Abstract
Preferred Topics: PROPHY / AEROFLIPHY / CFDMPS
Corresponding author: ROCAMORA Ancelin
e-mail of corresponding author: ancelin.rocamora@onera.fr
Type: Oral
Status of corresponding author: Student

Title
Simulation of Plasma Injector Module for Plasma Assisted Combustion in scramjet

Authors
Ancelin Rocamora [1], Julien Labaune [1], Fabien Tholin [2], Aymeric Bourlet [1], Christophe Laux [3]*

** Corresponding author*
[1] DMPE, ONERA, Université Paris-Saclay, F-91123 Palaiseau, France, surname.name@onera.fr
[2] DPHY, ONERA, Université Paris-Saclay, F-91123 Palaiseau, France, surname.name@onera.fr
[3] EM2C, CNRS, CentraleSupélec, Université Paris-Saclay, France, christophe.laux@centralesupelec.fr

Abstract

Plasma-assisted combustion (PAC) is a promising field of combustion that could lead to a breakthrough in propulsion systems, especially enlarging the flying domain of scramjets. Among several kinds of plasmas, DC electric arcs are relevant due to their production of large volume of thermal plasmas with high energy deposition. S. Leonov in [1] demonstrates their efficiency and applies them through a specific design: the Plasma Injector Modules (PIMs). Such device consists in a DC electric arc between a high voltage rod electrode inside the fuel injector and the grounded wall of the combustion chamber that are separated by an oval shaped planar dielectric plate. They generate a plasma within the flow ensuring at the same time heating and mixing of the chemical species as well as flow control in the combustion/mixing zone.
To better understand the complex multi-physics phenomena involved in PIMs discharges, and to further improve this technology, numerical simulations are conducted in this study. Most simulations performed in the literature are limited due to the complex plasma phenomena, particularly arc restrikes. These take a particular importance as they control the electric arc extension. This phenomenon would impose timesteps and cell sizes not compatible with CFD calculations. To overcome this issue and keep a reasonable timestep ($\sim 10^{-7}$s), the restrike model proposed by [2] that has proven successful for arc-supersonic flow interactions, has been employed. It is a two-step model that firstly assumes that the streamer follows the electric field line to compute the best way for streamers and secondly adds a plasma channel with a typical streamer radius and electrical conductivity along the field line. The presence of an electric arc significantly increases the maximal temperature in the combustion chamber from 3 000 K to 10 000 K. However, there is no combustion kinetic model in the literature that is valid over such a large temperature range.
This work presents at first a simulation of PIMs in a non-reactive flow to validate the restrike model based on the results obtained in [4]. Then a simple set of chemical reactions inspired by [3] with an extension of the validity domain beyond 3 000K is used to validate the effect of PAC on the flow observed experimentally in [5]. Finally, we discuss the selection of the most representative species and reactions to be used in a PAC kinetic model combining a high temperature kinetics from atmospheric reentry community and classic hydrogen combustion kinetics valid up to 3 000 K.

References

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