1 Introduction

Porous materials are usually applied in HVAC system ducts as passive silencers. The application of porous as passive absorbers in elbow silencers has been investigated. The performance of the elbow silencers is expressed in terms of insertion loss in dB across the frequency bands. The characteristics of the material influence significantly the performance. Simulation of the performance in a FEM software was conducted to evaluate the parameters that impact the insertion loss of the silencer. The results of the simulation study are presented in this paper.

2 Background

Details of a typical elbow silencer are shown in Figure 1. The main focus is to evaluate the transmission loss of the sound as the flows traverses the corner, treated with porous materials.

![Figure 1: Schematic details of an elbow silencer.](image)

The acoustic performance is evaluated by solving the governing wave equations between the inlet and outlet of the turning vanes. The porous materials are considered bulk materials and solution domain includes propagation within the bulk materials [1, 2, 3]. The insertion loss, IL, is given by,

$$ IL = 10 \log \left( \frac{L_{w, in}}{L_{w, out}} \right) $$

[1]

where $L_{w, in}$ is the sound power at the inlet plane and $L_{w, out}$ is the sound power at the exit plane. FEM (Finite Element Analysis) methods were applied to evaluate the IL. The powerful software COMSOL Multiphysics was used as the FEM solver.

COMSOL Multiphysics is a powerful equation solver using FEM (Finite Element Methods) techniques. It results in very accurate results, provided the data for the input results are accurate. The only major disadvantage is the computing time and storage capacity of the machine used to solve the fundamental wave equations governing both the free air and porous material regions.

The propagation through the material requires the complex wave speed and acoustic density and they can be obtained from either of the two References 2 and 3. The main input parameter for the determination of the wave speed and density is the flow resistivity of the porous material.

To test the parametric analysis of elbow silencers, the experimental results of Itamoto et.al. will be used for comparison with COMSOL results [5]. The details of two different types of elbows and their inclusion as a single and double elbows are shown in Figures 2, 3 and 4 respectively.

![Figure 2: Details of elbow silencers (From Reference 5).](image)

![Figure 3: Single elbow (From Reference 5).](image)
A number of the elbow combinations were modelled in COMSOL as 2-D and 3-D models and the results are discussed below.

3 Results and discussion

The results of the comparison are shown in Figure 5 and 6 for single and double elbows.

![Figure 4: Double elbow (90º turn) (From Reference 5).](image)

![Figure 5: Comparison results for single elbows.](image)

![Figure 6: Comparison results for double elbows.](image)

The results of Table 1 clearly show the importance of flow resistivity of the porous absorber. Further, the test results of Logawa and Hodgson showed that the flow resistivity is a function of frequency and can vary by about 10% to 15% across the frequency bands. Three dimensional modelling is also critical to provide results with engineering accuracy.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Octave band Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 deg E-900-E - Experiment</td>
<td>2 10 21 24 25</td>
</tr>
<tr>
<td>180 deg E-900-E - Prediction 3D (18,000 MKS Rayls)</td>
<td>0 7 17 31 28</td>
</tr>
<tr>
<td>180 deg E-900-E - Prediction 2D (18,000 MKS Rayls)</td>
<td>0 7 26 20 21</td>
</tr>
<tr>
<td>180 deg E-900-E - Prediction 3D (5,000 MKS Rayls)</td>
<td>0 6 17 26 26</td>
</tr>
</tbody>
</table>

Table 1: Insertion Loss of Double Elbow Silencers.

4 Conclusion

The insertion loss results of elbow silencers were determined from experiment and numerical analysis. The results showed the importance of flow resistivity of absorbers.

Acknowledgments

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References