Active Reduction of Turbulent Boundary Layer Induced Noise

The turbulent boundary layer (TBL) is one of the dominant noise sources in high subsonic aircrafts. Especially in modern aircrafts, where common materials for fuselages are currently substituted by carbon-fiber-reinforced-plastics (CFRP), it is essential to avoid a decrease of passenger comfort as a result of an inferior transmission loss of the new materials. Increasing the transmission loss of CFRP panels, they can be equipped with active structural acoustic control (ASAC) systems. These systems consist of a control unit and surface mounted actuators and sensors. Structural vibrations of the panel are measured by the sensors and filtered by the control unit to estimate the radiated sound power in the far field. The transfer path from actuators over the structure to the sensors is called the controlled plant. Based on this information and a mathematical model of the controlled plant, the controller calculates the signals for the actuators in order to reduce the noise radiation.

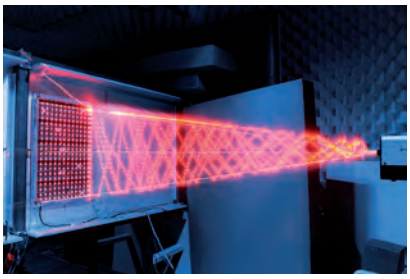

Fig. 1:
Measurement of CFRP panel vibrations using a laser scanning vibrometer.

Wind Tunnel Experiments

The Institute of Composite Structures and Adaptive Systems verified an ASAC system in an experimental study in the aeroacoustic wind tunnel of DLR in Braunschweig. The wind tunnel has an open test section and its nozzle has a cross-section of 1.2 x 0.8 m². The section is enclosed by an anechoic chamber to enable acoustic measurements. For realization of TBL experiments, a closed test section has been designed and built. The active controlled CFRP panel is mounted in the side wall of the section. The TBL is growing steadily over the length of the closed test section until it reaches the CFRP panel with a thickness of approximately 41 mm at Mach 0.16. The panel (500 x 800 x 1.3 mm³) is stiffened with four stringers and equipped with five piezo-ceramic patch actuators and ten accelerometers. Actuator placement was accomplished by an in-house ASAC pre-design tool. Panel fabrication as well as actuator application were made by DLR. Active structural acoustic control has been used to reduce the broadband TBL noise transmission in the bandwidth from 1 to 500 Hz. Robust H-infinity control algorithms were applied in the experiments and showed high performance even in presence of plant uncertainties. The so-called generalized plant framework of robust control is utilized to improve control results. By inclusion of 260 additional surface velocity outputs identified from laser scanning vibrometer (LSV) measurements (Fig. 1), an enhanced global observability has been established.

Fig. 2:
Radiated sound power measured with sound intensity probe.

Broadband Noise Reduction

The experiments proved the possibilities of ASAC systems for thin-walled and stiffened CFRP structures. Though the structural excitation due to the TBL is spatially and temporally weakly correlated, a broadband reduction of the transmitted noise in the bandwidth from 1 to 500 Hz could be demonstrated. In third-octave bands reductions of radiated sound power of up to 6 dB(A) were realized (Fig. 3). Future work will concentrate on the extraction of noise models for the TBL excitation to further improve the control performance.

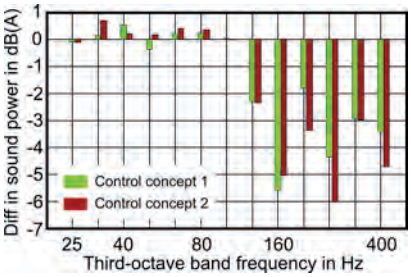

Fig. 3:
Reduction of radiated sound power.

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