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Numerical Investigation of the Effects of Post-Combustion due to Fuel Outflow in Bleed Engine Cycles of a Retro Propulsion-Assisted Launch Vehicle

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Abstract
Reusable launch vehicles (RLV) have the potential to be a resource- and cost-efficient alternative to conventional space transport systems. Several first stages of RLVs are in the maturing process and the European long term strategy aims towards the development and characterization of RLV relevant technologies for their next generation of launchers. We are basing our studies on the EU funded Retro Propulsion Assisted Landing Technologies (RETALT) [1] project, which was formed with the goal of investigating Vertical Take-off Vertical Landing (VTVL) launch vehicles. In this paper, the first stage of the VTVL Two Stage to Orbit (TSTO) RETALT1 configuration will be used for the assessment of thermal loads during the flight trajectory. The mission plan for the first stage of the RETALT1-vehicle is to return either to the launch pad or a drone ship via a re-entry burn and a retro propulsion maneuver. During this retro propulsion phase high thermal loads are acting on the rocket structure and especially the landing legs, the base plate and the aerodynamic control surfaces. These thermal loads due to the main engine exhaust of the RLV have been characterized in previous studies by Laureti et al. [3].
Only little research has been devoted to the topic of post combustion due to the outflow of gas generators and air vents of cryogenic fuel tanks in VTVL-configurations in general. Owing to these secondary exhaust jets, unburned hydrogen is ejected near the high temperature outflow of the main engines, which could lead to a significant post combustion with the surrounding atmospheric oxygen and deviating thermal loads along the vital parts of the rocket structure. In order to provide an assessment of the additional influence of the post combustion and thermal loads, Computational Fluid Dynamics (CFD) simulations are carried out using the DLR-TAU code with the Reynolds Averaged Navier Stokes (RANS) method. As the post-combustion of the nozzle- and gasgenerator-outflow is to be observed, a reduced Jachimowsky mechanism [2] for a species mixture of the liquid hydrogen, liquid oxygen combustion mixture and ambient air is applied as chemistry model.
In this publication the validity of the computational mesh by means of a GCI-study and the influence of the turbulence modeling with different approaches is to be investigated. With these results first observations of the flow field characteristics and the thermal loads acting on the RLV will be done in order to identify the simulation parameters, including crucial points along the flight trajectory for investigations of the heat flux distribution across the surface structures of the vehicle.

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