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CFD BASED METHOD FOR MODELING CONVECTION WITHIN THERMAL SYSTEM ANALYSIS TOOLS FOR LAUNCHERS

Abstract

A method is outlined, which aims for deriving a kind of Surrogate Model (SM) for gas convection inside cavities to be used in a Lumped Parameter Thermal Mathematical Model (TMM) for thermal system analysis. E.g. the thermal behavior of the upper stage of the Ariane launcher during its lifetime from ground loading until the end of the mission is predicted with such a TMM. It is implemented in the European standard thermal analysis tool ESATAN-TMS. The method proposed makes use of standard ESATAN entities only, i.e. heat sources and linear conductors. It is deduced from two detailed Computational Fluid Dynamic (CFD) simulations, the so called COLD and HOT case. Traditionally or for preliminary design, Heat Transfer Coefficients (HTC) based on Nusselt number correlations may be employed instead. However, these HTCs show limited accuracy in particular inside technical relevant cavities of high geometric complexity and large temperature differences. In order to prove the benefit of the proposed method in comparison to the traditional HTC approach, a typical upper stage cavity between the liquid Oxygen tank and the liquid Hydrogen Tank with venting inlets and outlets as well as boxes and ribs is studied under thermal equilibrium conditions at the end of ground tank loading. Two different TMMs are built: one with the traditional HTC approach and one with the proposed SM. The TMM results are compared with the CFD simulations not only for the COLD and the HOT case but also for cases with thermal boundary conditions between the COLD and the HOT case (interpolated cases) and cases with thermal boundary conditions beyond the COLD and the HOT case (extrapolated cases). By definition the SM show zero deviation for the COLD and the HOT case, whereas the HTC approach lead to high temperature differences around the boxes and some 10% deviation for the heat flux into the propellants, as can be expected. For the interpolated and extrapolated cases studied, the SM show not more than half of the deviations of the HTC model. In conclusion, the proposed method is straightforward to apply and show superior behavior compared to the HTC approach for the cavity studied in both, accuracy and adaptability to a change of boundary conditions. An outlook is provided how this method may be applied to other applications as e.g. a SM for the prediction of the thermal stratification of cryogenic propellants inside launcher's tanks.