Design and Manufacturing of Hierarchical Multi-Functional Materials Via High Resolution additive Manufacturing

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Academic Abstract

This master's thesis deals with the coefficient of thermal expansion of 1st and 2nd order unit cells and the improvement of the multi-material printer. The first step is to compute the theoretical thermal expansion of a multi-material 1st and 2nd order octet-truss by using different ratios between the material with high and low thermal expansion and by changing the skew angle. Afterwards, the as base material used resins are investigated with regards to their coefficient of thermal expansion to get a selection of materials with high and low thermal expansion for assigning them to the tested samples.

Thermal expansion tests of multi-material unit cells of 1st and 2nd order octet-truss with a high ratio of the coefficient of thermal expansion and various skew angles are conducted to proof the analytic prediction for achieving a negative volumetric coefficient of thermal expansion.

After a series of thermal expansion tests for the octet-truss, the literature was reviewed to check other unit cells regarding their potential to shrink by assigning them materials with different coefficient of thermal expansion. Modified versions of the dodecahedron and the – here called – quatraeder are promising in this case and further investigated. Especially the latter one is analyzed at its second hierarchical order and offers an even more negative volumetric coefficient of thermal expansion than the octet-truss.

Moreover, the home-made prototype of a multi-material printer is analyzed regarding its reliability and use of resources. Actions like a list of requirements and the creation of a morphologic box are taken to find a suitable solution to improve the current system. By creating three different concepts of the morphological matrix, the concepts are rated and the best one is chosen to be implemented. The implementation of the measures that led to a proper working printer include a revision of the setup, the recoating, as well as the washing and drying process. Furthermore, the design is reconsidered and redesigned for both faster and easier execution of changes. In this way a reduction in the use of resources, the avoidance of contamination, and the increase of reliability is assured.

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General Audience Abstract

This master's thesis deals with the challenges of undesirable thermal expansion in lightweight materials. Under thermal load parts or components usually expand and this can lead to malfunction or breakdowns. To encounter this issue of the undesired expansion this work investigates a class of lightweight materials of which the thermal expansion coefficient can be controlled. Moreover, an additive manufacturing approach to produce these thermal management materials with high fidelity and reliability are critical to reach this goal.

To achieve these two major research objectives analytic predictions, simulations, and measurement of thermal expansion coefficient with respect to temperature changes are conducted. Design and optimization of a high precision multi-material manufacturing apparatus has been conducted, leading to significant increase in production quality including reliability, efficiency, and costs.

Research Project

The research project presented in this Master's Thesis aims to demonstrate the potential of a tunable coefficient of thermal expansion (CTE) and the improvement of the multi-material printer regarding reliability and efficiency. It is a joint research project between the Department of Computer Integrated Design (DiK) at Technische Universität Darmstadt (TUD) and the Additive Manufacturing Lab at Virginia Polytechnic Institute and State University (VT), also known as Virginia Tech. The research project was advised by Prof. Dr. Xiaoyu (Rayne) Zheng (VT) and by Prof. Dr.-Ing. Reiner Anderl (TUD).

The research project was carried out according to the requirements for the Dual Degree Master Program between Technische Universität Darmstadt and Virginia Polytechnic Institute and State University. The published version of the master's thesis can be found via Universitäts- und Landesbibliothek Darmstadt:

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