Engineering and Innovation Research Studentship 2024/2025

Project title:	**Application of innovative aperiodic metamaterials to reimagine podiatric orthotics**
Discipline	Computational design and manufacture
Key words:	Additive manufacturing, haptic response, cellular solids
Supervisory team:	Iestyn Jowers, Richard Moat
URL for lead supervisor's OU profile	https://www.open.ac.uk/people/irj29

Project Highlights:

- Investigate solutions to improve the lives of children who suffer from a debilitating disease
- Design, model and test metamaterials to meet identified performance requirements
- Engage with national faculties to observe mechanical behaviour in real-time
- Present results at international conferences

Overview:

Calcaneal Apophysitis (aka Sever's disease) is a debilitating medical condition that impacts the lives of children worldwide, due to the presentation of heel pain that inhibits physical activity [1]. A common approach to limit the impact of symptoms is to prescribe the use of orthotics, insoles to be used in patients' shoes (see Figure 1). Studies, e.g. [2], suggest that custom made orthotics are more effective than off-the-shelf solutions, but these are more costly to produce and typically only last up to 6 months, due to interference stresses between different layers of materials and between the shoe and insole. This project is concerned with the application of a new type of metamaterial to the problem of producing longer-lasting cost-effective custom-made orthotics, with the aim to improve the mobility, and thereby the health and wellbeing, of affected children.

Figure 1. Example of a foot orthosis, from [2]

Developments in additive manufacturing (aka 3D printing) have made it possible to manufacture metamaterials designed for performance. This opens opportunities to create materials that are optimised for their application. In this project the focus is on honeycombs [3], cellular metamaterials defined by a two-dimensional structure expanded into the third dimension, as shown in Figure 2. Cellular materials offer significant mechanical benefits, with material in place to carry necessary forces but empty space elsewhere, resulting in desirable material to weight ratio, as well as high specific stiffness and energy absorption. In particular, the project will explore applications of honeycombs based on the recently discovered 'hat' tiling [4], that has been shown to give rise to structures that exhibit zero Poisson's ratio, a metric that characterises the deformation behaviour of materials according to their orthogonal response to applied force. This secondary deformation is usually visually apparent as a sideways bulge, and can limit the longevity of multi-material components, because of the interference shear stresses that arise between different materials.

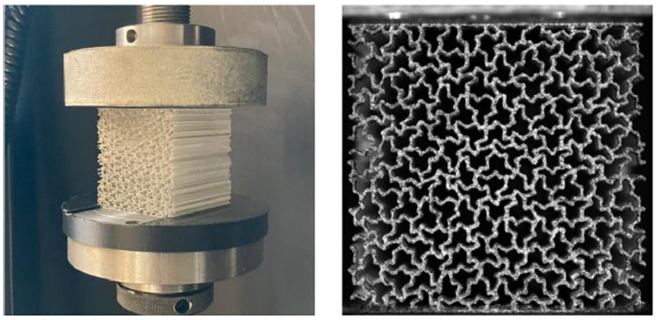

Figure 2. Mechanical testing of a honeycomb, from [4]

This project is a systematic exploration of how honeycombs based on the 'hat' tiling can be employed in producing custom orthotics, to improve the lives of children who suffer from Sever's disease. The supervision team brings together multidisciplinary expertise from computational design and material science. We will support an investigation that:

- elicits requirements for orthotics that alleviate the symptoms of Sever’s disease
- identifies methods to design metamaterials that meet these requirements
- validates the outcome by producing working prototypes, via additive manufacturing and synchrotron and neutron tomographic imaging

Methodology:

To explore the first aim, the research will be supported by a practicing NHS podiatrist, who will provide case studies and expertise. The case studies will be analysed to identify the key parameters for custom made orthotics, which will be formalised in a simulation model. This will inform research into the second aim, where honeycomb structures based on the ’hat’ tiling will be investigated. Different patients will require different combinations of stiffness and energy absorption to different parts of the foot, and the simulation model will be used to develop blended honeycomb structures that give the necessary behaviour. Finally, the research will be validated by identifying appropriate additive manufacturing methods and parameters that will make it possible to physically realise the orthotics in appropriate materials. There will be opportunities to use advanced x-ray and neutron sources at UK national faculties to observe in-situ the behaviour of the resulting orthotics during simulate use.

References & Further reading:

1. Fares et al. (2021) Sever's Disease of the Pediatric Population: Clinical, Pathologic, and Therapeutic Considerations. Clin. Med. Res. 19(3):132-137
2. Alfaro-Santafé et al. (2021) Effectiveness of Custom-Made Foot Orthoses vs. Heel-Lifts in Children with Calcaneal Apophysitis (Sever’s Disease): A CONSORT-Compliant Randomized Trial. Children 8, 963
3. Clarke et al. (2023) A systematic numerical and experimental study into the mechanical properties of five honeycombs, Compos. Part B-Eng. 264, 110895
4. Clarke et al. (2023) An isotropic zero Poisson's ratio metamaterial based on the aperiodic ‘hat’ monotile. Appl. Mat. Tod. 35, 101959

Further details:

Applicants should have experience in programming and enthusiasm for manufacturing technology and/or materials science. Experience of mathematics and/or human-centred design is desirable.

The student will join a well-established team researching engineering design and manufacturing at the Open University, with a track record in this area (see references [3, 4]).

Applications should include:

- A 1000 word cover letter outlining why the project is of interest to you and how your skills match those required
- an academic CV containing contact details of three 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
- IELTS test scores where English is an additional language

Applications should be sent to **STEM-EI-PhD@open.ac.uk** **by 16.02.2024**