School of Mathematics and Statistics

Faculty of Science, Technology, Engineering and Mathematics

2018 PhD Projects

Project title	Design and validation of 3D printed aperiodic cellular structures
Principal supervisor	Uwe Grimm
Second supervisor	Iestyn Jowers, Richard Moat
Discipline	Applied mathematics
Research area/keywords	Aperiodic Order, cellular structures, 3d printing
Suitable for	Full time or part time applicants

Project background and 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.

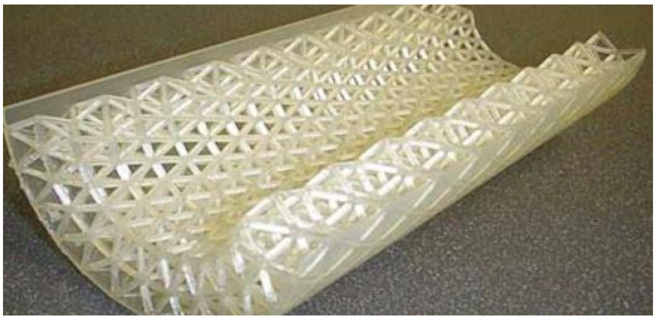

Figure 1: Example of an internal cellular structure

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 has an interdisiplinary nature, and will be supervised in collaboration with colleagues in the School of Engineering and Innovation. It involves an investigation of aperiodic structures at an intermediate mesoscopic scale, with the aim to incorporate these as internal cellular structures in high-value components. 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.

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

Background reading/references

- Baake M, Damanik D, Grimm, U (2016). What is Aperiodic Order? *Notices of the AMS* **63**, 647-650; arXiv:1512.05104.
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- Rosen DW (2007). Computer Aided Design for Additive Manufacturing of Cellular Structures. *Computer Aided Design & Applications* **4**, 585–594.
- Torres-Sanchez C, Corney JR (2011). A novel manufacturing strategy for bio-inspired cellular structures. *International Journal of Design Engineering* **4**, 5–22.