University of Bristol
Bristol Composites Institute (ACCIS)

ACCIS – Advanced Composites Collaboration for Innovation & Science
UKRI Engineering and Physical Sciences Research Council
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Catapult Offshore Renewable Energy

Topological Optimization of Large, Additively Manufactured Composite Structures with a Graded Lattice Core

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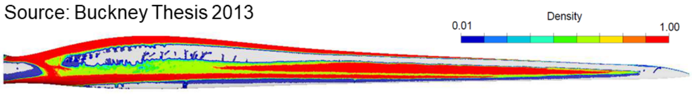
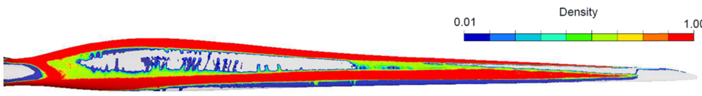
Large structures require strong and stiff components to resist the primary loads imposed upon them. For instance, unidirectional carbon fibre composites are used in many large structural applications. Additively manufactured short fibre composites cannot be used to replace these components, however their value lies in providing the opportunity to combine traditional composite laminates with high-performance graded lattice architectures, which, in synergy, will provide improved structural performance and manufacturability. To design these large structures, modified SIMP density-based topology optimisation is an ideal tool to produce solutions where the solid regions represent the irreplaceable composite laminates and the graded regions represent the cellular lattice architectures. 3-dimensional topology optimisation solutions are used to demonstrate this concept on a simple composite beam, similar to a sandwich panel design. This proof-of-concept directs further study of the topic.

Background

Source: Buckney Thesis 2013



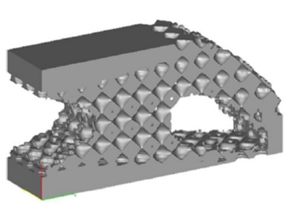
Minimum Compliance, Volume Constraint = 12.5%



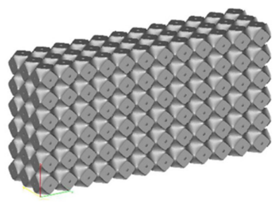
Minimum Volume, Stress Constraint = 0.4% strain

Topology optimisation has been proven as a design method by solutions providing features which are now commonplace in wind blade design

Source: Strategies for functionally graded lattice structures derived using topology optimisation for additive manufacturing - Panesar et al. 2017



Graded Lattice, $V_f = 0.5$, $V_e = 0/(0.3\text{-}0.85)/1$

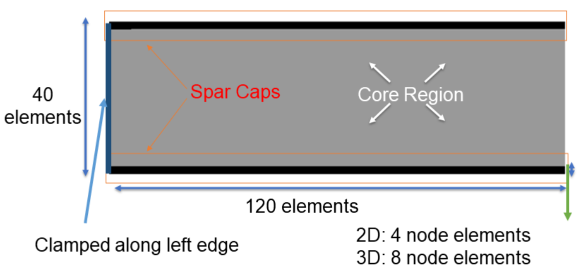


Uniform Lattice, $V_f = 0.5$, $V_e = 0.5$

Converting density distributions from topology optimisation solutions into an additively manufacturable self-supporting graded lattice improves compliance by 50% over a uniform lattice of the same volume fraction

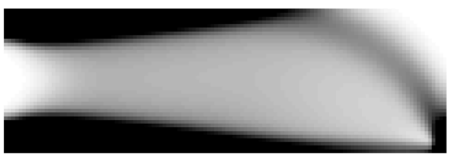
Topology Optimisation Study

Initial research involved optimising a sandwich panel type design, with the spar caps made from variable thickness laminates and the core region representing a graded lattice based on the density of the solutions. A cantilever beam problem was imposed and the optimal distribution of material was found.

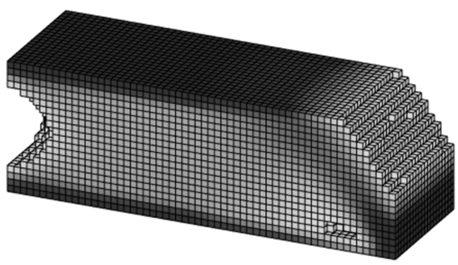


The spar cap regions were given an isotropic stiffness property 10x that of the core region. Penalisation factor (p) and volume fraction was varied.

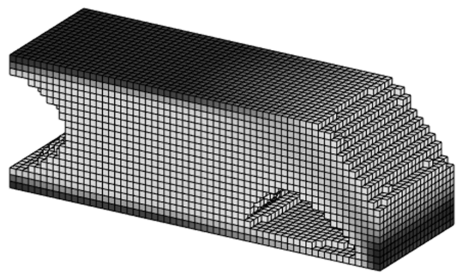
2D Solution, p = 1



2DSolution, p = 3



3D Solution, $V_f = 0.5$



3D Solution, $V_f = 0.25$