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Comparison of characterization methods for rigid porous materials

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ABSTRACT

One of the most common problems in the development of silencers is to provide sufficient absorptive behavior using less costly materials that are effective over the desired wide frequency band and are thin, lightweight and application-friendly [1]. Theoretical and empirical models for the acoustic properties of porous or granular media allow inverse determination of some porous properties. In this work, classical description of porous media as a homogeneous equivalent fluid is assumed, and are applied using a numerical predictive model for a porous granular medium consisting of a face centered cubic sphere packing on which measurements were taken [2]. The comparative absorption result of the numerical versus experimental models are discussed.

Keywords: Porous, Absorption, Impedance tube

1. INTRODUCTION

Material parameters in a porous acoustics materials are sometimes difficult or not directly measurable [3], especially in the case of a medium consisting of pores with a wide scale range and random compounds. To describe the acoustic behavior of porous or granular materials, sound propagation models are used. The prediction of several parameters by such models is applicable to various fields, for which, equivalent fluid models are used in many situations [4]. Here, the main assumption is that the solid part of the material is rigid and immovable. Therefore, the behavior of the material as a mass medium is of interest. Such models focus on macroscopic behaviors and do not zoom into the microscopic occurrences in the pore scale. There are several microscopic scale studies on the subject none of which upon the authors' knowledge, have made the ends meet and given an a thorough analysis of what each and every parameter involved in macro-scale physically means in micro-scale.

Absorptance is usually tested with a standard 2-microphone impedance tube in accordance with an ISO 2001 standard. The tube in this study is fixed in a vertical state to avoid the influence of gravity on granular material for reasons of surface symmetry. Measurements are carried out in the frequency range from 100 Hz to 4.5 kHz. The sample is mounted in the sample holder, supported by a rigid plate.

2. FINITE ELEMENT MODELLING

A finite element model was created on a stack of beads (Figure 1). Each spherical bead has 3 mm radius and the distance between them range from 200 to 500 μm. The diameter of the impedance tube is 44 mm. The length of the pipe must be more than three times the diameter. The network is set very fine and network convergence is complete. Stack layer has the thickness of 30 mm. For the case of 300 micrometer distance, the created mesh consists of 1.2 million domain elements, 400 thousand boundary elements, and 33 thousand edge elements. The absorption coefficient is calculated using the equation 4.4 in Kampinga's thesis [5].

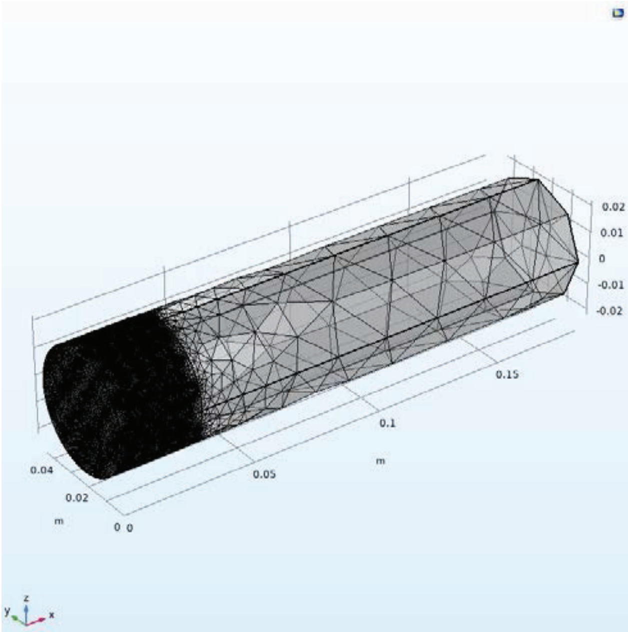

Figure 1- Model of an impedance tube in Comsol Multiphysics with the full-scale beads in the sample-holder

Although the crosslinking and solution process is quite costly, we hope that comparing the simulation and measurement results with inversion and direct methods will allow us to find patterns of morphology versus the porous acoustic behavior of our samples. In Table 1 we see the peak absorption occurring at various distances of the beads.

Table 1- Seeking for higher absorption peak by decreasing the distance among beads

Distance between 6mm diameter beads	Maximum Absorption
500	0.24
375	0.31
300	0.37
250	0.43
200	0.48

If we do a linear curve fitting using the data from the above table, we will see that according to such a calculation, at around 14 μm, we should get the absorption 1. Since the experimental results of a stack of the same layer thickness as in the model consisting of glass beads of the same diameter, in the same tube results in absorption peak of close to 1, we would need to decrease the distance further down. Given the amount of time such a solution will take, such a solution is not yet accomplished and is under

3. CONCLUSIONS

Granular materials are typically characterized using acoustic models. However, the accuracy of the prediction depends heavily on the input parameters and the chosen method. Three-dimensional finite element modeling was shown on an sample of a stack of glass beads in an impedance tube, and the resulting absorption curve was calculated as a result. It is concluded that the distance among the beads needs to be further increased in order for the measurement and simulation to become potentially comparable.

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