A HYBRID METHODOLOGY FOR THE IDENTIFICATION OF INCOHERENT NOISE SOURCES

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1.0 Introduction

Modeling of noise sources is difficult when there are many potential noise sources and the interaction among them is complex. The measurement of sound field in these situations is laborious due to the need to make measurement at a large number of potential locations. A hybrid numerical/experimental approach based on Nearfield Acoustical Holography (NAH) alleviates some of the difficulties associated with the purely numerical or experimental technique. However, traditionally NAH has been applied mostly for the identification of coherent noise sources on planar structures using measurements taken on a planar grid [1-3]. The planar NAH was subsequently extended for the noise source identification on separable geometry such as cylindrical and spherical surfaces using measurements taken on conforming surfaces [4-10]. In the present development a generalized NAH that is applicable for the identification of multiple, incoherent noise sources on complex geometry is developed.

2.0 Mathematical Background

Numerical method such as boundary element method [11] can be used to generate transfer functions that relate the sound field in the acoustic domain to the surface velocity on an arbitrary source geometry. This relationship can be symbolically represented as

$$\{p\} = [T]\{V\} \qquad (1)$$

where p is the field acoustic pressure, V is the normal acoustic velocity on the surface and T is the transfer matrix. In principle, the above matrix equation can be solved to identify the noise sources (i.e. V) on any complex arbitrary surface.

In a typical analysis, $[T]$ is not a square matrix since the size of the matrix depends on the number of pressure measurement locations and the number of surface nodes. As result, equation (1) is solved by using a Singular Value Decomposition (SVD) technique. The application of SVD to the transfer matrix results in

$$[T] = [U][\sigma][V]^H, \qquad (8)$$

where superscript H indicates Hermitian (conjugate transpose) of a matrix, $[\sigma]$ is a diagonal matrix consisting of the singular values ranked from the highest to the lowest values and $[U]$, $[V]$ are unitary matrices containing the eigenfunctions of the SVD decomposition. The accuracy of the reconstruction process depends considerably on the SVD process [17]. A Tikhonov regularization scheme has been utilized in the present study.

The procedure described above is applicable for noise source identification of coherent sources. In situations where sources are generated by independent mechanisms, the number of independent sources are determined initially. This information together with a partial coherence technique is then used to separate the composite field into coherent partial fields. The noise sources corresponding to each partial coherent field are then identified using the NAH procedure described earlier in this section.

3.0 Results and Discussion

Interior noise in a propeller driven aircraft represents a non-stationary source that changes position with respect to time. Using a scanning microphone system, a pressure hologram of these kinds of sources can be acquired if measurements are taken at time increments which correspond to a fixed position in space of the rotating source.

For the aircraft this fixed position can be obtained from a synchro-phaser signal off of the propeller shaft, and data acquisition is synced to it. This simulates a stationary source and a coherent hologram can be acquired. One benefit of this is the ability to use signal averaging at each microphone position to increase the SNR of the pressure measurement. The analysis was done on a Beechcraft 1900D airplane [12].

The geometry of the fuselage and the hologram surface is depicted in figure 1. In the lower mosaic, the fuselage surface is cutout so that the hologram surface is visible. The hologram surface includes two closely spaced sets of pressure measurements at the ends, which are used to prescribe the velocity at the end caps using Euler's equation. The hologram consists of 30 axial rings with 43 microphones each in addition to the end caps.

The hologram pressure, looking aft, measured at 103.7 Hz using the outer 43 microphones of the array, acquired during the in-flight experiment is depicted in figure 2. One can see that the pressure is 180 degrees out of phase on either side of the aircraft. The quality of the data is outstanding. The smoothness of the pressure is proof that the synchro-phaser was an excellent time reference for the triggering of the data acquisition system.

We present the reconstruction of the normal velocity for the blade passage frequency (BPF) at 103.7 Hz. The reconstruction boundary is the exposed surface of the fuselage lining, located 8.59 cm from the hologram. The actual skin of the fuselage was 12.4 cm from the hologram surface. Figure 3 depicts the magnitude on a decibel scale of the reconstructed normal velocity looking aft. Only the top 20dB of data is shown as indicated by the color bar. The velocity is normalized by the velocity of an accelerometer located on a fuselage panel in the prop plane. The asymmetry of the panel vibrations is consistent with other measurements on this aircraft.

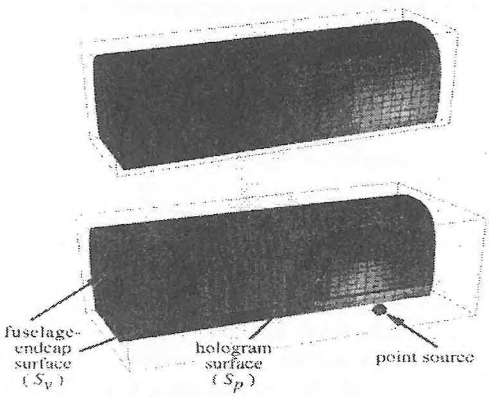

Fig. 1 Geometry of the Fuselage and Hologram

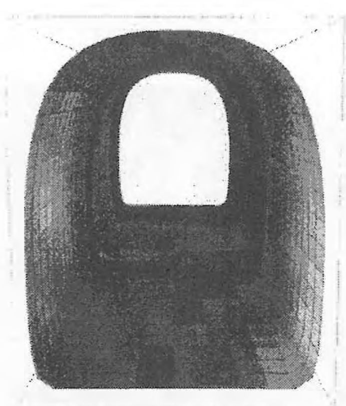

Fig. 6 Hologram Pressure Looking Aft

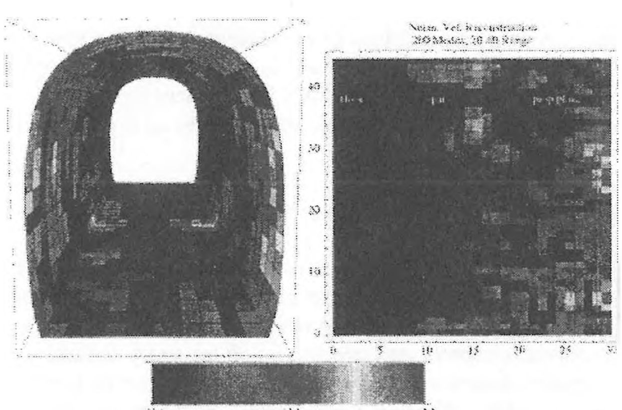

Fig. 3 Magnitude of the Reconstructed Normal Velocity

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