PERFORMANCE ANALYSIS OF ANNULAR PASSIVE SILENCERS – AN UPDATE

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1 Introduction

One dimensional analysis of the performance of annular silencers containing porous absorbers was presented in early 1990s by Ramakrishnan and Watson [1]. The impact of the perforated covering of the porous materials was not included in the earlier results. Further, the influence of duct end reflections were also not included. The multi-physics software, COMSOL, can handle three dimensional propagation as well as the effect of perforated sheets. Six simple annular silencers, tested using ASTM standards, were used in a two-D and three-D models developed in the multi-physics simulation software. The impact of the perforated sheet was also included in the simulations. The predicted results were compared to the test data. The main aim of the current investigation is create updated versions of design curves for performance evaluations of passive silencers. The comparison results are presented in this paper.

2 Background

Details of typical annular silencers are shown in Figure 1. The main focus is to evaluate the transmission loss of the sound as the flows traverses the area with porous materials.

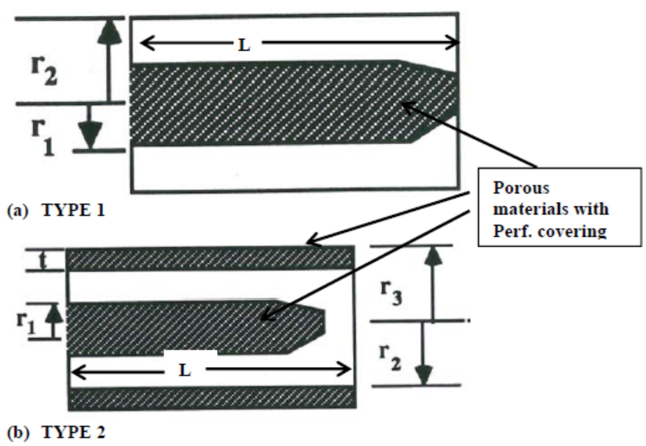

Figure 1: Schematic details of annular silencers.

The acoustic performance is evaluated by solving the governing wave equations between the inlet and outlet of the silencers. 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,

$$IL = 10\log\left(\frac{L_{w,in}}{L_{w,out}}\right) \qquad [1]$$

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 Multiphysiscs was used as the FEM solver [4]. The only major disadvantage of COMSL 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 performance of the silencers, the experimental results of Reference 1 will be used for comparison with COMSOL results. The details of two different types of annular silencers are presented in Table 1.

Number	Type	L, cm	r_2, cm	r_1/r_2	t, cm
SIL 1	1	105	61	2	10
SIL 2	2	122	61	1.5	10
SIL 3	2	122	61	2	10
SIL 4	2	122	61	3.43	10
SIL 5	2	61	31	1.71	10
SIL 6	2	61	31	2.4	10

Table 1: Six Annular Silencer Types.

The six silencers were simulated in COMSOL as Two-D and Three-D models and the results are discussed below.

3 Results and discussion

The results of the comparison between the Two-D and Three-D models are shown first in Figure 2, 3 and 4 for silencers SIL 1, SIL 2 and SIL 5.

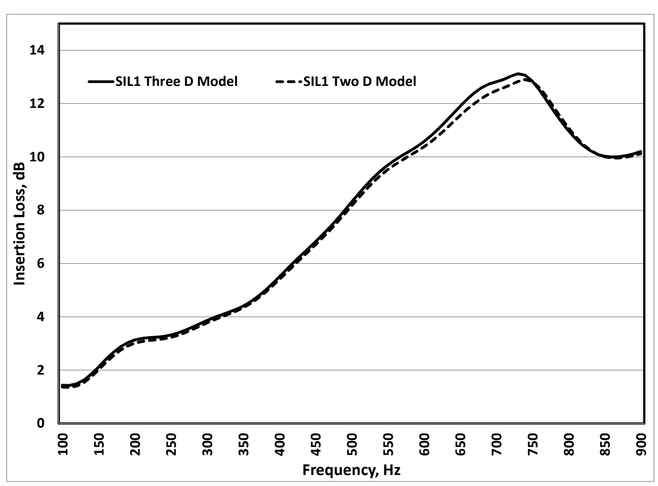

Figure 2: Comparison results for SIL 1.

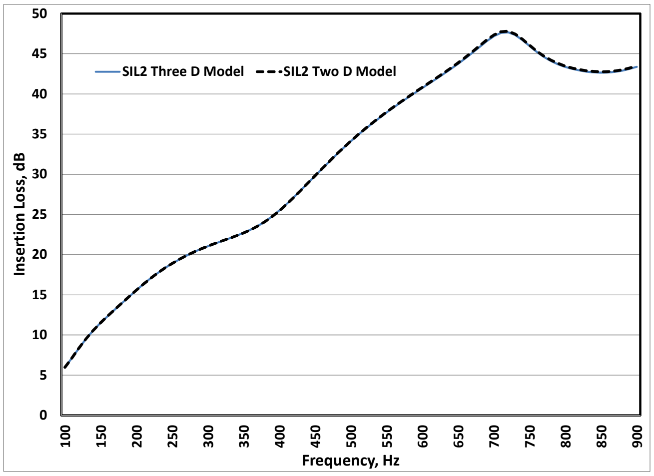

Figure 3: Comparison results for SIL 2.

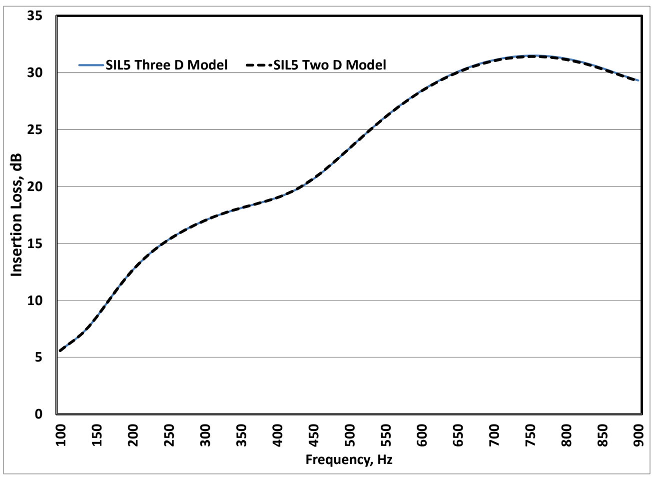

Figure 4: Comparison results for SIL 5.

The simulation model requires a minimum of 5 elements per wavelength. The required number, even though the six silencers are not large, for Octave band numbers 6 (2000 Hz band) and 7 (4000 Hz band) would be in the millions. The 'run time' would be around 36 hours. Hence comparison results between the Two-D model and the Three-D model for three silencers were presented from 100 to 900 Hz in Figures 2, 3, and 4. The results clearly indicate that Two-D modelling is more than adequate.

The IL results for the six silencers were evaluated using Two-D simulation, with the flow resistivity set at 20,000 MKS rayls. The results were compared to the test data and One-D model of Reference 1. The results are shown in Table 2. It is seen that the Two-D model results compare well with test data except at a few high frequency cases. It must be pointed out the flow resistivity of the porous material used in the experiments (Reference 1) was assumed to be 20,000 MKS rayls. However, 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. Even the One-D model of Reference 1 was seen to compare well test data. It must be pointed out the COMSOL simulation is more realistic as it includes the effect of the perforate cover and the reflection effects at the silencer exit.

SIL #	Condition	Octave Band Number					
		2	**3**	**4**	**5**	**6**	**7**
1	TEST Data	**2**	**4**	**7**	**8**	**7**	**6**
	Reference 1	2	4	7	10	5	4
	Two -D Model	**2**	**3**	**8**	**11**	**6**	**3**
2	TEST Data	**10**	**19**	**29**	**38**	**41**	**24**
	Reference 1	8	19	27	37	38	15
	Two -D Model	**9**	**18**	**30**	**46**	**43**	**21**
3	TEST Data	**8**	**15**	**23**	**29**	**29**	**17**
	Reference 1	6	16	27	36	30	13
	Two -D Model	**7**	**15**	**25**	**33**	**25**	**11**
4	TEST Data	**8**	**12**	**17**	**23**	**20**	**14**
	Reference 1	5	13	23	27	16	9
	Two -D Model	**5**	**13**	**20**	**22**	**13**	**5**
5	TEST Data	**7**	**14**	**18**	**26**	**34**	**25**
	Reference 1	5	12	21	31	37	29
	Two -D Model	**7**	**15**	**23**	**32**	**35**	**23**
6	TEST Data	**6**	**13**	**15**	**22**	**27**	**18**
	Reference 1	5	12	18	25	28	19
	Two-D Model	**7**	**14**	**20**	**27**	**26**	**15**

Table 1: Insertion Loss of Annular Silencers.

4 Conclusion

The insertion loss results of annular silencers were determined from experiment and numerical analysis. The results showed the importance of flow resistivity of absorbers. The Two-D model was seen to provide good comparison with test data.

Acknowledgments

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References

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[5] B. Logawa and M. Hodgson. Duct-Liner Acoustical Characterization. Technical Report, Acoustics and Noise Research Group, University of British Columbia, July 2013.