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Author: Mr. Stefano Piacquadio
RWTH Aachen University, Germany, stefano.piacquadio@sla.rwth-aachen.de

Mr. Tobias Meinert
RWTH Aachen University, Germany, tobias.meinert@sla.rwth-aachen.de
Mr. Maximilian Schirp-Schoenen
RWTH Aachen University, Germany, maximilian.schirp-schoenen@rwth-aachen.de
Mr. Jannik Bühring
RWTH Aachen University, Germany, jannik.buehring@sla.rwth-aachen.de
Prof. Kai-Uwe Schröder
RWTH Aachen University, Germany, kai-uwe.schroeder@sla.rwth-aachen.de

LIGHTWEIGHT POTENTIAL OF ADDITIVELY MANUFACTURED METALLIC THERMAL PROTECTION SYSTEMS EMPLOYING LATTICE CORE SANDWICH STRUCTURES WITH INTEGRATED PHASE CHANGE MATERIALS

Abstract

Increasing efforts are continuously dedicated to improving the performance of Thermal Protection System (TPS). The so-called Integrated TPS (ITPS) was conceptualised to improve the mechanical stability of passive TPS for re-entry vehicles. In this perspective, a concept aimed at the realisation of load-carrying metallic TPS with an embedded Phase Change Material (PCM) is proposed in this work. The intrinsically higher energy density of latent-heat absorption in comparison with the purely sensible one is particularly attractive in all applications where mass is a restricting factor. In the limited time during a re-entry phase, properly applied PCMs can absorb the thermal loads primarily via latent heat. Many PCMs for both room and high-temperature applications have low thermal conductivity. This leads to a slow expansion of the melting front, which causes high thermal gradients between the heat source and the melting front itself. While this is commonly an issue for other thermal control applications, it constitutes an advantage in the case of a re-entry. The embedding of a PCM in a well-conducting matrix, i.e. open-cell metal foam, has been demonstrated to raise the effective thermal conductivity. In this work instead, an alternative approach is followed. A PCM is embedded in matrices made of high temperature-low thermal conductivity alloys, i.e. Titanium or Inconel, realised with additive manufacturing. Such composites applied as structural sandwich cores show high effective specific heat capacities and therefore lower core thicknesses with respect to common ITPS solutions. This shall allow obtaining lighter panels with higher buckling critical loads. Additively manufactured lattice core sandwich structures show, with respect to foam cores, similar porosity, higher specific stiffness and higher specific strength. These properties make them better candidates in an application where mechanical loads shall be carried by the thermal device itself. Additionally, the realisation of a load-carrying sandwich panel with sealed surfaces for liquid PCM containment happens directly with the generation of the lattice core and doesn't require additional operations. Additively manufactured sandwiches show strong resistance to the delamination problems typical of other sorts of sandwich cores. In this work, numerical studies are performed to evaluate the best candidate PCMs and lattice core matrices combination under re-entry mechanical and thermal environments.