Acoustic Insulating Systems for Noise Reduction

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Forewords

The research we present has been done with the support of:

ISMCM Sup’Méca
Vibro-acoustic group

Hutchinson
- Paulstra

Volage Limited
Cavok software

UNICAMP
Vibro-acoustic group
Contents

Introduction

Our main objective is to give numerical tools to industry for the design of acoustic insulation

We turned our attention towards the simulation of acoustic transmissibility tests

Main research

3 examples using the Transfer Matrix method and the Finite Element method for multilayered poroelastic systems will be shown

Conclusion

Actual benefit of virtual tests and coming research
Introduction
Acoustic Insulating Systems for Noise Reduction
Acoustic Insulating Systems for Noise Reduction
Acoustic Insulating Systems for Noise Reduction

- Longueur d'onde en fonction de la fréquence (th. de Biot)

- $\sigma = 25000 \text{ Kg.m}^{-3}\text{s}^{-1}$
- $\alpha_{\infty} = 1$
- $\Lambda = 192.8 \mu\text{m}$
- $\Lambda' = 384 \mu\text{m}$
- $\rho = 60 \text{ Kg.m}^{-3}$
- $E = 0.034 \text{ MPa}$
- $\nu = 0.3$

- CAVOK WaveLength Analyzer

- $3\text{mm at 5000Hz}$
The full simulation of interior noise remains for the most part inaccessible. That’s why we turned our attention to the simulation of tests of sub-structures which prove itself of most practical benefit for engineers.
Main research

Development of numerical tools and models
Our approach is the following:

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Acoustic Insulating Systems for Noise Reduction
Methods and complexity

![Diagram showing complexity of models vs. frequency]

- 3D Finite Element
- Extension BEM 2D

Acoustic Insulating Systems for Noise Reduction
Transfer Matrix

- layers of infinite extension
  - Only the thickness and material define the layers
  - It is an « ideal » case regarding true geometries

- Fast
  - Diffuse noise, less than 1 minute
  - Optimization is therefore possible

- Implementation using MATLAB
Example 1:

Automatic generation of a multi layer

• Goals
  – Respect a TL
  – Minimize mass

• Constraints
  – Total thickness (8 cm)
  – 10 layers at maximum
  – 14 materials available

• Parameters
  – Population: 100 individuals
  – Computations from 100 to 100 generations
Acoustic Insulating Systems for Noise Reduction

- **Goals**
  - Respect a TL
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  - Population: 100 individuals
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Example 1:

\[
TL = 10\log\left(\frac{1}{\tau}\right) \quad \text{(dB)}
\]

Minimum = 5.3779

Evolution of the best individual

TL of the best individual: mass = 17.2 Kg/m²
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- Poroelastic FE
  - Formulations: U-u, u-w, u-p
  - Order 1 or 2

- Direct computation of the TL in 2D
  - Diffuse noise
  - Radiated pressure field
  - External couplings neglected

- Cavok code
  - External solver (UMFPACK)
  - Specialized user-interface
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CAVOK

INPUT: Node Mesh

MAIN process

MERGE
create FE: acoustic, elastic, etc
assembly system

Post-Compute
values in elements

EXTRACT: K, X, F

Up to 1M DOF!

SOLVE
iterative (krylov)
direct multi-frontal

OUTPUT: Visualisation

CAVOK - Volage-Ltd.com
Example 2:

Mounting of specimen in acoustic rooms and boundary conditions

- 2D FE Model
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« ideal » FE model
Steel 1mm
+ Felt 20 mm
+ Heavy layer 2.3 mm
clamped

« realistic » FE model
Bruit Diffus
Wood (like in the experimental mounting)

SHORTCUT due to Boundary

TL = 10 log(1/τ) (dB)
Example 3:

- 2D FE Model

Aircraft Insulation
Study of noise path
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TRANSMISSION LOSS

- Plate 1: Dural 1.2 mm
- Plate 2: Nida 5 mm
- Poro: Yellow Glass Wool 240x46 mm²
- Mechanic junction
- Air

Magenta TMTX Biot
Cyan TMTX F.Eq
Blue EF ss suspensions
Vert EF avec liaison rigide
Jaune EF avec suspension souple (10x)
Rouge EF avec suspension souple sans air

Zone intermédiaire
Transmission par les suspensions
Transmission acoustique

External load: Plane waves

Courbes TL:
TMTX = Matrices de transfert
EF = Éléments Finis
F. Eq = Fluide Équivalent
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Conclusion
I) Acoustic insulating systems integrating poroelastic materials remain difficult to compute

Even for sub-structure, it is needed to use several methods to cover the frequency range of interest

In particular, 2D FE models were introduced and are a good mean to preserve structural complexity, size of models and computational time

II) Coming research: New version of Cavok code, Cavok V3; study of a full cross section of an aircraft body

Thank you for your attention