

Abstract

Noise pollution has become a major concern across many modern engineered systems, from transportation and industrial equipment to everyday household appliances. Devices in these various domains must comply with strict noise-emission requirements, which has driven extensive research into reducing the noise radiated from their structures and enclosures. To satisfy weight and dimensional constraints, lightweight casings are widely used. These structures are not only efficient from a design perspective but also provide the possibility of applying active control to improve their acoustic performance.

In vibro-acoustic coupled systems, openings in plate structures serve several practical functions across automotive, aerospace, marine, and naval engineering applications, such as facilitating heat dissipation, routing electrical cables, enabling personnel access, and reducing weight. These openings create a mixed interface—vibrating structure plus openings—so total sound comes from two coupled paths. The low-mid band is critical yet hard to treat passively under weight, space, and transparency constraints.

The dissertation develops a design-oriented analytical framework with three novelties. First, the model is parametric in opening shape and location for systematic exploration and optimization. Second, plate, enclosure, and free-field are coupled in one formulation: Rayleigh-Ritz plate with hyperbolic-trigonometric admissible functions for thin, clamped panels with openings; enclosure modal expansions augmented at the interface to enforce pressure/velocity continuity; radiated power via a radiation-resistance matrix for parametric studies. Third, total sound power combines plate radiation with sound transmission through the opening, clarifying how geometry redistributes energy between paths.

Combined finite-element and boundary-element modelling visualizes the coupled fields and verifies the theory. Laboratory tests on a concrete-frame enclosure with a thin steel plate confirm natural frequencies, mode shapes, vibration spectra, and sound power. The models reproduce the measured shifts and redistribution of vibro-acoustic responses due to the geometry changes.

On this basis, this work establishes a deterministic opening-design workflow. Treating geometry as decision variables (area, placement, and orientation) shapes the response and reduces low-band emissions. Optimized designs achieve up to 12 dB peak reduction in total sound power within 100–350 Hz. The results revealed that having discontinuities in the opening contour leads to higher resonances in the acoustic response of the system in the mid-range of the considered frequencies. Also, if the opening is placed asymmetrically, the system shows additional resonances at these frequencies.

Active strategies under broadband excitation are evaluated. A sound-power-aware actuator-placement method is introduced for inertial actuators on plates with openings; it uses sound-power sensitivities and opening pressure to target leakage-influenced regions with high authority. Experiments compare Active Structural Acoustic Control (ASAC) on the plate, Active Noise Control (ANC) at the opening, and a dual-actuator-type arrangement. The dual case gives the greatest attenuation at error microphones—averaging around 15 dB and peaks exceeding 30 dB—outperforming ASAC-only and ANC-only while remaining compatible with compact device-casing constraints.

The framework is applied to transparent-patched plates to separate radiation and transmission in multi-material panels. A frequency-dependent transmission factor represents the patch, distinguishing plate-borne radiation from through-opening leakage and guiding actuator layout

when transparency is required. Comparisons show how patch areal mass and stiffness modify the mixed interface and how active placement should adapt.

Overall, this research links opening geometry, actuator layout, and mixed-interface physics to measurable vibro-acoustic response. It delivers validated models, an opening-design methodology with demonstrated passive reductions, and active strategies—including a dual-actuator configuration—that achieve substantial broadband attenuation in the low-mid frequency band.