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DATA-DRIVEN EMULATION MODELS FOR ROCKET ENGINES INJECTOR DESIGN

Abstract

Over the last decade a change in paradigm has been experienced in the development of rocket engines with an enhanced focus in cost effectiveness. Additionally, new mission requirements are expected in the future, thus posing a threat for vectors with inadequate propulsive elasticity. Future estimates hence predict a competitive commercial launch and space transportation sector.

Design of new rocket propulsion systems is therefore under the growing pressure of reducing development costs while satisfying performance through a wide range of scenarios. Validated computational fluid dynamics (CFD) codes for the simulation of combustion chambers can play an important role in this context. These provide a low-cost alternative to experiment-driven design. Nonetheless, a holistic approach for design optimization is not yet practical as exploration of the entire engine design space through full-scale CFD evaluations is too expensive in terms of computational time. Surrogate models may avoid this conundrum through fast inference times, without significant loss in predictive accuracy.

The aim of the present work is to use an artificial intelligence algorithm trained on data from Reynolds Averaged Navier Stokes (RANS) numerical simulations to generate data driven surrogate models for a shear coaxial injector GOx/Methane combustion chamber. A single element combustion chamber experimentally tested at the Technische Universität München (TUM) is taken as reference case. A Design of Experiments (DOE) considering 9 parameters (geometrical and operating conditions) serves as departing point for this study. More than 3500 axysimmetric simulations are carried out to cover the design of experiments. Scalar and average quantities (0D), wall quantities (1D) and field quantities (2D) are considered to extract different surrogate models. As a first step, depending on the size of the output, different machine learning techniques are employed to extract surrogate models of different dimensions: gaussian process, fully connected neural networks (FCNN) and convolutional neural networks (CNN). A comparison between different approaches is developed and carried out.

A posteriori, a scrutiny of the quantities predicted by the surrogate models (0D, 1D and 2D) is carried out including validation through analyses of conservation and physical consistency. Cross model consistency, where possible, and error sources are also evaluated.