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Corresponding author: DI MARTINO Giuseppe
e-mail of corresponding author: giuseppe.dimartino@dlr.de
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Title
Flight Experiment of Transpiration Cooled Sharp Edge Fins on the Sounding Rocket HIFLIER1

Authors
Giuseppe DI MARTINO[*,1]*, Jonas Peichl*[1]*, Fabian Hufgard*[2]*, Christian Duernhofer*[2] *Stefan Loehle*[2]

** Corresponding author*
[1] *DLR Institute of Structures and Design, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany, Giuseppe.dimartino@dlr.de*
[2] *High Enthalpy Flow Diagnostics Group, Institute of Space Systems, University of Stuttgart Pfaffenwaldring 29, 70569 Stuttgart, Germany*

Abstract
The flight in hypersonic conditions implies important challenges for the vehicle development concerning especially the thermal protection of the external structures, which are exposed to the actual thermal loads. In the cases of sharp edges, like for example for wing leading edges, stabilizer fins and air intakes, the high heat loads become even more critical, because the strong shock cannot be detached from the surface as it is the case for blunt bodies.
Since the 1990s, lightweight ceramic matrix composites (CMC), such as C/C-SiC, are of fundamental importance as thermal protection systems due to their high temperature resistance and thermal characteristics. The FinEx experiment on the HiFire-5 flight experiment [1] proved the successful implementation of this material for stabilizer fin structures. However, additional active cooling of the structure could become necessary for flight at increasing Mach number or for longer operational time, i.e. for increasing integral thermal load. In this framework, one of the possibilities is represented by transpiration cooling, which consists in feeding a fluid coolant through a porous wall into the hot gas region, with the effect of directly cooling the wall itself and mixing into the boundary layer resulting in a lower convective heat flux [2,3].
In order to combine the application of CMC structures with the transpiration cooling technology, the DLR Institute of Structures and Design has worked in the past years in the development of a variant of the C/C-SiC CMC material with defined porosity level designed specifically for transpiration cooling applications, denominated OCTRA (Optimized Ceramic for Hypersonic Application with Transpiration Cooling) [4].
In order to test the mentioned technologies applied to stabilizing fins with sharp leading edge under real hypersonic flight conditions, the DLR Institute of Structures and Design is responsible to the design and construction of a sounding rocket module (so called FinEx II), which houses four identical fins, whose leading edges are made of the porous OCTRA material. Of them, one will remain uncooled as reference, while the other three will be subject to the transpiration cooling in different operating conditions during two separate phases of the trajectory, i.e. once during ascent and once during descent. The module will be hosted on the sounding rocket developed in the framework of the Hypersonic International Flight Research Experimentation (HIFLIER1), a project coordinated by the US Air Force Research Laboratory (AFRL) in collaboration with DLR's Mobile Rocket Base (MORABA) for the management of the flight mission campaign. The flight of the sounding rocket is scheduled in June 2023.
In the present paper, a general overview of the FinEx II module design will be presented. The design process is supported by numerical analyses for the estimation and verification of the fins thermo-structural behavior and for a first qualitative evaluation of the fluid dynamic effect of the transpiration cooling on the convective heat flux on the fins and the corresponding temperatures. Preliminary ground tests in collaboration with High Enthalpy Flow Diagnostics Group at the Institute of Space Systems of the University of Stuttgart for the calibration and verification of the experimental concept, from the characterization of the permeability of the fin leading edges to the calibration of the coolant gas

system operating conditions, will also be described. Finally, in the case of successful flight, some preliminary flight data will be presented.

References

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