Triply Periodic Minimal Surfaces (TPMS) for Additive Manufacturing of High-Performance Beams

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Abstract

Triply periodic minimal surfaces (TPMS) are mathematical surfaces characterised by having zero mean curvature in every point (1), favouring optimal material distribution with exceptional mechanical performance (2). These geometries are extensively studied for their applications in biomedical engineering, particularly in prosthetic devices and osseous scaffolds (3). Their porous structures not only mimic the mechanical properties of bone but also promote stress transfer and minimise stress shielding effects, making them ideal for load-bearing applications.
First TPMS were discovered and studied in the second part of the twentieth century, but their realization was impossible until the rise of additive manufacturing.

This study relies on TPMS geometries to design and fabricate beams with enhanced mechanical performance and material efficiency (4). The design is developed using computational models, followed by experimental testing on samples fabricated with additive manufacturing techniques to ensure validation.

The realization of beams with superior properties compared to conventional designs is achieved by tuning the density of the TPMS structures throughout the beam or by a gradual transition between different TPMS geometries. Both approaches are dependent on load and boundary conditions. (5)

This study shows how TPMS can revolutionize structural design by combining advanced manufacturing methods with bio-inspired concepts. This work contributes to the development of sustainable and high-performance systems, creating opportunities for future innovations.

References

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