Vibro-acoustic modeling, analysis and optimization using COMSOL Multiphysics

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Acknowledgement
Kui Yao (IMRE)
Zhenbo Lu, Eddie Lau (NUS)
Xu Song, Wei Zhai (SIMTech)
HDB

2017-11-22
Contents

• **Building**-Development of noise mitigation window
• **Research**-Acoustic metamaterial
• **Material**-Porous absorbing material

**Interests & capabilities**

Vibro-acoustic modeling; Noise and vibration control; Architectural acoustics; Aerospace and automotive engineering; Active noise control; Acoustic metamaterial
Ventilation window

- Heavy traffic generates roadway noise
- Train passes through residential area

Sound barrier simulation

HDB window

- Sound transmission loss of small aperture
- Oldham, JSV, 1993

Frequency (Hz)

TL (dB)
Sound Reduction Index

Sound reduction index (SRI)

\[ R = 10 \times \log_{10}(W_{in}/W_{out}) \]

Indoor noise level

\[ L_{in} = L_{out} - SRI + Cr \]

Why SRI is important?
Sound Reduction Index

Predicting SRI using FEM:

\[ \text{SRI} = 10 \log_{10}(W_S / W_R) = L^W_S - L^W_R \]

Sound power of a diffuse room:

\[ L^W_S(f_c) = 10 \log \left[ \frac{A}{2 \rho_0 c_0} \left( \sum \frac{10^{L^W_S/10}}{N_S} \right) \right] \]

Reverberation in source room
Prediction vs. Experiment

Predicted SRI shows good agreement with full-scale experimental results.
Active Noise Cancellation

ANC concept

Traditional loudspeaker vs. Transparent speaker

ANC configuration

Simulation and experiment results

P1: Primary; P2: Secondary

ANC Target: P2 cancels P1

\[ q' = -q(P_1 / P_2) \]
Acoustic metamaterial

- Artificial structure
- Acoustic stop-band
- Negative effective parameters
- Sub-wavelength property
- Tunable performance...

Fang, Nature materials 5, 2006
Periodic Helmholtz resonators

Physical Review B 85, 2012
3D periodic resonators

Sheng et al.
Decorated membrane resonator
Both reflection & absorption

Nature communications, 2014
Wave modulation

Li and Assouar, APL 2016
Low-frequency absorption
Membrane-type acoustic metamaterial

Tunable resonator with dielectric elastomer prototype

Validation with different membrane pre-stretch ratio

Frequency shift with voltage
Membrane-type acoustic metamaterial

Membrane with distributed mass

Comsol simulation vs. experiment

Mechanism study - vibration mode
Acoustic metasurface

Periodic waveguide

Fabricated sample

Metasurface for sound insulation

Transmittance

Transmission Loss (dB)
Metalllic foam

Impedance calculation

\[
\tilde{\rho}(f) = \rho_0 \left[ 1 + 0.0571 \left( \frac{\rho_0 f}{\sigma} \right)^{-0.754} - j0.087 \left( \frac{\rho_0 f}{\sigma} \right)^{-0.732} \right]
\]

\[
\tilde{c}(f) = c_0 \left[ 1 + 0.0978 \left( \frac{\rho_0 f}{\sigma} \right)^{-0.700} - j0.189 \left( \frac{\rho_0 f}{\sigma} \right)^{-0.595} \right]^{-1}
\]

IN625 Open-cell foam

Impedance tube

FEM model
Conclusions

• Comsol Multiphysics is a useful FEM tool to conduct vibroacoustic research.
• Knowledge and experience is important to build correct models.
• The Optimization Module and Application Builder can be integrated to serve a wide range of industrial projects.
• Acknowledgment:
  • Metal Foam Designs with Acoustic Damping Properties: Experimental and Simulation Studies, Inter-RI project with SIMTech

If you have questions & needs about noise and vibration control, acoustic product design, Please feel free to contact us:

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Thank you!