Active structural acoustic control [43.40.Vn, 43.50.Ki]

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Sound fields radiated by vibrating elastic structures often create important noise problems. Previous active control solutions have employed sound sources to control this radiation. This approach typically requires many sources to control the noise from complex structures so that the spatial distributions are reasonably matched and control spillover is minimized. Recently, a more efficient approach has been demonstrated for controlling low to midfrequency structural sound radiation, termed "active structural acoustic control" (ASAC). Instead of using loudspeakers ASAC applies control forces directly to the structure so that the radiated sound-pressure field is minimized. The advantages are that effective control can be implemented with fewer control actuators, and the transducers can be arranged to be reasonably compact.

Early work in ASAC, carried out at NASA Langley and VPI&SU[1] in 1985, demonstrated that sound transmission into cylinders could be controlled by point forces applied to the cylinder wall. The application here was to develop advanced techniques for controlling interior noise within aircraft. It was shown that only certain structural modes couple or radiate to the interior space and thus it was necessary to control only those modes. This effect was termed "modal suppression." As the structural motion that gives rise to the sound-pressure response is being controlled, the interior sound field is reduced globally independent of its modal shape. This principle was applied at Douglas Aircraft to a full-scale DC-9 fuselage. Global control was achieved[2] for structure-borne interior noise transmitted through the engine pylons, using only two point-force control actuators. Weight, mounting considerations, and control spillover effects led to recent cooperative work at NASA and VPI&SU to study the use of piezoceramic actuators bonded to structural members.[3] On a full-scale composite fuselage model a four-actuator, six-sensor system has achieved interior global attenuations of 8 to 15 dB over a range of test conditions.[4] Optimization of the transducer size and distribution is expected to produce further improvement.[5,6]

Controlling marine hull radiated sound is another important application of ASAC, now being investigated in research funded by ONR/DARPA. Previous work in this area studied the control of free field radiation from lightly loaded panels.[7] It showed that sound radiated into a free field could also be globally attenuated by a limited number of control actuators.[8] However another mechanism of control was observed. For the off-resonance cases examined, a reduction in sound radiation occurred with little change in the averaged structural response. It was concluded that the residual or closed-loop structural response has a lower radiation efficiency for the same level of response.[7] This effect was termed "modal restructuring." More recently it was shown that modal suppression corresponds to a decrease in all structural wave-number components while modal restructuring corresponds to a reduction only in the supersonic (radiating) components; the subsonic components are largely unaffected.[9] The significance of modal restructuring is that large attenuations of radiated sound can be achieved by an appropriate change in the controlled structural mode shapes without affecting the overall amplitude. This approach is shown to require significantly less control energy.

Other work on free field application of ASAC has centered on using optimally shaped piezoelectric sensors and actuators bonded or embedded in the structure[10] (an adaptive or "smart" structure). Emphasis has been placed on shaping the sensors so that the radiating components of the structural motions are observed, i.e., the sensor acts as a structural wave-number filter. Good reductions in radiated sound levels were observed for both on and off-resonance conditions. This work has now been extended to include the influence of heavy fluid loading on structural motions.[11] Experiments performed cooperatively by VPI&SU and NRL have shown that the ASAC technique still provides high global attenuations when the radiation loading induces significant modal coupling.

In order to implement the ASAC technique a control strategy is required. Initial work has concentrated on using time domain, multichannel adaptive least means square algorithms.[12] More recent work has utilized state space feedback approaches used in conjunction with radiation filters to model the structural acoustic coupling.[13]

In summary, the ASAC technique has demonstrated much potential in aerospace and marine applications. Future work will center on extending these techniques to broadband disturbances, more complex structures and improved modeling. It is known that optimizing transducer positions is as important as increasing the number of control channels. A multidisciplinary approach is required to synthesize a design procedure that integrates the elements of structural acoustics, transducer, and control technology. The pay off will be in significant cost and weight savings, and in performance improvements for other industrial applications.

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