E&I Research Studentship project proposal 2019

Project title: Design and validation of 3D printed aperiodic cellular structures

Supervision Team:
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Project Highlights:

- Explore cutting edge research into 3D printing and new geometries
- Validate mathematical theory through design and experimentation
- Present results at international conferences

Project Description:

Developments in additive manufacturing (aka 3D printing) have made it possible to manufacture components designed for performance. The inclusion of internal cellular structures in a component puts material in place to carry necessary forces but leaves empty space elsewhere. Figure 1 shows an example of an internal structure, based on a tetrahedral grid, which is used to improve the strength of a component while reducing its mass due to the amount of material used. We anticipate that cellular structures with aperiodic order will offer further improvements in mechanical performance, and will be of interest in areas such as aerospace, medical engineering, and product design.

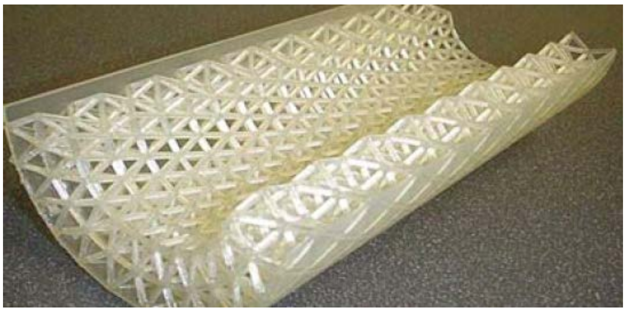

***Figure 1:** example of an internal cellular structure*

Aperiodic crystallographic structures are ordered but are not symmetric under translation. They form a relatively new field of inquiry, and recent discoveries have fundamentally changed our understanding of the mathematics of crystallography and its applications in materials science. The study of aperiodic order has introduced new tilings of space that were previously unimagined, and the subsequent discovery in the 1980s of quasicrystals – material structures that exhibit aperiodic order – has led to explorations of the remarkable mechanical properties of materials that arise from these tiling structures. To date, research on aperiodic structures has mostly been about either the macroscopic scale, e.g. about tilings of space like the famous Penrose tiles, or the microscopic scale, e.g. about arrangements of atoms in quasicrystals. This project is an investigation of aperiodic structures at an intermediate mesoscopic scale, with the aim to incorporate these as internal cellular structures in high-value components, e.g. Figure 1.

The supervision team brings together multidisciplinary expertise from mathematics, design, and material science. We will support an investigation into methods for generating and manufacturing structures based on aperiodic order according to external shape constraints, with an aim to demonstrate the mechanical advantage of aperiodic structures. These aims align with the following hypotheses:

1. Methods of generative design and additive manufacture can be used to create aperiodic structures according to geometric constraints
2. Aperiodic cellular structures will have improved mechanical properties compared to periodic or stochastic structures, and will open new possibilities in design and manufacturing

Research Methods:

To explore the first hypothesis, the research will investigate algorithms for generating aperiodic frameworks, and address key problems, including creating geometric data models suitable for analysis and manufacturing; matching boundaries to required surface shapes; and ensuring rigidity of the structures.

Successful validation of the first hypothesis is critical for addressing the second, but we are confident that methods for generating and manufacturing aperiodic structures can be found. Uncertainty lies in how efficient these methods can be in terms of autonomy and speed, and how much human intervention is necessary. In particular, autonomously transforming and scaling generated structures to fit specified boundary geometries will be a major challenge.

To explore the second hypothesis, the research will involve physical testing of manufactured components. This will enable comparison of the mechanical properties of foams, periodic and aperiodic structures. Analytical models will be constructed based on existing models, and will be applied to predict general properties. But, the complex geometry of the new structures and the uncertainty about resulting material properties mean that the validity of these models will be questioned.

Further details:

Applicants should have a strong background in mathematics and enthusiasm for manufacturing technology. Experience of programming is desirable. The student will join a well-established team researching engineering design and manufacturing at the Open University.

Further reading:

Baake M, Grimm U (2012) Mathematical diffraction of aperiodic structures, Chemical Society Reviews, 41: 6821-6841

Rosen DW (2007) Computer Aided Design for Additive Manufacturing of Cellular Structures. Computer Aided Design & Applications, 4(5): 585-594

Torres-Sanchez C, Corney JR (2011) A novel manufacturing strategy for bio-inspired cellular structures. International Journal of Design Engineering, 4(1): 5-22

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 **2**8 February 2019