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Do Locally Reacting Acoustic Liners Always Behave as They Should?

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Abstract

BY definition, a liner is locally reacting (or point reacting) when the local response of the liner is dependent only upon the local acoustic pressure and not upon the structure of the acoustic field in the duct. This implies that no sound propagation may take place in the liner parallel to the liner surface.

Helmholtz resonator-type acoustic liner materials are normally assumed to be locally reacting. However, it is shown that different behavior arises when neighboring cells are interconnected (e.g., by water drain holes) or when the cell cross dimensions are not small enough with respect to acoustic wavelength. The assumption of local reaction is then violated and the liner intended to be locally reacting will not behave as it should, that is, not as expected. In these cases the two-microphone technique of in-situ impedance measurement will provide erroneous data. Further, it is shown that when using the two-microphone technique on really locally reacting liners the location of the surface microphone has to be chosen carefully in order to provide accurate data.

Contents

In contrast with other observations,[1-3] important effects of water drain holes were measured on a Helmholtz resonator-type acoustic liner in the NLR flow duct facility.[4] Several measurements were carried out both on a large cell aircraft engine lining material (Types LC and LCD in Fig. 1) and on a small cell test material (Type SC in Fig. 1). Type LCD had drain holes in the honeycomb material in such a way that drain grooves were formed in a lateral direction through the panel.

Effect of Drain Holes on Insertion Loss

In Fig. 2 the insertion loss of 15×105 cm Type LCD and Type LC panels at several flow Mach numbers (M) is shown, the negative numbers indicating upstream sound propagation.

The frequency at which maximum attenuation occurs is shifted by ⅓ octave band at $M=0$ and even 2 or 3 ⅓ octave bands at $M=-0.45$. At $M=-0.30$ and a frequency of 1000 Hz, the insertion loss is even halved by the drain holes. It should be noted that the broad band noise used for this experiment was analyzed into ⅓ octave bands, implying a possible smoothing effect on the attenuation spectrum.

Phase Shift Measurements at Cavity Bottom

Within a locally reacting acoustic liner, waves are free to travel only normal to the liner surface. This implies that only a plane wave travels through the cell, providing a constant acoustic pressure across the back wall of the cell.

In order to verify the presence of local reaction, phase shift measurements were carried out with two Kulite pressure transducers of 2 mm diameter, 12 mm apart in the bottom wall of a cavity located centrally in a 15×15 cm panel of Type LCD material at $M=0$ and at $M=-0.50$. For these

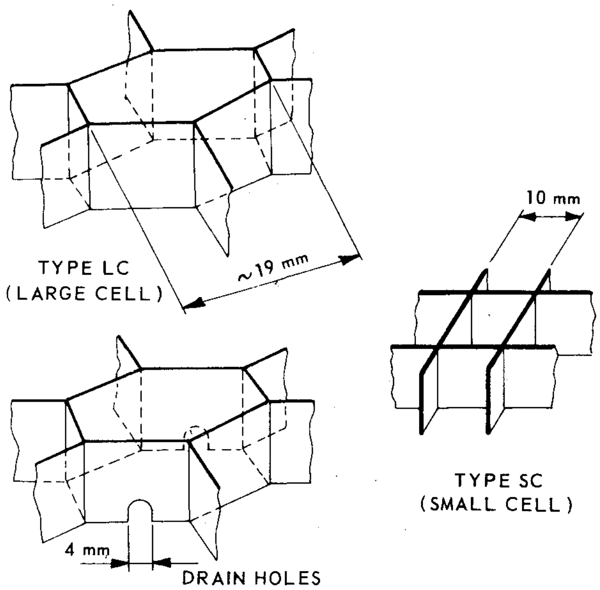

Fig. 1 Geometry of liner core materials.

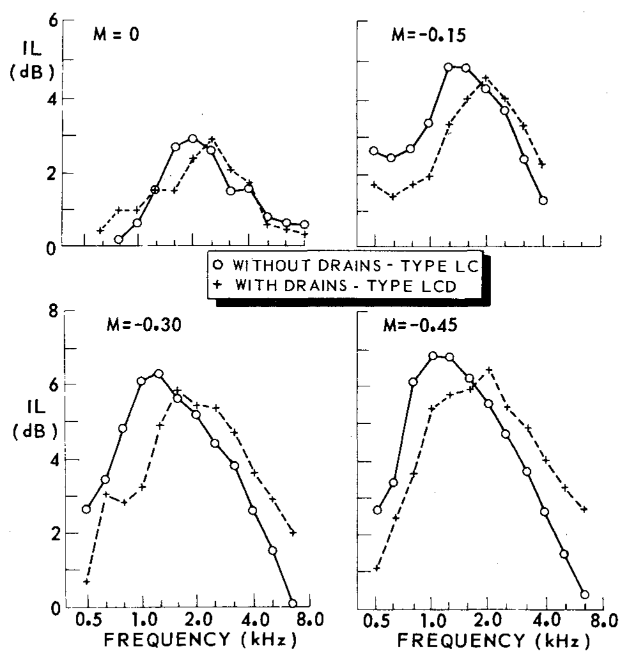

Fig. 2 Effect of drains on insertion loss (*IL*).

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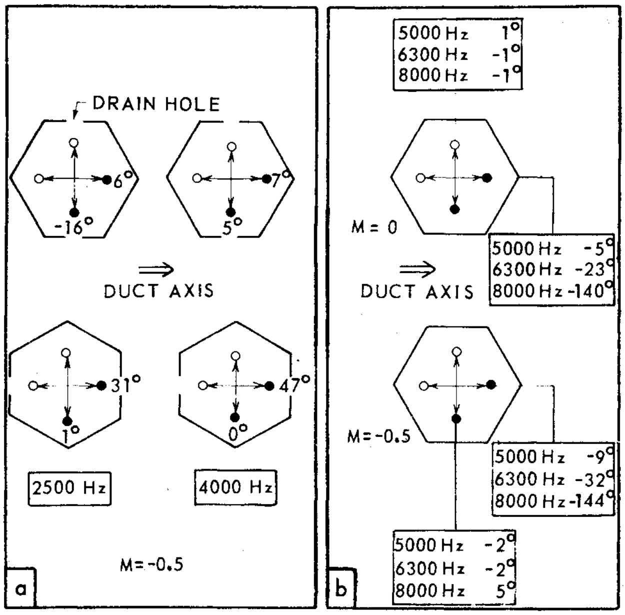

Fig. 3 Phase shift at cavity back wall of panel: a) with drain holes, b) without drain holes.

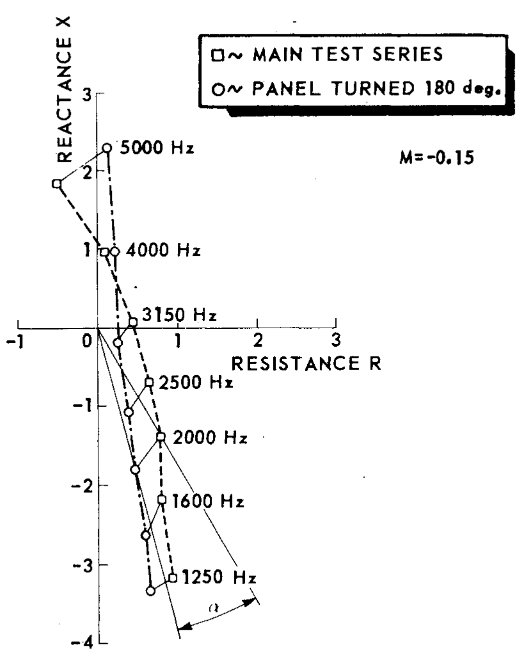

Fig. 4 Effect on measured impedance of turning Type LC panel.

measurements, together with the impedance measurements to be discussed in the next section, a high-intensity pure-tone noise source was used. Panel orientation and orientation of the microphone pair were varied independently. It is observed from Fig. 3a that with the microphone pair lined up in the direction of the drain grooves a considerable phase difference may occur, indicating that the liner does not react locally.

After completely sealing the drain holes of the instrumented cell, significant phase shifts were observable only above a frequency of 5000 Hz as indicated in Fig. 3b. At 5000 Hz the wavelength of sound in free space is about 68 mm, which is 3.5 times the cavity cross dimension. The ratio of wavelength and cavity cross dimension below which phase differences appear at the cavity bottom wall is certainly dependent upon cavity depth. When the cavity depth-to-width ratio is too small to provide full decay of possible cavity cross modes before reaching the cavity bottom wall, phase differences may appear at this wall. When such phase differences are present, the two-microphone technique provides an erroneous impedance.

Impedance Measurements

The impedance was measured in-situ with the two-microphone technique at several flow Mach numbers in a cell located centrally in a 15 × 15 cm panel of Type LC material. This was done only for conditions of a constant phase across the cell bottom wall. The surface microphone has a 3 mm offset from the geometric center of the cell.

At $M = -0.15$ a further measurement was made after turning the panel 180 deg in its own plane and a systematic deviation was found for similar conditions of frequency and local sound pressure level (135 dB on average), see Fig. 4. Yet no unambiguous impedance could be provided for this panel, not even below 5000 Hz.

By turning the panel 180 deg the surface microphone is displaced 6 mm relative to the cell center, resulting in a shift of the phase of the measured surface pressure p_s with respect to the bottom wall pressure p_0. This phase shift results in a corresponding change in the measured impedance Z. A plane wave sound field at grazing incidence would provide the maximum possible phase shift, while the actual phase shift will be smaller according to the specific mode distribution in the duct. At a frequency of 2000 Hz at $M = -0.15$ the 6 mm displacement would provide a phase shift of about 15 deg in the plane wave case, the actual change in measured impedances being 14 deg (angle α in Fig. 4). A similar explanation holds also for other frequencies, except for 3150 Hz (see Fig. 4).

In the small cell liner panel (Type SC) the surface microphone is located centrally in the cell, providing a symmetrical setup. On this panel no effect of turning was observed so that the measured impedance is unambiguous, indicating that the surface microphone was located properly.

From these observations it is recommended that impedance measurements with different panel orientations be made as a routine check when using the two-microphone technique. When a noticeable effect on impedance is found, the liner material is reacting nonlocally and/or the surface microphone is not located properly. Further information may then be obtained with an additional microphone at the bottom wall of the cell.

Acknowledgment

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