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Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: REUSYS (several papers for ReFEx were submitted – a dedicated session would be great)
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Title

ReFEx: Reusability Flight Experiment - Aerothermodynamics

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Abstract

The Reusability Flight Experiment (ReFEx) is intended to demonstrate aerodynamic control in the return stages of its trajectory. This work presents a joint experimental and numerical study that was conducted for further insight into the aerothermal loads at various configurations relevant to the return stages. Experiments were conducted on a 1:4 subscale model with the intention to assist numerical re-building and specifically the prediction of flight vehicle heat loads. Such numerical models are foreseen to be of additional use during post-flight analyses.

Experiments were undertaken in the High Enthalpy Shock Tunnel Göttingen (HEG) at the German Aerospace Center (DLR). This is a free piston-driven shock tunnel originally commissioned for simulating flight-relevant reentry conditions. It has been used in various national, EU and international projects dealing with, amongst other subjects, reentry geometries. A subset of the conditions of the HEG were used in this work with a freestream unit Reynolds number of $6.4 \times 10^6\ m^{-1}$ and a mass-specific stagnation enthalpy of $3.0\ kJ/kg$.

Examination of multiple shock-shock and shockwave/boundary layer interactions (SWBLIs) affecting the aerothermal loads of ReFEx required systematic variation of the flight model geometry during the experimental campaign. The test model was adjusted to different angles of attack and its carnards were also adjustable. Furthermore, “belly-up” and “belly-down” configurations were also tested. These are relevant to the roll maneuver of ReFEx during its return trajectory.

Temperature-sensitive paint (TSP) was used to obtain heat-flux densities along the body surface. Thermocouples were used for in-situ calibrations of the insulating base layer, onto which the TSP was applied. Heat flux densities were then determined using a temporal integration of the temperature history and the calibrated base layer material properties. TSP layer thicknesses were on the order of 3 – 5 µm and the estimated uncertainty in heat flux derivations were 5%. The TSP layer signal-to-noise ratios were conducive to resolving shock-shock interactions and SWBLIs across multiple scales. Additionally, pressure transducers were installed in the nose of the model.

Together with the experiments, RANS computations carried out in the DLR TAU code were undertaken to validate existing models and grid resolutions used for the complex flow created around the ReFEx vehicle during return. Results from the computations will be discussed together with the experiments. Aspects to be considered include the bow shock formed at the nose of the model and its interaction with the carnards; the separation region upstream of the carnard mounting structure; and the gap flow between the carnard and its mounting structure.

References

[1] Bauer, W., et. al.: DLR Reusability Flight Experiment ReFEx, Acta Astronautica 168 (2020) 57–68, https://doi.org/10.1016/j.actaastro.2019.11.034