Simulating Perforations in MSC Actran

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Vibro-Acoustics Consortium
Introduction

Building Interior

Outdoor Noise Barrier

Engine Enclosure

HVAC Duct

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Objectives

• To model different perforation geometries to better understand how the shape of the perforation affects MPP properties.
• To investigate perforate and small channel modeling capabilities in MSC Actran.
MSC Actran has two simplified models to simulate the visco-thermal effects.

**Low Reduced Frequency (LRF) Model**
Uses closed form equations to model the small tubes. Geometry should be regular (cylindrical or rectangular). The code identifies the geometry and then assigns appropriate equation parameters to represent it.

**Distance-Based Linearized Navier-Stokes-Fourier (DBLNSF) model**
Determines visco-thermal effects using a simplified Navier-Stokes-Fourier model. Geometry may be arbitrary.
MSC Actran Axisymmetric Model

MSC Actran has built in tool to quickly create box-like geometry mesh.

Symmetry axis
Simulation Approach Sound Absorption

DBLNSF Model

Visco-thermal Wall

Velocity Inlet

Rigid End

Cavity Depth

Visco-thermal Component

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Comparison Absorption Coefficient

<table>
<thead>
<tr>
<th>Cavity Depth</th>
<th>Hole Diameter</th>
<th>Model Diameter</th>
<th>Perforation Rate</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 cm</td>
<td>0.4 mm</td>
<td>2.8 mm</td>
<td>2.0%</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

![Graph showing absorption coefficient comparison between Maa's Formula, LRF Model, and DBLNSF Model across different frequency bands.]
Comparison Absorption Coefficient

<table>
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<tr>
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<tbody>
<tr>
<td>10 cm</td>
<td>0.5 mm</td>
<td>2.8 mm</td>
<td>3.2%</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

Maa’s Formula
LRF Model
DBLNSF Model

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# Method Comparison

<table>
<thead>
<tr>
<th>Method</th>
<th>Calculation Time</th>
<th>Domain</th>
<th>Symmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEM</td>
<td>10 min</td>
<td>Frequency</td>
<td>2D axisymmetric</td>
</tr>
<tr>
<td>CFD (Herdtle et al., 2013)</td>
<td>?</td>
<td>Time</td>
<td>2D axisymmetric</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompressible</td>
<td></td>
</tr>
</tbody>
</table>

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Comparison Absorption Coefficient

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<thead>
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<th>Cavity Depth</th>
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<tbody>
<tr>
<td>5 cm</td>
<td>0.22 mm</td>
<td>2.2 mm</td>
<td>1.0%</td>
<td>0.7 mm</td>
</tr>
</tbody>
</table>

![Graph showing comparison of FEM, CFD, and Maa's Formula for absorption coefficient against frequency (Hz).]
Comparison Absorption Coefficient

<table>
<thead>
<tr>
<th>Cavity Depth</th>
<th>Inlet Hole Diameter</th>
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</tr>
</thead>
<tbody>
<tr>
<td>5 cm</td>
<td>0.1 mm</td>
<td>1.0 mm</td>
<td>1.0%</td>
<td>0.7 mm</td>
</tr>
</tbody>
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Comparison Absorption Coefficient

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FEM Model Tapered Holes

Symmetry axis
Comparison Effect of Draft Angle

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Slit Type MPP Absorbers
Tapered on Both Sides

Symmetry axis
Comparison Effect of Draft Angle

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<th>Cavity Depth</th>
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<tr>
<td>5 cm</td>
<td>1 mm</td>
<td>5 mm</td>
<td>4.0%</td>
<td>1.0 mm</td>
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Absorption Coefficient vs Frequency (Hz)

- 11.3 Degrees
- 31 Degrees
- 38.7 Degrees

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Simulation Approach Transfer Impedance

Step 1 Determine $[T_{total}]$

$$[T_{total}] = [T_1][T_2][T_3]$$

Simulation 1 $v_1 = 1, v_2 = 0$

Simulation 2 $v_1 = 0, v_2 = 1$
## MPP Transfer Impedance

### Run 1

\[
T_{11}^* = p_{1|v_1=1,v_2=0} \\
T_{21}^* = p_{2|v_1=1,v_2=0}
\]

\[
T_{11} = \frac{T_{11}^*}{T_{21}^*} \\
T_{21} = \frac{1}{T_{21}^*}
\]

### Run 2

\[
T_{12}^* = p_{1|v_1=0,v_2=1} \\
T_{22}^* = p_{2|v_1=0,v_2=1}
\]

\[
T_{12} = T_{12}^* - \frac{T_{11}^* T_{22}^*}{T_{21}^*} \\
T_{22} = -\frac{T_{22}^*}{T_{21}^*}
\]

\[
T_{total} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix}
\]
Modeling Procedure

Step 2 Determine \(z_{tr}\)

\[
[T_{total}] = [T_1][T_2][T_3]
\]

\[
[T_2] = [T_1]^{-1}[T_{total}][T_3]^{-1}
\]

\[
[T_2] = \begin{bmatrix} 1 & \rho c z_{tr} \\ 0 & 1 \end{bmatrix}
\]
Comparison Transfer Impedance

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Normalized Transfer Impedance vs. Frequency (Hz)

- FEM (Real)
- FEM (Imag)
- Maa’s Formula (Real)
- Maa’s Formula (Imag)
Case 1 Transfer Impedance

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![Graph showing transfer impedance data]
Summary

• LRF and DBLNSF models may be used to model perforations in MSC Actran.
• Sound absorption predictions seem to be adequate.
• Potential analysis tool for designing new types of MPP absorbers.