SILESIAN UNIVERSITY OF TECHNOLOGY
Faculty of Automatic Control, Electronics and Computer Science
Institute of Automatic Control

Modelling and control of device casing vibrations for active reduction of acoustic noise

Doctoral Dissertation

by

Stanisław Wrona

Supervisor
prof. dr hab. inż. Marek Pawełczyk

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Abstract

Some of the most common noise sources in the human environment are devices and machinery. In an industrial scale, a high-level noise may lead to hearing losses and health problems. On the other hand, noise generated by domestic appliances do not represent a health threat, but may obstruct work or leisure. Passive methods are commonly applied to reduce the excessive device noise, however, they are ineffective for low frequencies and often are inapplicable due to increase of size and weight of the device and its potential overheating. When passive methods are exhausted, alternatively, active control methods can be applied. They efficiently complement the passive methods in their weak points—low-frequency noise and heat transfer problems.

The classical active noise control uses loudspeakers and microphones to reduce noise, but in three-dimensional space it often results in only local zones of quiet. In case of the device noise, global noise reduction is more desired. To obtain this goal, an active structural acoustic control can be applied, which uses vibrational inputs to reduce the actual noise emission. In the literature, such technique was successfully used for individual noise barriers. The objective of this dissertation is to extend this approach to whole device casings, hereinafter called an active casing approach.

To graduate the complexity, initially a rigid casing is examined, which limits the couplings between walls to the acoustic field. Then, a light-weight casing is considered, characterized by strong additional vibrational couplings. The introduced structures are analysed from the vibroacoustic and control-related point of view.

The mathematical model of the casing walls is developed and experimentally validated for a wide range of cases. The model unifies the mathematical formulation of various aspects that were dealt with separately in earlier works available in the literature. These include thin and thick plate theory, elastically restrained boundary conditions, thermoelastic damping model, and additional elements mounted to the casing surface—masses, ribs, actuators and sensors.

The developed model is widely used for a series of optimization problems. Starting with finding efficient locations for actuators and sensors based on controllability and observability measures. Then, a frequency response shaping method of casing walls is proposed. It is validated in both simulation and laboratory experiments.

Finally, the developed structures are used for active control experiments. The rigid casing is evaluated for single- and double-panels. Different error sensors are employed. The light-weight casing is examined utilizing the previous experiences to properly configure the control system. High levels of reduction are obtained, exceeding 20 dB of global noise reduction, what confirms a high practical potential of the developed approach. When examining different active control techniques, a set of recommendations is formulated for efficient implementation of the active casing method.