PERFORMANCE EVALUATION OF DUCT BENDS

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1. INTRODUCTION

Acoustical performances of simple elbow (round and rectangular) fittings, used in building HVAC systems, have been conventionally evaluated using empirical relations based on laboratory and/or field measurements as seen in the results of Ver[1]. Basic tabular results can also be obtained from ASHRAE handbooks[2]. One dimensional modelling techniques were unable to provide reliable results. And hence a-multi-dimensional commercially available software, COMSOL, was used to provide simple design curves for rectangular elbows lined on all four sides[3]. The software applies finite element techniques to solve for the acoustical performances. The model is also capable of using the material properties of the liner materials. The liner is considered to be bulk reacting. Preliminary results of the multi-dimensional model will be presented in this paper.

2. ATTENUATION OF DUCT FITTINGS

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have developed simple steps to evaluate the attenuation of duct fittings such as elbows, lined and unlined, based on the results of Ver[1]. Examples of these results are shown in Figures 1 and 2. However, these results couldn't be represented easily in a tabular form and in addition are based on simple empirical relationships. With the availability of powerful numerical tools, the simple results can be updated to provide a larger set of attenuation results.

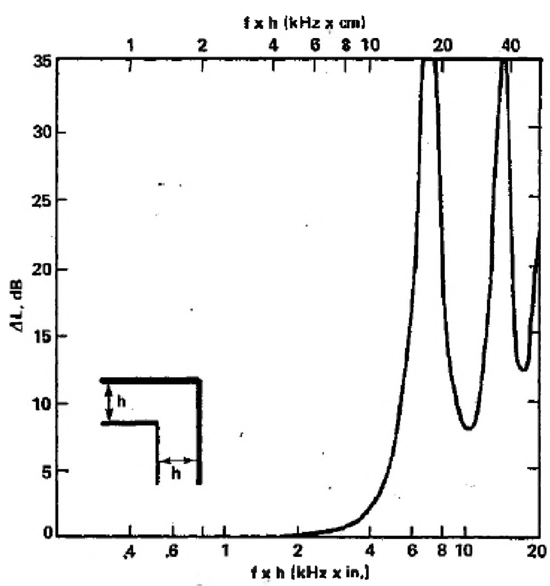

Figure 1. Attenuation of Unlined Elbows, from Ver[1].

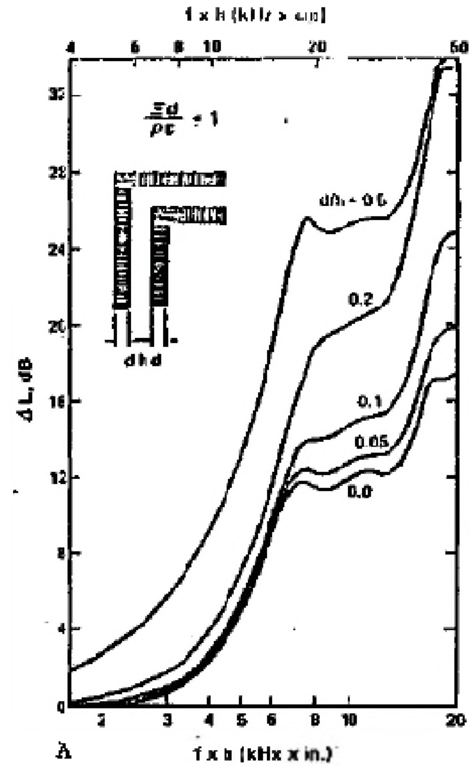

Figure 2. Attenuation of Lined Elbows, from Ver[1].

[Ξ is the flow resistivity of the liner per unit thickness and ρc is the characteristic impedance of air in Figure 2.]

The current investigation has made use of COMSOL, a powerful multiphysics numerical analysis tool and has attempted to provide results based on multi-dimensional analysis.

3. BACKGROUND

The schematic details of a lined elbow fitting are shown in Figure 3. The liners are symmetric in Figure 3. The liner details are: liner depth is 'd'; the open air-way width is 'h'; and the liners are used for a minimum of two-duct width on either side.

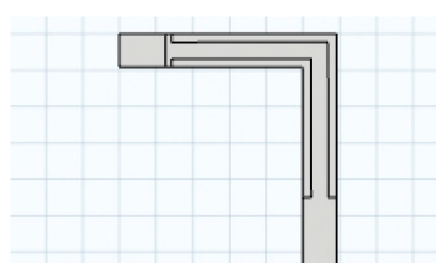

Figure 3. Details of a Lined Elbow.

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 Bies and Hanson[4]. The mathematical modelling details were presented in Ramakrishnan and Watson[5].

4. COMSOL MODEL

The elbow geometry can be easily modelled as 3-D. In this investigation, however, the elbow is modelled in a 2-D configuration as shown in Figure 3. The liner material is assumed to be isotropic and homogeneous fibrous material of given flow resistivity, 'Ξ'. The acoustic propagation in the liner material uses the complex propagation constant and complex density of bulk reacting material. A given acoustic field was assumed at the inlet of the elbow and the outlet is connected to a long anechoic termination. To accommodate high frequency calculation, COMSOL suggests using a length of pipe in front of the elbow within which scattered acoustic field is calculated to provide the required acoustic field at the inlet of the lined (or unlined) elbow. The application of COMSOL for simple rectangular ducts with baffles was validated in Ramakrishnan[6].

The elbow attenuation is given in Equation (1) below.

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

where, W_{in} is the sound power at elbow inlet and W_{out} is the sound power at the elbow outlet. The results of the acoustic propagation from COMSOL model are presented in the next section.

5. RESULTS AND DISCUSSION

The main focus of the current investigation is to provide an extensive tabular set of results for lined elbows similar to the tables given in Reference 2. The first step is to compare the COMSOL results to those of Ver[1]. Two sets of results are shown in Figures 4 and 5.

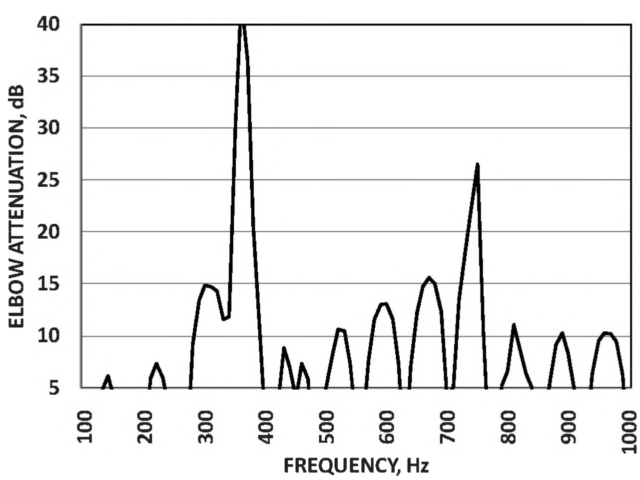

Figure 4. Attenuation of Unlined Elbows, h = 0.56 m.

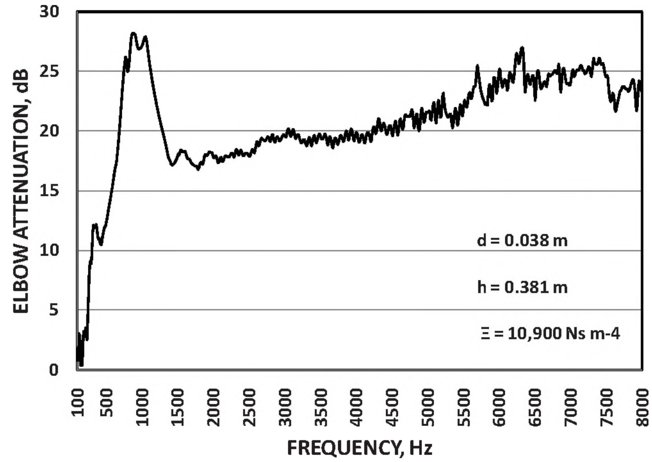

Figure 5. Attenuation of Lined Elbows.

The COMSOL results from 2-D modelling are seen to produce results similar in trend to the results of Ver[1]. It must be pointed out that the scales are different between the results of Figures 1 and 4 and Figures 2 and 5. Further, sample results of three elbows (unlined, lined- d/h of 0.1 and 0.5) are given in Table 1 below.

Table 1. Attenuation of Elbow Fittings, dB.

	125	250	500	1000	2000	4000
Type 1	1.5	4.4	5.4	5.3	6.2	8.7
Type 2	1.3	5.8	13.2	22.7	18	20.2
Type 3	4.4	12.2	22.9	23.4	16.4	14.4

6. CONCLUSIONS

Attenuation results for duct elbow fittings were evaluated using two-D representation in commercial application software, COMSOL Multiphysiscs[3]. COMSOL model results were seen to be closer to the test data similar to the results of Istvan Ver[1]. The intent of producing a large set of tabular results has also been initiated.

REFERENCES

1. Istvan Ver, "A Study to Determine the Noise Generation and Noise Attenuation of Lined and Unlined Duct Fittings," Report #5092, ASHRAE RP-265, June 1983.
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