E&I Research Studentship project proposal 2019

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

Supervision Team:
Keith Attenborough, School of Engineering & Innovation (keith.attenborough@open.ac.uk)
Shahram Taherzadeh, School of Engineering & Innovation (shahram.taherzadeh@open.ac.uk)

Project Highlights:

Use of 3D printing Technology to produce efficient sound absorbing materials

- Additive manufacturing techniques such as 3D printing will allow us 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. A granular material is composed of discrete particles, which 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]. A recent analytical model requires eight parameters to characterise the acoustical properties of a layer of porous material.

Far simpler pore structures, for example using inclined slits, can be designed to have useful acoustical properties. The only parameters involved are slit width, spacing, inclination to the surface and standard deviation of slit width distribution [Attenborough, 2018].

Figure 1 shows that the ‘target’ normal incidence absorption coefficient spectrum of a 2 cm thick layer of polymer foam (continuous black line) can be achieved with a slightly thinner (1.9 mm thick) rigid-framed layer with 0.08 mm wide slit pores inclined at 42° to the surface (broken blue line). An even lower frequency peak absorption (dash-dot brown line) can be obtained using a log-normal distribution of slit pore widths (mean width 0.036 mm) inclined at 40°.

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].

Other possibilities involve pore non-uniformity, insertion of partitions within the material [Attenborough 2019] and additional dissipation mechanisms if the frame is elastic.

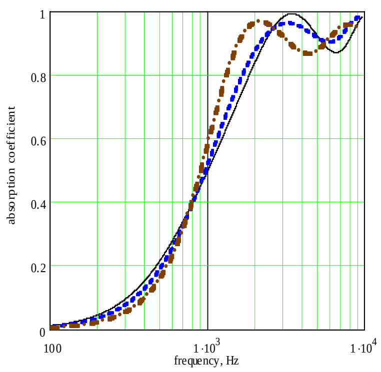

Figure 1 Target absorption spectrum (continuous line - porosity 0.95, flow resistivity 40 kPa s m^{-2}, viscous characteristic length 50 μm, thermal characteristic length 150 μm, tortuosity 1.3, layer thickness 0.02 m) compared with spectra predicted for 1.9 cm layer of identical slit pores (broken blue line- slit width 80 μm, inclined at 40° to the normal) and 2 cm thick layer log-normal distribution of slits with mean width 36 μm (dash-dot brown line).

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.

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, the proof of concept will be achieved by manufacturing samples with scaled-up microstructures. These will result in target acoustical properties that are scaled down in frequency i.e. 10 to 1 scaling of the dimensions used in producing Fig.1 would produce absorption peaks near 200 Hz.

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 absorbing plates based on these analyses; further measurements based on these new designs.

Write up.

Further reading:

C. Perrot *et al* J. APPL. PHYSICS 111, 014911 (2012)

K. Horoshenkov et al J. Acoust. Soc. Am. **139** 2463 (2016)

P. Leclaire et al J. Acoust. Soc. Am. **134** 1772-1782. (2015)

Fee *et al* Journal of Chromatography A, 1333 18–24 (2014)

K. Attenborough**,** APPL. ACOUST**.** 130, 188-194 (2018)

K. Attenborough, APPL. ACOUST. 145, 349–357 (2019)

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
- An Open University application form, downloadable from: http://www.open.ac.uk/postgraduate/research-degrees/how-to-apply/mphil-and-phd-application-process (Note: This is an Advertised studentship and you do not need to submit a proposal).
- IELTs English Language test scores on application. An average of 6.5 and no less than 6 in anyone of the four components. Applicant should have these results when applying.

Applications should be sent to STEM-EI-Research@open.ac.uk by 28 February 2019