Silesian
University
of Technology

Noise-Controlling Casings

Stanislaw Wrona

Seminar at Technical University of Crete
1st - 12th May, 2023

Introduction

Noise reduction

1. Noise is currently one of the most significant threats to the human well-being;
2. Commonly used noise reduction methods are often ineffective against low-frequency device noise;
3. This motivates scientists to look for new ways to reduce noise.

Classification of noise reduction methods

Among the active methods of noise reduction, two approaches can be distinguished, according to the phenomena used:

1. ANC – Active Noise Control;
2. ASAC – Active Structural Acoustic Control;

Classification of noise reduction methods

Among the modern methods of reducing noise, three categories of solutions can be distinguished:

1. Active methods;
2. Semi-active methods;
3. Passive methods;

4. Hybrid methods.

Classification of noise reduction methods

Among the modern methods of reducing noise, three categories of solutions can be distinguished:

1. **Active methods**;
2. Semi-active methods;
3. Passive methods;
4. Hybrid methods.

Figure: Plate with additional mass.

Classification of noise reduction methods

Among the modern methods of reducing noise, three categories of solutions can be distinguished:

1. Active methods;
2. **Semi-active methods**;
3. Passive methods;

4. Hybrid methods.

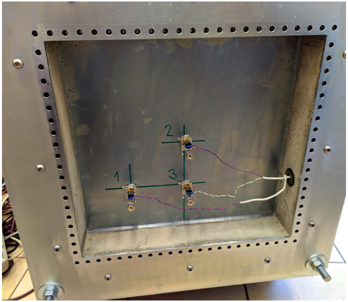


Figure: Double-panel barrier with semiactive links.

Classification of noise reduction methods

Among the modern methods of reducing noise, three categories of solutions can be distinguished:

1. Active methods;
2. Semi-active methods;
3. **Passive methods**;
4. Hybrid methods.

Figure: Washing machine with actuators.

Classification of noise reduction methods

Among the modern methods of reducing noise, three categories of solutions can be distinguished:

1. Active methods;
2. Semi-active methods;
3. Passive methods;

4. **Hybrid methods.**

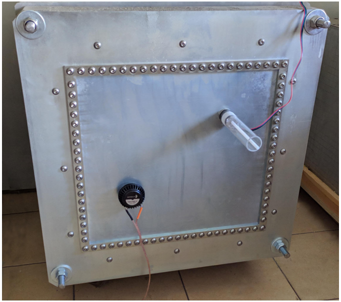


Figure: Plate with actuator and semi-active element.

Purpose of the seminar

- The aim is to discuss **modeling**, **optimization** and **control** methods in noise reduction systems based on "noise-controlling casings".
- As part of the section devoted to control, all three categories of noise reduction methods will be discussed.
- The presentation is of a review character, but it contains a number of practical remarks and solutions.

Modeling

Modeling

- Modeling of vibroacoustic systems is crucial for their effective optimization.
- Optimization can lead directly to noise reduction by finding the optimal configuration of **passive elements**.
- Optimization can also find favorable locations of **actuators and sensors** for semi-active and active methods.
- Mathematical modeling focused on the barriers that separate the noise source from the receiver.

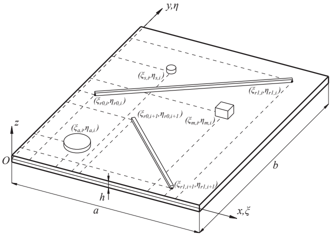


Figure: Schematic diagram of the plate with additional elements attached.

Modeling of barriers based on plates

- A model describing the vibrations of a plate with elastic boundary conditions, with additional concentrated masses and stiffeners.
- It allowed to predict **natural frequencies** and **vibration modes**.
- The model allowed **to shape** the frequency response of the plate.
- The practical effectiveness of this approach will be shown later.

Figure: A concrete box with a one- or two-panel barrier separating the recipient from the noise source.

Modeling of acoustic radiation

- True capabilities of the method were revealed after a significant extension of the model with the phenomenon of **acoustic radiation**.
- The purpose of the acoustic barrier is to reduce noise, and the vibration amplitude is not important.
- It became possible to shape the distribution of vibrations in such a way as to reduce their **coupling with the acoustic medium**.
- This effect was doubly beneficial if the noise source stimulated the barrier purely acoustically.

Figure: Rigid casing when measuring acoustic radiation through a set of microphones.

Acoustic radiation and actuators

- Less than half of the resonances contribute significantly to the transmission or radiation of noise.
- Including the phenomenon of **acoustic radiation** in the model enabled a significant improvement in energy efficiency for acoustically significant modes.

Figure: Actuators whose arrangement was optimized.

Double panel barriers

- Extension of the model to the form representing **two-panel barriers**.
- A new kind of **semi-active element** has been proposed.
- The proposed bistable link allows **adaptations of the barrier properties** to the current noise spectrum.

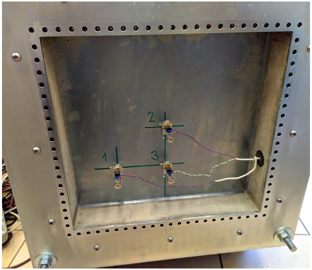
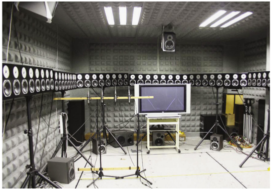


Figure: Double panel barrier.

Modeling of a room for classical methods

Work done in collaboration with Universitat Politècnica de València.

- The approach to optimizing noise reduction systems is also applicable to **classic active noise reduction** systems in rooms.
- A numerical model of the room was used, consisting of over 36,000 identified electro-acoustic paths.
- Thanks to the optimization, it was possible to **shape the zones of quiet** in space.



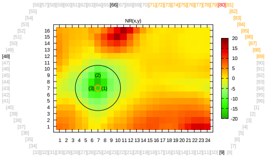


Figure: The laboratory located in the Audio Processing Laboratory, at the Polytechnic University of Valencia.

Optimization

Optimization

Having a verified system model, it is possible to use it to design new or significantly improve existing noise reduction systems.

The objective functions used can be divided into three categories:

- aiming to shape the properties of the vibroacoustic system;
- aiming for optimal arrangement of actuators and sensors;
- combining the two previously mentioned goals.

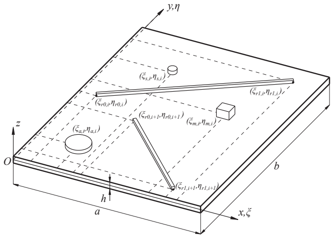
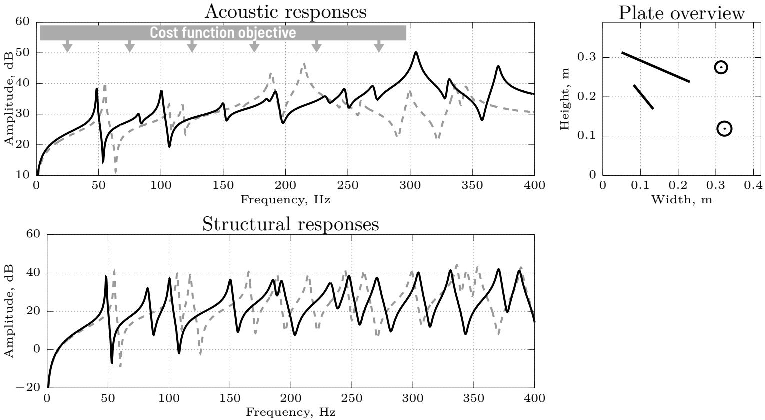


Figure: Schematic diagram of the plate with additional elements attached.

Shaping the frequency response

Minimization of radiation within a given range



Control

Control

Control strategies:

- Active casing method;
- Semi-active control for double-panel barrier.
- Semi-active control for a single-panel barrier.
- Hybrid control for single-panel barrier.
- Passive “control” has been introduced earlier.

Figure: Photos of the laboratory setup for the actively controlled washing machine casing.

Active casing method

Implementation for a washing machine

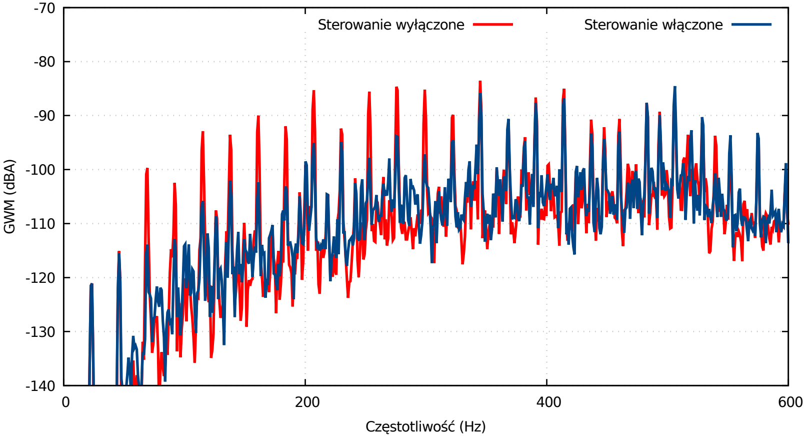


Figure: PSD with A-weighting for error mics E0 - E8. Unbalance weight equal to 500 g. Spinning speed 1340 RPM.

Active casing method

Implementation for a washing machine

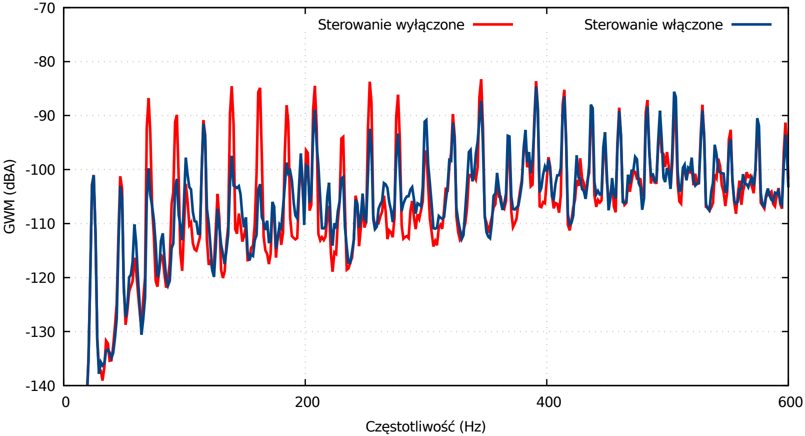


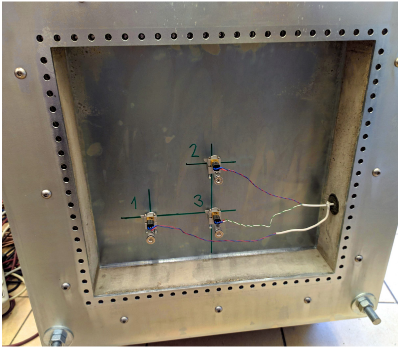
Figure: PSD with A-weighting for monitoring mics M0 - E3. Unbalance weight equal to 500 g. Spinning speed 1340 RPM.

Semi-active control for double-panel barrier

Casing with a double-panel barrier

Work carried out in cooperation with Hong Kong Polytechnic University.

(a) Photo of the concrete box with the outer panel mounted.



(b) Photo with semi-active links visible in the interplate space.

Figure: Photos of the laboratory stand.

Semi-active control for double-panel barrier

Semi-active element

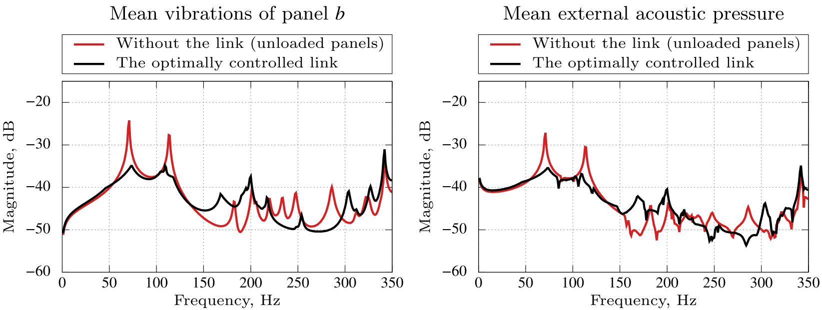
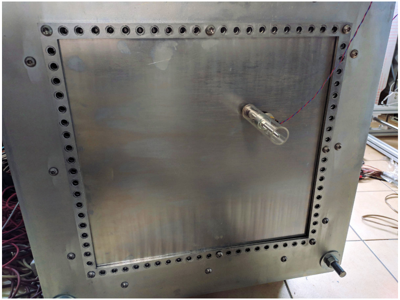


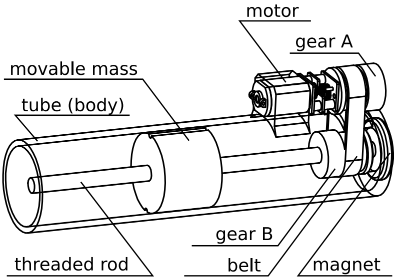
Figure: Frequency characteristics for semi-active control obtained for a link located between the panels. The thickness of the panels was 1 mm and 2 mm, respectively.

Semi-active control for a single-panel barrier

Casing with a single-panel barrier



(a) Photo of the concrete box with the panel mounted.



(b) Scheme of a semi-active element.

Figure: Zdjęcia stanowiska laboratoryjnego.

Semi-active control for a single-panel barrier

Semi-active element

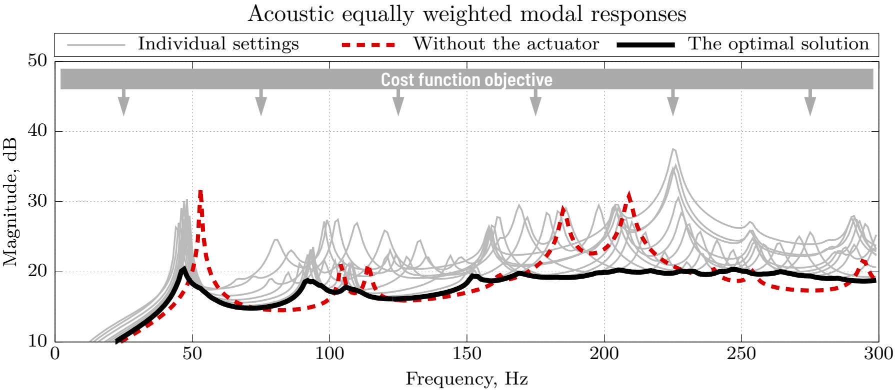


Figure: Acoustic equally weighted modal response of the panel, obtained for optimization index J_2.

Hybrid control for single-panel barrier

- Two operating modes are possible: semi-active only, or active with semi-active support.
- In the active mode, the characteristics are adjusted to the noise spectrum.
- Depending on the mode, other settings of the semi-active element are more favorable.
- Adding a semi-active element in simulation studies gives better results than an additional actuator.

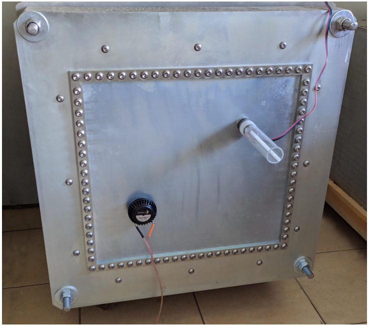


Figure: Plate with actuator and semi-active element.

Conclusion

Conclusion

Noise reduction methods applied to device casings have a high potential to support or replace classic sound-absorbing materials.

Depending on the availability of external energy, it is possible to choose between passive, semi-active and active solutions.

In the low frequency band, active methods can offer more than 10 dB of reduction.

Assuming stationary or non-stationary narrow-band noise, the presented passive and semi-active solutions can also offer more than 10 dB reduction.

Silesian University of Technology

Noise-Controlling Casings

Stanislaw Wrona

Seminar at Technical University of Crete
1st - 12th May, 2023

The presented research was funded by the European Union's Horizon Europe programme under the Marie Sklodowska-Curie grant agreement number 101073037.

National Science Centre Poland