SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
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SYSTEMATIC ASSESSMENT OF ADVANCED "SHARP-EDGED" LIFTING BODY RE-ENTRY CONFIGURATIONS

Abstract

Complex curved shapes in combination with close tolerances are significant cost drivers for the thermal protection system (TPS) of re-entry vehicles. A simple shaped, facetted geometry just formed by flat surface areas consisting of flat ceramic panels inter-connected by relatively sharp leading edges may reduce costs significantly without compromising aerodynamic performance. In contrary, avoiding the detachment of shocks could improve hypersonic aerothermodynamics. A major challenge of this unusual configuration is the high heat flux expected at the small radii "sharp" edges. However, these fluxes might be successfully addressed either by porous effusion cooled ceramics or by simple expendable and ablatable inserts.

DLR has successfully flown into the hypersonic regime a similar facetted test configuration called Shefex in 2005. The next research step is foreseen with a flight of Shefex II in the coming year at increased Mach number for another proof of the concept. A first potential future application of sharp-edged return vehicles has been proposed in [1].

The principal usefulness of the advanced, facetted, sharp-edged geometry is to be technically assessed in parallel for a typical re-entry configuration. This study is currently performed at DLR in a multi-disciplinary cooperation. The chosen approach ensures that system-requirements are the major design drivers instead of theoretical optimization focused on a single discipline. The DLR departments responsible for launcher system studies, hot structures and thermal protection, and of high-speed and re-entry aerothermodynamics are involved in this endeavour. Sophisticated simulation techniques are employed including Navier-Stokes CFD and TPS-sizing based on unsteady heat flux calculations in combination with trajectory simulation.

A generic re-entry vehicle with on-orbit and payload return capability in the 100 kg class is selected as the baseline concept. Different aerodynamic shapes are investigated in a flyable configuration taking into account the trim requirements of the vehicle's centre of gravity including a practical internal accommodation of subcomponents and payload. The sharp-edged configuration is numerically tested on how far deviating from conventional re-entry is acceptable. The calculated aerothermodynamic loads are used for the preliminary sizing of the ceramic TPS along the simulated flight trajectory, taking into account the underlying metallic structure. System masses and outer shape are adapted in an iterative approach in order to find a promising configuration with maximum cross range and within an overall acceptable thermal balance.

The paper further compares the most promising sharp-edged configurations with a conventional blunt re-entry capsule and with a non-winged lifting body type of similar size. The differences in mechanical and thermal loads, vehicle masses, aerodynamic efficiencies, and the achievable cross range capability of all these re-entry vehicles are outlined.

1. ESSMANN, O; SIEMER, M.; LONGO, J. M. A.; WEIHS, H.: REX – Free Flyer: A reusable orbital return vehicle for experiments under microgravity conditions, IAC-08-A2.5.08, 2008