Paper ID: 72435
oral

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Smart Materials and Adaptive Structures (9)

Author: Mr. Christian Waldvogel
Switzerland

Mr. Dániel Salamon
Switzerland
Ms. Lea Fritschi
Switzerland
Dr. Leopold Summerer
European Space Agency (ESA), The Netherlands
Dr. ralph bärtschi
Switzerland

ADAPTIVE DENSITY MINIMAL SURFACES: A NEW METHOD FOR THE DESIGN OF HIGH-PERFORMANCE MULTI-FUNCTIONAL 3D-PRINTED SPACE COMPONENTS.

Abstract

The design freedom and manufacturing possibilities that arise with the adoption of Additive Manufacturing (AM) call for new approaches to the functional scope of single-build, integrated components. Parts designed for AM often contain filigrane lattice infills optimized rather for printability than for mechanical performance; and so they remain largely absent from FEM simulations due to software and computing issues. As the need to construct adhering to design guidelines of a chosen AM process further adds to these pains, the full utilization of the advantages at hand remains largely elusive.

To this end, we used our discovery of an infinite family of freely configurable, aperiodic minimal surface approximations (*Adaptive Density Minimal Surfaces* ADMS) to develop an *autonomous design* system for AM. It allows for the creation of versatile, additively manufactured components that simultaneously fulfill a multitude of requirements while providing exceptional stability using minimal material, and fast, printer-friendly, energy-efficient manufacturing.

Allowing for material-efficient support-free printing, print paths without self-intersections, free print orientation, simple powder evacuation, and minimal post-treatment, ADMS are inherently ideal for AM. Furthermore, ADMS generation is optimized for each case and fully simulation-driven, with very high fidelity between simulation and mechanical test. Geometric requirements along several instances of multi-physics boundary conditions are simultaneously satisfied, stress efficiently diffused during both manufacture and mission, with stress concentrations avoided. ADMS consist of a maximised smooth surface separating two interwoven channels, which may double as heat exchanger, insulation, or two-component storage. Elasticity, vibration damping and shock absorption can be controlled.

To quantify the suitability of ADMS for space components, an Early Technology Development Activity was conducted in the scope of the ESA OSIP programme. Based on previous and concurrent work (bioresorbable ceramic medical implants, structural heat exchangers, and internally cooled injection moulds), as well as inputs from ESA, a satellite interface bracket based on an existing specification was chosen as a testbed. We designed and manufactured a Titanium part (industry-standard, Ti-6Al-4V) and an Aluminium variant (Al-Si10-Mg, preferable due to its favourable de-orbit characteristics).

Simulations show that our components fulfill all requirements. Comparisons with components from other design methods like lattice structures or topology optimization show a significant reduction of mass and production cost for the ADMS part. The results of the mechanical tests will be received in July 2022.