VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Yifan Zhu**

The public defense will take place on **Wednesday 2nd July 2025 at 11:30am** in room **D.2.01** (Building D, VUB Main Campus)

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DESIGN AND ANALYSIS OF ADDITIVELY MANUFACTURED MECHANICAL METAMATERIALS

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Abstract of the PhD research

Architected metamaterials are ubiquitous in nature, as seen in the microstructure of bamboo, the nacre structure of seashells, and the club of the mantis shrimp. Advances in additive manufacturing have enabled the fabrication of such complex geometries for engineering applications. However, despite extensive research, traditional cellular material designs remain dominant, and the full potential of mechanical metamaterials has yet to be realised. This thesis develops novel metamaterials that improve performance and manufacturability across three categories: lattice, origami, and honeycomb.

For lattice structures, a perforated plate lattice was introduced to enable fabrication using powder- or liquid-based additive manufacturing. An original spherical shell lattice was also developed, progressing from using conventional straight or flat constituent members. Additionally, isotropic lattice structures were adopted as sandwich cores and a new stiffness optimisation scheme was proposed.

In origami metamaterials, a new creaseless herringbone buckling pattern origami was created, differing from traditional ones featuring straight-folds. This was integrated into a sandwich core and compared with the Miura configuration. Furthermore, three design strategies were employed to tune bending performance.

For honeycomb structures, inspiration from the leaf folding strategy of *Rhapis excelsa* led to a meta-honeycomb made with corrugated plates, which was conceptualised, manufactured, and validated, demonstrating superior mechanical performance.

Beyond introducing novel designs, this thesis addresses fabrication challenges and explores the adoption of these metamaterials for programmable mechanical properties. The findings highlight their potential contributions to aerospace, biomedical, and sports industries through lightweighting and enhanced mechanical performance.