# Engineering and Innovation Research Studentship 2024/2025

| Project title: | Aperiodic honeycombs for morphing wing applications |
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| Discipline | Computational mechanics, materials engineering, engineering design |
| Key words: | Additive manufacturing, cellular solids, finite element analysis |
| Supervisory team: | HK kim, Richard Moat, Iestyn Jowers, |
| URL for lead supervisor's OU profile | https://www.open.ac.uk/people/hkk43 |

## Project Highlights:

- Investigate applications of novel aperiodic composites in aerospace application
- Design, model and test metamaterials to meet identified performance requirements
- Design and create bespoke finite element based code for non-periodic materials
- Present results at international conferences

## Overview:

The creation of a wing or other aerodynamic device that can morph to alter its aerodynamic performance without the need for moving parts is long sought-after (see figure 1)[1]. A key limiting factor in many existing designs lies in the materials available. With most existing materials, when the device morphs in one direction, there is a corresponding change in shape in another directions caused by the Poisson's effect. This issue can be resolved using a material with Poisson's ratio close to zero, a mechanical property that is exceptionally rare [2].

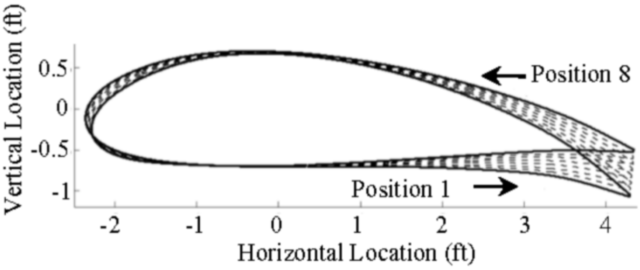

Figure 1. schematic of the deformations desired in a morphing wing design [1]

Developments in additive manufacturing (aka 3D printing) have made it possible to manufacture metamaterials designed for performance, including tailored Poisson's ratio. 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 for aerospace applications, with material in place to carry necessary forces but empty space elsewhere, resulting in desirable material to weight ratio. In recent work [4] cellular materials made using topologies based on the mathematics of aperiodic order have been shown to give unprecedented flexibility in tailoring Poisson's ratio. This project will explore applications of honeycombs based on the recently discovered 'hat' tiling [5], that has been shown to give rise to structures that exhibit zero Poisson's ratio, the key design criterion for morphing wing structures.

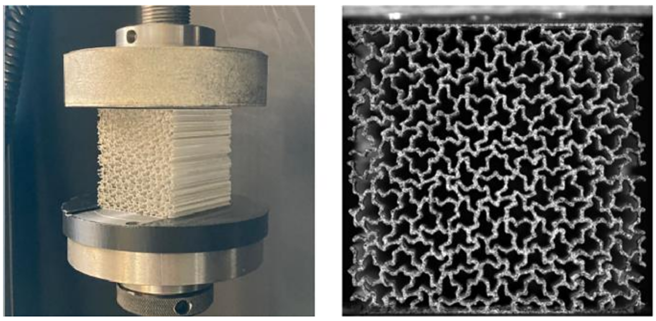
Figure 2. Mechanical testing of a honeycomb, from [5]

This project is a systematic exploration of how aperiodic honeycombs, in particular those based on the 'hat' tiling, can be employed in a morphing wing structure, which ultimately will enable more efficient and safer aircraft. This will involve the following aims:

- Identifying an appropriate morphing wing design to implement aperiodic honeycombs
- Implement non-linear deformation into existing linear elastic finite element code for aperiodic materials
- Systematic surveys of material performance using the newly designed finite element code
- Validation of findings via modelling and testing

## Methodology:

The aims of this project will be achieved through a combination of finite element simulation and in-situ mechanical testing. Literature surveys and case studies will inform the choice of a viable morphing wing design applicable to the application of aperiodic composites. In order to determine the optimal honeycomb design, surveys of the non-linear mechanical performance of a wide variety of 'hat' based aperiodic topologies will be necessary and thus require the development of non-linear functionality into our existing aperiodic FE code. Finally, example structures will be created in CAD, manufactured using additive manufacturing and their performance validated using both traditional finite element simulation and in-situ digital image correlation.

## References & Further reading:


1. Zhao, K., Schmiedeler, J.P., & Murray, A.P. (2012). Design of Planar, Shape-Changing Rigid-Body Mechanisms for Morphing Aircraft Wings. Journal of Mechanisms and Robotics, 4, 041007.
2. Puttmann, J. et al. (2012) 'Design of a Morphing Skin by Optimizing a Honeycomb Structure With a Two-Phase Material Infill', in Volume 1: Development and Characterization of Multifunctional Materials; Modeling, Simulation and Control of Adaptive Systems; Structural Health Monitoring. ASME, pp. 169–175.
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. Imediegwu, C., et al. (2023) Mechanical characterisation of novel aperiodic lattice structures, Mat. Des. 229, 1119
5. 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 finite element analysis and be confident writing extensive code in python. They should also have an enthusiasm for manufacturing technology and/or materials science. Experience of mathematics and CAD is also 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 [3-5]).

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**