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MULTI-FIDELITY ANALYSIS OF HYDROGEN-FUELED SCRAMJETS TO PREDICT EMISSIONS

Abstract

This work presents the further improvements of the HyPro system analysis tool, developed at the University of Strathclyde, for the preliminary design study of combined cycle engines. Specifically, this work focuses on the validation of HyPro in predicting the emissions produced by scramjets, which have gained considerable interest in multi-stage to orbit design concepts due to their high specific impulse at high-Mach regimes.

The study of engine performance can be performed with differing levels of fidelity and is directly related to the complexity of the physical processes which are accounted for in a model. Several models have been implemented in HyPro to describe the supersonic combustion inside scramjets with increasing levels of fidelity. The simplest considers complete combustion with an efficiency. Equilibrium chemistry can also be included, particularly in mixing-limited scramjet combustors. Mixing in both of these cases can be taken into account by splitting the flow into a reacting and non-reacting part. Finally, 0-dimensional reactors (perfectly-stirred and plug-flow) with finite-rate chemistry can be used in the case of a chemistry-limited scramjet combustor. They can be stacked in various geometries to create an interpretation of 2D space, without the computational cost of CFD.

The low fidelity implementations modelling both emissions and performance are validated for several hydrogen-fueled scramjet test cases for which experimental data is available. Information from Reynolds-Averaged Navier-Stokes CFD simulations is used to specify the boundary conditions for the HyPro combustor models. The results of the different approaches are compared to the CFD predictions and available experimental data.