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Title

Numerical Framework for the Investigation of a Transpiration Cooled LOx/LH₂ Rocket Engine Combustion Chamber

Authors

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Abstract

Transpiration cooling using novel permeable materials like ceramic matrix composites is considered as an effective cooling method for coping with the high heat loads in modern rocket engine thrust chambers [1]. In order to assess the efficiency of transpiration cooling for a rocket engine application, a numerical study of a full-scale rocket thrust chamber with combined transpiration and regenerative cooling has been conducted. The virtual thrust chamber demonstrator TCD2 introduced in the German Collaborative Research Center SFB TRR40 acts as a framework for the conducted simulations. The TCD2 is a LOx/LH2-main stage engine with 1000 kN thrust, comparable to the Vulcain 2 engine [2].
The aim of this study is to present a numerical framework for the development of transpiration cooled rocket combustion chambers based on the commercial CFD software ANSYS CFX. The framework couples the hot gas flow domain and the coolant reservoir domain with the porous domain. The numerical setup is applied to an exemplary virtual transpiration cooled LOx/LH2 main stage rocket engine. Two different approaches modeling the hot gas flow with non-reactive flow and reactive flow are introduced and evaluated. The described setup was used for a parametric study to identify desirable properties for the porous material. A numerical framework for the thermal analysis of transpiration cooled rocket combustion chambers based on the commercial CFD solver ANSYS CFX was developed. The framework was demonstrated on the virtual thrust chamber demonstrator TCD2. The transpiration cooling was modeled using a fully coupled approach based on previous studies, extending the existing setup with the modeling of the backside flow in the coolant reservoir and the cooling channels. Here, the coupling approach evolved from the addition of a backside plenum to the Volumetric approach, which proves numerically more stable for the usage of detailed parametric studies. For modeling the hot gas flow inside the combustion chamber, two different approaches were pursued. On one hand, a non-reactive approach was investigated, with a ideal replacement gas tuned to match the heat transfer characteristics of the reactive hot gas flow determined from combustion simulations. On the other hand, the hot gas was modeled as a reactive flow, implementing a flamelet combustion model. A comparison of the hot gas models showed that the non-reactive model can only be applied to the shortened geometry and hence overestimates the heat transfer significantly when applied to a full chamber. In the presented study, the potential of transpiration cooling in main stage LOx/LH_2 rocket engine could be demonstrated. Due to the usage of generic material properties in a parametric study, the influence of the permeability as a main driving factor for the cooling performance could be shown. The effectiveness of the transpiration cooling increases with higher permeabilities due to the increasing

coolant mass flow rate. A significant heat flux reduction could be detected even in the wake of the porous segment, indicating a lasting cooling film formed by the transpired coolant.

References

[1] J. Peichl, A. Schwab, M. Selzer, H. Böhrk, and J. von Wolfersdorf. Innovative Cooling for Rocket Combustion Chambers. In N.A. Adams et. al, editor, *Future Space-Transport-System Components under High Thermal and Mechanical Loads*, volume 146 of *Notes on Numerical Fluid Mechanics and Multidisciplinary Design*. Springer Nature, Cham, 2021.

[2] D. Eiringhaus, H. Riedmann, and O. Knab. Virtual Liquid Propellant Thrust Chamber Demonstrators. In *Sonderforschungsbereich/Transregio 40 Annual Report 2018*. Garching, 2018.