3D PRINTED PLA-HYDROGEL FRACTAL ACOUSTIC COMPOSITE METAMATERIAL

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1 Abstract

In this work COMSOL Multiphysics simulations and experiments were performed on metamaterials with fractal geometries and hydrogel fillers. The results show key features which affect the meta-behaviour of these structures. The metamaterials have a Hilbert fractal geometry (from zero to the third order) with internal gap widths ranging from 0.5 mm to 5 mm. The comparison between metamaterials was carried out by evaluating their response in term of absorption coefficient (AC) and transmission loss (TL) between the empty metamaterial made by polylactic acid (PLA) and the composite one made by hydrogel and PLA.

2 Introduction

Excess noise has detrimental effects on human health and wellbeing. The mitigation of this type of pollution is not trivial but essential to improve the collective quality of life [1]. For mechanical, civil, and aerospace engineering applications, one of the common ways to deal with unwanted sound is to exploit the mass law or utilise thick layers of absorbing materials [2]. However, that is not always possible due to weight or space restraints, and new solutions and technologies are needed. Composite metamaterials can be part of the answer [3, 4].

3 PLA-Hydrogel Composite

Composite materials have many potential applications in several engineering fields. One side which has not yet been explored is the use of composites to produce multiphase metamaterials for acoustic applications. Combining additive manufacturing technology with hydrogel is something new [5], and according to the experimental results they seem quite promising [6]. PLA fractal metamaterials' acoustic performance with and without hydrogel fillers was measured using ASTM standard E2611-09 tests with an impedance tube.

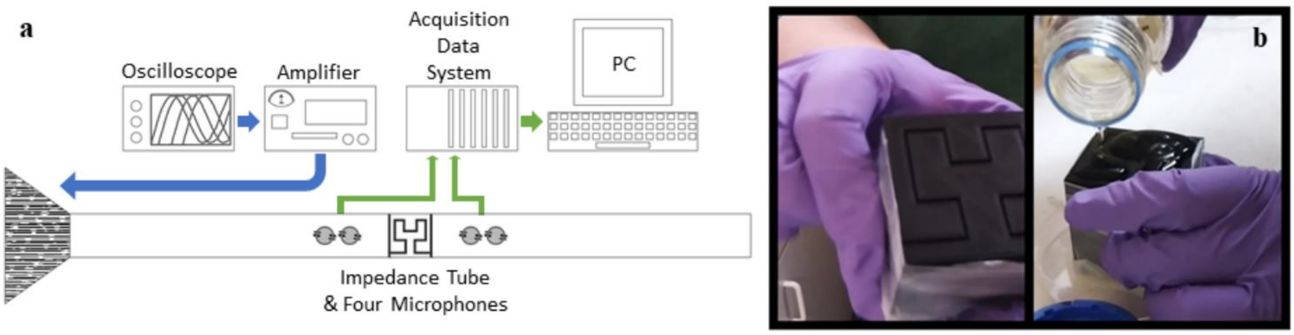

Figure 1: Impedance tube (a), Composite metamaterial (CMMs) manufacturing with hydrogel (b)

Figure 1(a) shows a drawing of the test rig configuration used in the experiments to identify the absorption coefficient (AC) and transmission loss (TL). The specimens were subjected to white noise in the test room. Four microphones linked to an acquisition data system and a PC were used to record data in a range between 200 and 3000Hz. Figure 1(b) shows one of the samples representing the composite metamaterial. The hydrogel used to cast into the metamaterial is an F127 alginate hybrid gel with distilled water. This fluid type was used as an infill material because of its microporous structure and interesting acoustic properties which have not been thoroughly investigated yet [6].

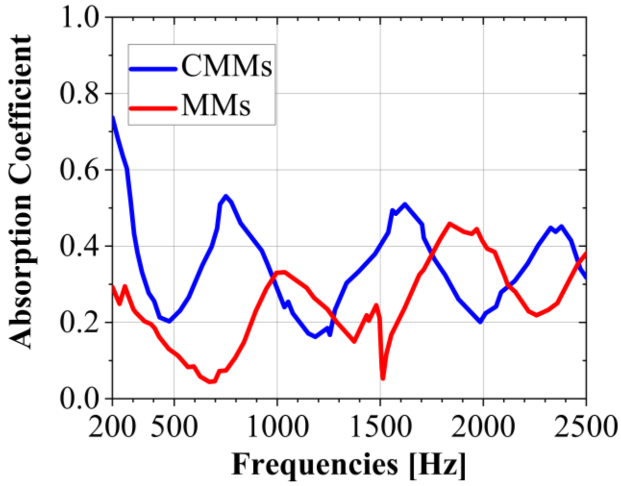

Figure 2: Experimental comparison between CMMs and MMs

Figure 2 shows the difference in terms of absorption coefficient between the composite metamaterial (CMMs) and the traditional metamaterial (MMs). For the low-frequency range (below 500 Hz), the acoustic absorption for the composite metamaterial is more than double compared to the traditional MMs. A high level of AC in some areas of the frequency spectrum (especially at 200 Hz with AC values close to 0.8) indicates a high dissipation of acoustic energy. These results underline a novel way to absorb energy from sound using these composite metamaterials passively.
This work provides an experimental feasibility study on how the introduction of composite metamaterials can contribute to the dissipation of acoustic energy and increase the TL in a structure. Hilbert fractal lattice configurations have been used as a recursive and geometrical shape with different gap widths in this work. Moreover, mechanical characterisation was also performed via compression tests to understand some critical mechanical properties as a step towards practical applications.

References

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