WHITE PAPER

Characterizing Cabin Noise

By Mark Valentino

Characterizing Cabin Noise

Directives to assess and minimize cabin noise have become a top priority for the aerospace industry. From large commercial jets, to helicopters, to small propeller aircraft the need is the same, which is for a reduction of cabin noise. This is critical to the commercial success and competitiveness of the aerospace manufacturing industry and desired for passenger comfort.

High amplitude acoustic signals, whether in the audible ranges of the human ear (20Hz to 20 kHz) or beyond human hearing capability (infrasounds and ultrasounds) can range from being noisy and cause mild discomfort to resonating human body components and inducing headaches or nausea. This is why there is an increasing demand to reduce noise levels inside the aircraft to improve passenger comfort.

Deriving the noise source

Noise source location and source strength must be derived first before acoustic engineers can improve the condition. Some preliminary tests can be achieved in wind tunnels, but for maximum noise and the best characterization an in-flight study is preferred. Noise can be derived from many sources some of the most common are from fuselage structure vibrations, exterior wind noise leaking through windows and structure, gearbox noise, turbo propellers, engine noise and general squeak and rattle. Knowledge of acoustic field inside the fuselage can direct the noise abatement procedures for lighter and more efficient damping/insulation solutions. Noise generated from the passengers also needs to be accounted for in order to predict and control interior cabin noise.

Detecting the noise can be difficult when measuring sound power entering the cabin at different locations from multiple external sources which tend to become polluted due to hard wall surfaces and reverberant components within the cabin. Early noise source identification methods included accelerometer measurements and intensity measurements utilizing two “phase matched” microphones spaced closely apart. Although easy to use, they were time consuming, lacking in resolution and provided limited information.

Modern methods using a large array of many microphones, strategically placed, along with complex software enable us to obtain a greater amount of information, in a fraction of the time. Spherical beamforming, HELS (Helmholtz Equation Least Square) method and other acoustic holography methods have been implemented for for improved sound pressure mapping, acoustic pressure, surface velocity, acoustic power and intensity measurements.

The HELS method

HELS based NAH differs from the Fourier transform based traditional NAH method in that it uses an expansion of spherical wave functions to reconstruct the three dimensional acoustic field, which greatly simplifies reconstruction and enables complex problem solving on arbitrarily shaped surface with fewer measurement points. This saves both set-up time and material cost. According to Manmohan S. Moondra of SenSound LLC, with HELS method, “the acoustic pressures are expressed as an expansion of admissible basis functions, Ψ_{j}, that are particular solutions to the Helmholtz equation.

$$\hat{p}(\vec{x};\omega) = \sum_{j=1}^{J} C_j(\omega)\Psi_j(\vec{x};\omega)$$

The coefficients, C_j, that are associated with the expansion func tions are then determ ined by solving an over-determined linea r syste m of equa tions obtained by m atching the assum ed f orm solution to the m easured acoustic pressures, and the errors incurred in this process are minimized by least squares."

TEST AND SET-UP

A middle size business jet was used in the test. All interior panels in the passenger cabin were removed. In flight testing was conducted at a flight level 30000 feet and Mach 0.73. The closed surface included the forward cabin skin and floor, aft cabin skin and floor and two closing surfaces (between the cockpit and the forward cabin and at the aft divider location). A conformal circular microphone array of 60 microphones was built (fig 1) to cover the circumferential measurements and a planar microphone array of fifty microphones (for example, PCB model 130E22) was built for the closing surfaces measurements. The circumferential measurements were taken every 2 cm in the longitudinal direction, located 2 cm from the skin.

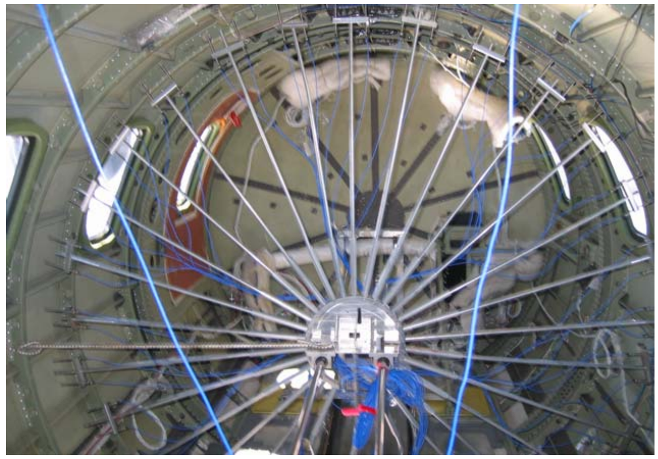


Fig 1. Circular microphone array, PCB Microphone model T130D21

Fig. 2 Fuselage

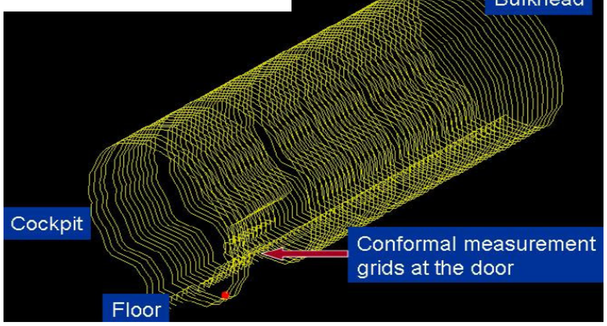
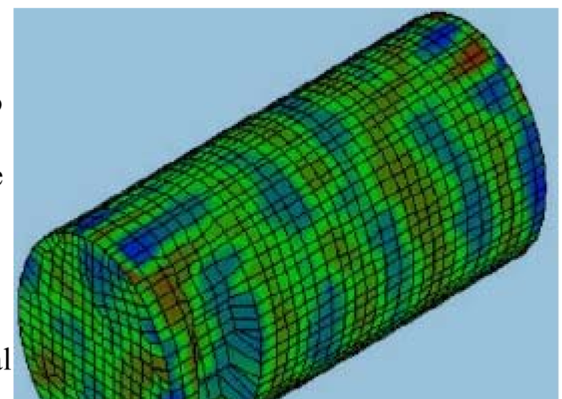


Figure 2 shows the grid with measurement points. Placement areas of highest interest and likely location of passengers should be assessed. The reconstructed location of the fuselage skin and the closing surfaces are then derived. The interior acoustic pressure field was reconstructed in seven interior planes including setup of custom microphone arrays and fixtures for circumferential and longitudinal measurements of acoustic pressures along the fuselage body. Identification of "hot spots" in the cabin skin where noise is more likely to be transmitted into the cabin can then be determined.

Control strategies

Once the noise is identified engineers can take appropriate steps to minimize them. There are active and passive methods to combat the noise sources and each method has its advantages. An example of an active method would be to place speakers in strategic areas and broadcast counteractive noise signals to cause destructive interference. When performing passive methods consideration should be made to weight reduction which also reduces gas cost and travel time. Some examples of passive methods include special panels, coupling between exterior and interior transmission of sound so it is impaired before it enters the cabin, and other dampening materials.



Distribution of surface velocity at 155Hz

Conclusion

HELS and other NAH based methods can provide noise source locations in order to improve the sound inside today's aircraft and helicopters, enabling manufacturers to reduce noise for their passengers.

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