Project title: 3D printing of porous materials for acoustical performance

Discipline  
Acoustics

Key words:  
Noise Control, 3D printing

Supervisory team:  
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Project Highlights:

- Exploration of microstructures in porous solids that lead to good sound absorption
- Use of 3D printing Technology to create bespoke sound absorbing materials.

Overview:

Sound absorbing materials are used widely in buildings and vehicles. Typically they are porous cellular, granular or fibrous materials containing fluid-filled networks of pores. In a cellular material there may be complete or partial membranes between adjacent foam cells. The discrete particles in granular material may or may not be fused or bonded together. A fibrous material consists of long, thin, rod-like structures, i.e. fibres, which may be interwoven and may be joined by a binding agent. The (connected) volume fraction occupied by the fluid is the porosity and the corresponding solid fraction is one minus the porosity. Typical bulk manufacture of the fibrous, granular or polymeric materials used for sound absorption results in complex microstructures that are difficult to control. Increasingly waste materials are used for making acoustical materials and these result in even more inhomogeneity. Much research effort has been expended in devising analytical and numerical models to predict bulk acoustical properties from the complicated microstructures of these materials on their [see, for example, Perrot et al 2012]. The most complete analytical model requires eight parameters to characterise the acoustical properties of a layer of porous material. Recent analytical developments [Horoshenkov et al, 2016] allow investigation of pore size distribution effects and the effects of closed or ‘dead end’ pores [Leclaire et al 2008]. Simple pore structures, for example inclined slits, can be designed to have useful sound absorption (see Fig.1). The only parameters involved are slit width, spacing, inclination to the surface and standard deviation of slit width distribution [Attenborough, 2018]. Other possibilities involve pore non-uniformity, insertion of partitions within the material [Attenborough 2019].

Fig. 1 Normal incidence absorption spectra (a) 26.4 mm thick perforated aluminium foam (red continuous line) and 25 mm thick 65° inclined 0.46 mm wide slits (black broken line), porosity 0.3 (b) 56.7 mm thick melamine foam (red continuous line), porosity 0.99 and 50 mm thick partitioned 60° inclined 0.2 mm wide slits (black broken line), porosity 0.95.

The problem is to how to manufacture porous materials with controllable acoustically useful microstructures. Advances in 3D printing including of porous microstructures [Fee et al 2014] may offer a way. There is a chance for working with the University of Lancaster on this problem.

Hypothesis and objectives

That porous materials with microstructures optimised for acoustical applications can be made using rapid prototyping methods including 3D printing.

Objectives

1. To use analytical models to explore simple rigid-frame microstructures that can achieve specified acoustical performances for target applications
2. To demonstrate proof-of-concept through manufacture of larger scale versions using 3D printing
3. To explore the possibility of designing 3D printed materials that are porous and elastic for target applications

Methodology

Calculations for rigid-framed media will be made assuming slit-like or cylindrical pores inclined to the surface or with non-uniform profiles and a size distribution. Modified Biot theory will be used to allow for elasticity effects. Since the 3D printing facilities available at the OU do not have sub mm resolution, proof of concept will be achieved by working with larger pore sizes.

Outcomes

The results will be reported in peer-reviewed academic journal publications, and presented at international conferences. The work could provide a basis for linking with commercial users of 3D printers having sufficiently fine resolution. The project is relevant to engineering, environmental and physical sciences research areas.

Timetable

Year 1:
Background reading and literature review of models and measurements for the acoustical properties of porous sound absorbers.

Becoming familiar with 3D printing and other Additive Manufacturing methods.

Year 2
Construction of sound absorbing porous surfaces/plates using OU’s existing 3D printing facilities with a specified pore structure;
Measurement of acoustic characteristics of these surfaces and comparison with existing theoretical models.

Year 3
Analysis of data gathered in year 2; creation of new designs for sound absorbers based on these analyses; further measurements based on these new designs.
Write up.

Further reading:
Fee et al Journal of Chromatography A, 1333 18–24 (2014)

Further details:
Students should have a strong background in Physics, Engineering or Applied Mathematics and enthusiasm for Acoustics. Experience and knowledge of acoustic measurement techniques is desirable but not essential. The student will join a well-established team researching Environmental Acoustics at the Open University.

Candidate Applications
- 1000 word cover letter outlining how they are equipped in their educational background and expertise to conduct the research project,
- a CV including contact details of two academic references
- Open University application form
- Applicants will need to demonstrate good competence in the English language. International students need an overall IELTS score of 6.5 with no less than 6.0 in any of the four categories of reading writing, speaking and listening.

Applications should be sent to STEM-EI-PhD@open.ac.uk by 28.02.20