Experimental study of a meta-poro-elastic system with needle inclusions to improve the low-frequency absorption performance

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This paper investigates experimentally the effect of embedding sub-wavelength scale inclusions in a foam layer on the sound absorption performance. It is shown that the absorption peak is due to the mass-spring effect, and is dependant on the inclusion mass and position.

1 Introduction

Poro-elastic materials suffer from lack of efficiency at low frequencies, despite their effective sound absorption behavior at higher frequencies. This motivated many researchers to focus on extending their application to lower frequencies, by means of meta-porous [1], and meta-poro-elastic systems [2], and benefiting from different effects, namely trapped mode effect [1], modified mode effect [3], and mass-spring effect [4]. The mass-spring effect exploits the frame vibration to increase viscous losses. So far, very limited research is dedicated to engineering meta-poro-elastic systems that benefit from the mass-spring effect. In this paper, a meta-poro-elastic design is proposed and validated experimentally, using the mass-spring effect as a mechanism to improve the sound absorption.

2 Meta-poro-elastic design

This work investigates meta-poro-elastic systems with small heavy inclusions in order to exploit the mass-spring effect. The mass-spring system has a specific resonance frequency and, beside modifying the mode(s) of the frame, it introduces an additional mode in the system.

The proposed design comprises a steel needle inclusion of diameter $r = 0.2$ mm inserted in a cylindrical foam sample of 40 mm thickness, and 40 mm diameter. The position of the needle in the foam layer is chosen such that the dependency of the mass-spring effect on the location of the inclusion, i.e. the stiffness of the spring, can be assessed. An schematic view of the two variations of the design are shown in Figure 1. Moreover, to evaluate the effect of the added mass on response of the system, design1-C is considered. In this configuration two needles are inserted at the same position as design1-B.

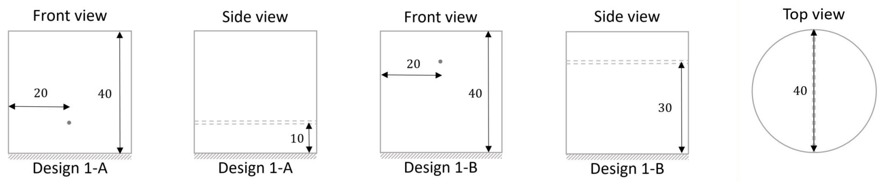

Figure 1: Schematic view of design 1-A(top), and design 1-B(bottom). The dimensions are given in millimeter.

3 Results and discussion

The absorption coefficient of the bare and meta-poro-elastic samples under normal incidence angle are shown in Figure 2. These values are measured using a Kundt tube that has a valid frequency range of 500 Hz to 4530 Hz, according to ISO 10534-2. Figure 2 shows that the needle inclusion causes the absorption peak of the bare foam to be split in two peaks. Furthermore, moving the inclusion further away from the rigid backing, shifts the first peak to lower frequencies, i.e. from 1100Hz for design1-A to 1000Hz for design1-B, due to due to an increased length of the foam which will be compressed, and hence a reduced stiffness. Moreover, a similar trend is noticed when the added mass is doubled. It should be noted that the efficiency of the mass-spring effect is highly dependent on the material properties of the foam since the additional mode induced by the resonance inducing inclusion puts the skeleton in out-of-phase motion with respect to the fluid phase and leads to an increase in viscous losses. Therefore, the presented results are considered as a proof-of-concept, and further improvement of the sound absorption is possible if the poro-elastic material is chosen wisely.

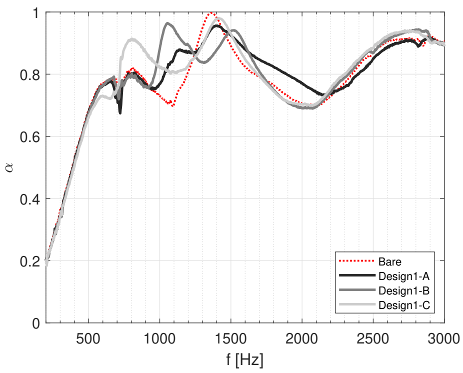

Figure 2: The absorption coefficients of the bare and meta-poro-elastic configurations measured using Kundt tube.

4 Conclusions

In this work, a meta-poro-elastic design with needle inclusions is presented to improve the sound absorption of the system at low frequencies, exploiting the mass-spring effect. It is demonstrated that using resonance inducing inclusions in an elastic-frame foam leads to an additional absorption peak. Moreover, it is experimentally validated that this absorption peak is tunable by tweaking the position and the mass of the inclusion.

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