Paper ID: 76941
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IAF SPACE PROPULSION SYMPOSIUM (C4)
Solid and Hybrid Propulsion (2) (4)

Author: Mr. alessandro rampazzo
University of Padova - DII, Italy, alessandro.rampazzo.10@studenti.unipd.it

Dr. Francesco Barato
University of Padova - DII/CISAS, Italy, francesco.barato@unipd.it
Prof. Daniele Pavarin
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy, daniele.pavarin@unipd.it

INVESTIGATION OF THE INFLUENCE OF GAS PHASE MOLECULAR MASS VARIATIONS ON HYBRID ROCKET REGRESSION RATE

Abstract

Hybrid rocket motors have several attracting features like simplicity, safety, low cost, thrust control, and environmental friendliness, which continues to spark the interest of a significant research and development effort. One of the main challenges in hybrid rocket combustion is the prediction of the fuel regression rate without leveraging empirical correlations. Marxman theory set the basis of the underlying physics of solid fuel regression. The counteracting behavior of the blocking effect induced by the fuel blowing tends to flatten the regression rates of conventional solid fuels to modest values. However, there are some discrepancies between the experimental findings and the theoretical predictions. For example, HTPB and HDPE show significantly different regression rates even with similar physical and chemical properties. A possible explanation could be related to the variation of fluid properties along the boundary layer, in particular the different molecular mass and thus, density, of the fuel decomposition products. In this paper, the influence of the ratio between the molecular mass of the blowing gas and the main stream gas on the friction and heat transfer is investigated through CFD simulations. In order to decouple the specific subject of this investigation from the other complex aspects of hybrid combustion, the simulations have been simplified to a cold flow analysis of a 2D horizontal channel with blowing from the bottom surface. Several gas combinations with different molecular mass ratios have been considered (air, helium, argon, freon, ethylene and butadiene). The results have been validated with previous literature studies and highlight the importance of the molecular mass ratio on the boundary layer development and behavior. To check the validity of the assessment, some simulations have been performed with the same gas (air) imposing a fictitious molecular mass to one of the two streams. The results confirm that a higher ratio between the molecular mass of the main stream gas and the blowing gas reduces the friction and the heat transfer to the blowing surface. Finally, the correlations verified by the cold flow simulations have been applied to the regression of HTPB and HDPE, showing a good agreement with experimental results.