Some elements on the influence of DC-gliding arc on H_2 combustion in scramjet

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Abstract: The results of this contribution concern plasma-assisted combustion in a supersonic flow. A current intensity study reproduces a threshold effect to initiate combustion. Analysis of arc dynamics reveals a mechanism for arc movement on either side of the plasma actuator ceramic, and provides information on changes in chemical composition due to plasma flow.

1. Introduction

Different technologies of airbreathing engines for hypersonic flight have been explored. All have to ensure the stability of the supersonic combustion. One of the approaches is to put an electric field near the injector to produce plasma. This plasma can act as a traditional flame holder like strut or cavity, but can also bring a thermal input in the combustor to speed up the reactions by producing more radicals.

An architecture called Plasma Injector Module (PIM) is developed by S. Leonov et al. [1] using Q-DC gliding arc and had been tested experimentally. In this study the simulation of possible application of PIM in LAERTE is performed in the Mach 2 facility LAPCAT-II.

Full test rig is simulated from nozzle to combustor with generator temperature under the autoignition one but enough to ignite with a 5 A electric arc.

2. Methods

The Navier-Stokes equations with transport of species are solved by the CFD solver CEDRE, with a ZDES approach. The resolution of the electric field is achieved by a quasi-neutral plasma solver: TARANIS. The 2 codes are coupled at each time-step with the CWIPI library as described in [2]. The kinetic scheme used as basis for the combustion of H_2 is the one described by C. J. Jachimowski [3] with the N_2 non-dissociation assumption.

3. Results and Discussion

To perform the study on the current sensibility, 6 cases are chosen: 5, 4, 3, 2, 1 and 0 A. The simulation begins from a stabilised calculation state with a 5 A electric arc in which stable combustion occurs. Going from 5 to 4 and 3 A, the combustion remains stable. The intermediate case with 2 A could corresponds to a very instable combustion regime. However, for 1 and 0 A, an extinction of the combustion occurs. This effect is similar to that observed experimentally.

In complement to this kinetic study, another is conducted on the arc root dynamic showing the ability to follow both sides of the insulated ceramic which is interesting for the mixing of the fuel.

A limit of the experiment studies is the difficulty to understand the impact of the high temperature on the chemical composition of the flow. Indeed, the temperature can reach 10 000 K in the electric arc. By using the Lagrangian approach for fluid particles, we can obtain the residence time in the arc. This information is needed to assess radical production and its influence on combustion.

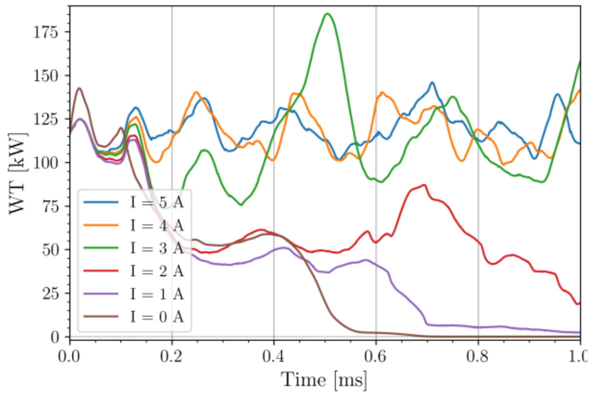

Fig. 1. Time evolution of the space-averaged heat release in the combustor for different current entry.

4. Conclusion

A current threshold has been evaluated numerically, under which a DC gliding arc is unable to maintain a stable supersonic combustion in H_2.

The ability of the arc to follow both sides of the PIM is piloted by the crossflow instabilities.

A statistical study on the residence time in the plasma for gas particles from mainstream and injector has been performed to feed a 0D model to determine the plasma composition.

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