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DESIGN STUDY ON MULTI-LAYERED STAND-OFF THERMAL PROTECTION SYSTEM USING POROUS TITANIUM SANDWICH PANELS

Abstract

Metallic Thermal Protection Systems (TPS) are considered to be a promising thermal insulation system for future reusable launch vehicles (RLV) and hypersonic airplanes (HSA) because of its ductility, easy refurbishment and enhanced weather resistance. Compared to the RLV, the heat flux on the Mach 5 HSA is lower. However, the total heating time of the HSA is much longer (approximately two hours) and the HSA is exposed to high temperatures with shorter intervals (supposing four flights a day). The purpose of this study is to design a Multi-layered Stand-off TPS (MLS-TPS) using porous Titanium sandwich panels (PoTi) and to discuss its applicability to the Mach 5 HSA. The MLS-TPS is in a square shape and a heated surface panel is separated from the fuselage panel made of aluminum alloy using posts at each corner (Stand-off structure). The PoTi is inserted between the surface panel and the fuselage panel. Its very low density (0.3g/cm3) contributes to weight reduction. The skin panel and the posts are made of SiC fiber/ SiC matrix composites (SiC/SiC). The spacers are used to create a space between the panels and they are fastened to the fuselage and the PoTi. In order to reduce the heat flux from the posts to the fuselage, there are gaps between the PoTi and the posts. This is the unique concept of this study. At first, thermal insulation performances at the Mach 5 cruise condition were estimated using three-dimensional finite element method (Abaqus CAE) within the limit of 20kW/m2 surface heat flux. As a result, temperatures of the fuselage in a steady-state are far less than the heat-resistance temperature of the aluminum alloy. Next, a trial MLS-TPS unit structure was assembled and heating tests were carried out in vacuum using an IR ramp heating system. The purpose of this experiment is to verify the agreement with a FEA result which demonstrates the heating test environment. The analysis and the experiment results show good agreement, and the high performance potential of the MLS-TPS for HSA has been successfully demonstrated.