VALIDATION OF COMSOL MULTIPHYSICS AND ACOUSTICAL PERFORMANCE OF SPLITTER-SILENCERS

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1. INTRODUCTION

One dimensional as well as pseudo two-dimensional models have been successively applied in the past to study the acoustical propagation in HVAC system ducts fitted with splitter-silencers[1, 2, 3]. Even though comparisons between experiment and theoretical finite-element models of the above formulations have been shown to be reasonably accurate within an engineering perspective, the one-D and two-D models were limited since elbows and staggered splitters were not amenable with the above modeling techniques. COMSOL multi-physics provides a powerful three-dimensional application software to solve a variety of different passive silencer designs[4]. As a first step, COMSOL was used in a two-D model mode to solve the splitter silencers whose results have been published in the literature from late 1980s and early 1990s. The results of the above exercise will be presented in this paper.

2. BACKGROUND

The schematic details of a rectangular splitter silencer are shown in Figure 1. The baffle splitters are symmetric in Figure 1. The splitter silencer details are: baffle depth is 'd'; the open air-way width is '2h'; and the silencer length including the diffuser portion is 'l'. Other combinations of rectangular silencers were presented in Ramakrishnan and Watson[1].

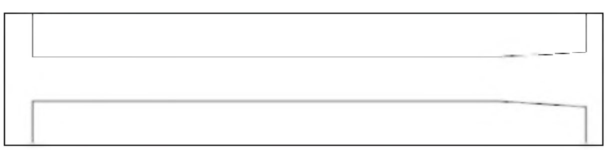

Figure 1. Details of a Rectangular Splitter Silencer

The sound propagates along the centre axis from left to right. The baffle materials are bulk reacting and hence appropriate complex wave speed and material density (complex in this case) can be obtained from References 2 and 3. The mathematical modelling details were presented in Reference 1.

2.1 Results of Ramakrishnan and Watson[1]

The mathematical model of Reference 1 assumed $e^{-\Gamma x}$ variation along the propagation axis where $\boldsymbol{\Gamma}$ is the complex wave number and was obtained for each of the propagating modes in the silencer configuration. The propagation assumption rendered the model into a pseudo-2-D model. Additional correction factors for reflection of sound at the silencer exit were approximated by using the expansion chamber characterization of Reference 2. Cubic finite-element discretization was used in the 'Y' (normal to the propagation direction) to solve for the complex wave number. Sample results for two silencers are presented in Table 1. The agreement between test data and the pseudo-2-D model is excellent except at high frequencies. The main reason for discrepancy is the lack of sufficient elements in the discretization process.

3. COMSOL MODEL

The splitter geometry is modelled in a 2-D configuration as shown in Figure 1. The splitter material is assumed to be isotropic and homogeneous fibrous material of given flow resistivity, 'σ'. The acoustic propagation in the splitter material uses the complex propagation constant and complex density of bulk reacting material. The inlet of the silencer has a given acoustic field and the sound is assumed to be connected to a long anechoic termination. To accommodate high frequency calculation, COMSOL suggests using a length of pipe in front of the silencer within which scattered acoustic field is calculated to provide the required acoustic field at the inlet of the silencer. The results of the acoustic propagation from COMSOL model are presented in the next section.

4. RESULTS AND DISCUSSION

Only a sample set of results are presented in this paper. The sound pressure levels within the splitter silencer are shown in Figure 2. The absorbing qualities of the fibrous material are clearly evident in Figure 2. The decay of sound levels at the silencer outlet can also be seen in the figure. One can also discern the appropriate behaviour of the anechoic termination providing a level of confidence in the COMSOL results.

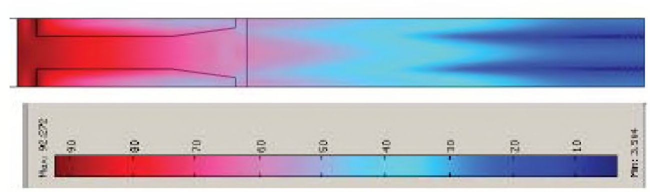

Figure 2. Sound Propagation inside Silencer #2 @ 1050 Hz.

The Insertion Loss, IL, of the silencer is given in Equation (1) below.

$$\boldsymbol{IL = \frac{W_{in}}{W_{out}}, dB} \qquad (1)$$

where W_{in} is the sound power at silencer inlet and W_{out} is the sound power at the silencer outlet.

IL for silencer No. 2 is shown in Figure 3 below. Insertion Loss for a splitter silencer usually peaks at a frequency, based the following three parameters – $N_1 = d/h$; $R = \sigma d/z_0$; and $\mu = 2fh/c_0$, where z_0 is the characteristic impedance of air and c_0 is the speed of sound in air. The IL smoothly decays around the peak frequency. Details of the three parameters are given in Reference 1.

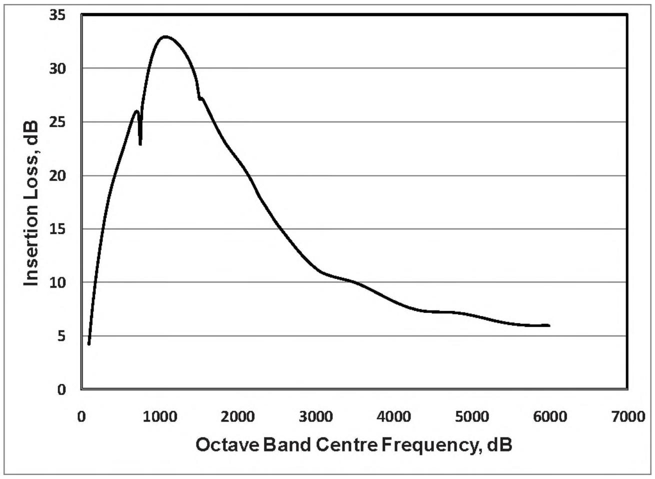

Figure 3. Insertion Loss of Silencer #2.

Similar behaviour is seen in the IL results of Silencer 2. The peak frequency for Silencer 2 is around 700 Hz. IL data increases quickly from 5 dB around 100 Hz to the peak value of 34 dB and decays slowly to 6 dB around 6000 Hz.

The insertion loss result at each octave band is calculated by summing the results within each band (the results were calculated with a constant band width of 20 Hz). The details of the summing process are given in Bies and Hansen[3]. IL results for two sample silencers are presented in Table 1. The results show that COMSOL Multiphysics model produces similar results as Reference 1 and compares well with the measured data.

5. CONCLUSIONS

Insertion loss results of rectangular splitter silencers were evaluated using two-D representation in commercial application software, COMSOL Multiphysiscs[4]. The results were compared to test data as well as predictions obtained applying a simple one-D cubic finite element model to solve the governing equations. The results show excellent agreement. COMSOL model results were seen to be closer to the test data similar to the results of Ramakrishnan and Watson[1].

6. ACKNOWLEDGEMENTS

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Table 1. Comparison of Insertion Loss Results.

Silencer Type		**Insertion Loss, dB @ Octave Band Centre Frequency**					
		125	**250**	**500**	**1000**	**2000**	**4000**
No 1. Unit Size = 305 mm, d/h = 1, and Length = 1525 mm	IL - Reference 1	4	12	26	44	36	13
	IL - Measurements	4	12	27	41	37	20
	IL – COMSOL Multiphysics	4	12	25	46	35	14
No 2. Unit Size = 408 mm, d/h = 1.13, and Length = 1525 mm	IL - Reference 1	6	14	21	29	17	8
	IL - Measurements	5	12	20	26	16	9
	IL – COMSOL Multiphysics	7	14	22	30	17	8