Paper ID: 95108
oral
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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Smart Materials and Adaptive Structures & Specialized Technologies, Including Nanotechnology (9)

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SPACE APPLICATION OF A MECHANICAL METAMATERIAL FABRICATED VIA BI-METALLIC ADDITIVE MANUFACTURING FOR DIMENSIONAL STABILITY

Abstract

The inherent thermal expansion of materials can be detrimental to satellite instruments that require high dimensional stability. When the satellite is subjected to temperature variations, this stability can be achieved by two methods: (1) active stabilization, with heating and cooling elements, and (2) passive stabilization, with thermoelastic metamaterials. Due to recent advances in the Additive Manufacturing field, there are now technologies that allow a 3D metal multi-material metamaterial for space applications to be designed and built. Metamaterials with a tunable coefficient of thermal expansion (CTE) are achievable by combining two materials in a specific lattice structure. In this work, metamaterials with negative and very positive CTE made out of an Invar + IN718 combination were printed in a PBF-LB machine equipped with a multi-material Schaeffler Aerosint recoater. These will be applied in an actuator for an experiment in a research satellite mission called SeRANIS. The actuator will operate as both passive and active stabilizer: the first concept is fulfilled by the inherent thermal expansion behavior of the metamaterial; and the latter, by attaching heating elements to specific parts of the metamaterial structure to intensify its behavior when necessary. The CTE of the metamaterials measured by dilatometry and digital image correlation match with prior FEM simulations. A combination of positive and negative CTE unit cells shows promising results to achieve a constant CTE along a wide temperature range. Single material tensile tests specimens resulted in similar values as in the literature and the multi-material specimens did not fail at the materials' interface, implying a good bonding between Invar and IN718. Shaker and thermal fatigue tests indicate that the metamaterial actuator is resistant to mechanical and thermal loads during launch and in orbit. The understanding of the thermal expansion behavior of the metamaterial is useful to predict and compensate possible deformations caused by temperature variations in orbit. The results show that the concept is a viable mechanism for dimensional stabilization of thermally cycled satellite structures.