20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

Geometric and shell-based finite element analyses of thin-walled Triply Periodic Minimal Surface (TPMS) structures

Abbas Jafari[1], Martinus P. Widjaja[2], Eleni Chatzi[3], Jörg F. Unger[4]

[1] German Federal Institute for Material Research and Testing (BAM), Germany. abbas.jafari@bam.de
[2] German Federal Institute for Material Research and Testing (BAM), Germany. martinus-putra.widjaja@bam.de
[3] Institute of Structural Engineering (IBK), Switzerland. chatzi@ibk.baug.ethz.ch
[4] German Federal Institute for Material Research and Testing (BAM), Germany. joerg.unger@bam.de

Paper ID: 59
Symposium S4: Mechanics of architected materials: Experiments and modelling
Extended Abstract

Abstract

Meta-materials with intricate geometric features enable tunable (macroscopic) mechanical properties, unlocking applications across engineering, biomedicine and further domains. However, the manufacturing process of these architected materials tends to introduce geometric imperfections in real objects and components. Geometric deviations from perfect (nominal) geometry impact the desired mechanical behavior of manufactured parts, which is typically estimated by means of physics-based simulators that assume idealized geometry. Investigating the real geometry of meta-materials is therefore essential for their reliable functionality and enhancing their digital models [2, 1]. This study introduces a procedure for quantitative geometric analysis of thin-walled Triply Periodic Minimal Surface (TPMS) structures, in particular, of Gyroid type. The sensitivity of solid-based Finite Element (FE) analysis to geometric imperfections motivates the incorporation of geometric details of as-printed objects into FE simulations. A parameterization of geometric variability and deviations in real thin-walled meta-materials is proposed using two key geometric features: “mid-surface position” and “wall thickness”. These features initially provide quantitative metrics that enable a direct comparison between real and nominal geometries. Secondly, these parameterized features can be directly embedded into shell-based FE models, thereby enhancing their ability to

represent the as-manufactured geometry. Such shell-based FE models require significantly lower computational cost compared to solid-based FE models, while allowing an efficient, surrogate means for incorporating real geometric details. The proposed procedure for estimating the aforementioned geometric parameters uses the Signed Distance Field computed for contour meshes that are extracted from computer tomography (CT) images. This process is demonstrated using real printed specimens, followed by an illustration of the influence of incorporating the estimated geometric features into FE simulations.

Keywords:

Triply periodic minimal surface (TPMS) Shell-based finite element model Thickness variation Mid-surface

References:

[1] X. Cao, H. Yang, X. Ren, W. Wu, L. Xi, Y. Li, and D.Fang. Mechanical performance and defect analysis of theimperfect micro smooth gyroid cylinder shell structure.https://doi.org/10.1016/j.compstruct.2021.114320, publishedin Composite Structures, Volume 273, Article 114320, 2021.

[2] B. Lozanovski, M. Leary, P. Tran, D. Shidid, M. Qian,P. Choong, and M. Brandt. Computational modelling of strutdefects in slm manufactured lattice structures.https://doi.org/10.1016/j.matdes.2019.107671, published inMaterials & Design, Volume 171, Article 107671, 2019.