Smart Active Lining Modules – Technology for Acoustic Comfort in Future Aircraft

Acoustic comfort is an important issue in aircraft industry. Important external noise sources are the turbulent boundary layer (TBL) and the engines (jet or rotor). The induced aerodynamic and acoustic pressure fluctuations on the hull propagate as structure- and airborne sound through the fuselage into the cabin. The degree of sound transmission and with it the level of interior noise, strongly depends on the sound insulation of the primary fuselage structure and the interior lining elements. The increasing use of lightweight materials in aircraft industry such as carbon fiber reinforced plastic (CFRP) fuselage structures induces great acoustic challenges, which can not be solved solely by means of passive acoustic insulation. Active structural acoustic control (ASAC) is especially effective in the low-frequency domain (< 1kHz), where the sound transmission loss of passive structures is very low. The proposed Smart Active Lining Modules use ASAC technology to resolve the conflict between lightweight construction and acoustic comfort (Fig. 1).

Fig. 1:
Principle of Smart Lining Technologie.

Smart Lining Technology

The Smart Active Lining Module consists of a conventional honeycomb sidewall panel augmented with active structural acoustic control (ASAC). The ASAC system comprises actuators (electrodynamic exciters, piezopatches), sensors (accelerometers, microphones), a control unit (feedforward, feedback) and a power supply. The concept of the Smart Lining Technology is that each module acts as an autonomous unit still with external power supply. Each unit provides in combination with other modules improved acoustic comfort either in the entire or in selected regions of the cabin (first or business class or crew rest compartment). In order to achieve a perceptible improvement of acoustic comfort, the ASAC system of the Smart Active Lining Module must be broadband. In the case of stochastic acoustic disturbances caused by the TBL, this goal can only be achieved by means of a causal controller. Due to the geometric constraints of the aircraft fuselage, the causality of the control system must be realized by the application of fast analog and digital signal processing combined with optimized actuator and sensor schemes.

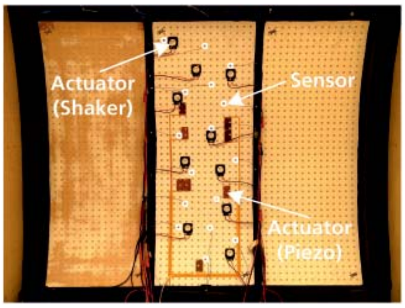

Fig. 2:
Experimental setup of a double-wall aircraft fuselage with Smart Lining in the sound transmission loss facility of DLR.

Proof of Concept

In order to prove the concept of the Smart Lining Technology, a laboratory setup was realized in the sound transmission loss facility of the Institute of Composite Structures and Adaptive Systems. The demonstrator represents an aircraft-relevant double-walled structure consisting of a curved and stiffened CFRP-fuselage and three honeycomb sidewall spacer linings. As can be seen in Fig. 2, only the middle lining was augmented with an ASAC system.

As in real aircraft operation, the stochastic disturbance is introduced on the primary fuselage structure. From there it propagates as structure- (suspension) and airborne (cavity) noise to the linings and induces structural vibration and sound radiation into the anechoic room assuming to be representative for the aircraft cabin. Fig. 3 contrasts the measured normal surface velocity distribution in passive and active mode. The sound power reduction in the corresponding third-octave band (center frequency 200Hz) amounts to 6.5dB(A).

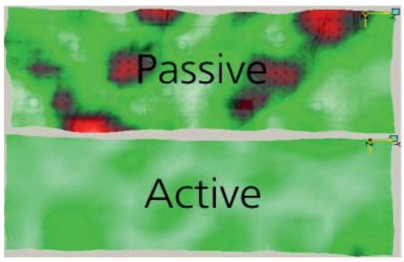

Fig. 3:
Measured normal surface velocity distribution at 183.5Hz without (above) and with active control (below).

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