequency. The experimental results presented are obtained on a dedicated test bench for different frequencies. Finally, the narrow bandwidth of the HAPS is discussed with a view to its use as a controllable tonal sound source for active noise control, or other applications.

This work is supported by Association Nationale Recherche Technologie (ANRT, France) and Safran Nacelles (Le Havre, France). We thank Marc Versaevel of Safran Nacelles for his collaboration.