Investigation of kerosene-hydrogen mixtures: kinetics and emissions analysis

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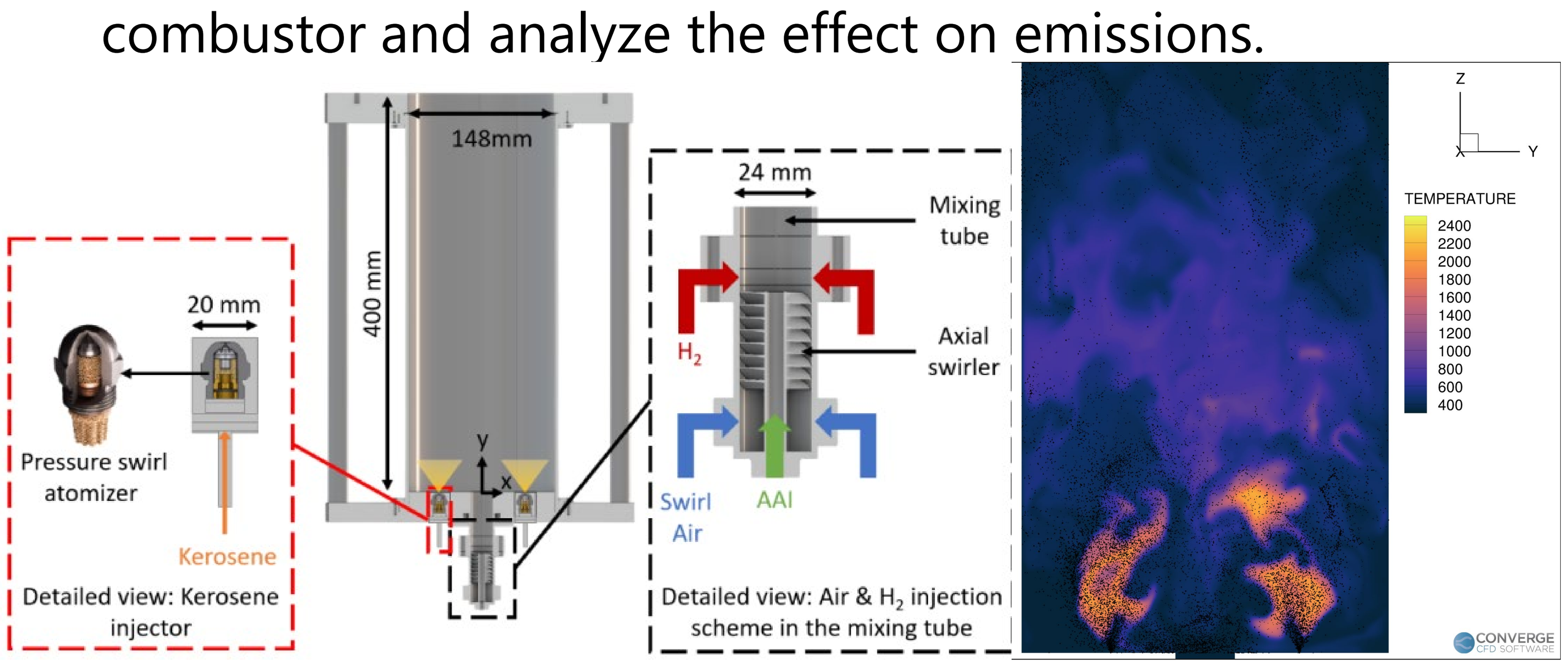
BACKGROUND

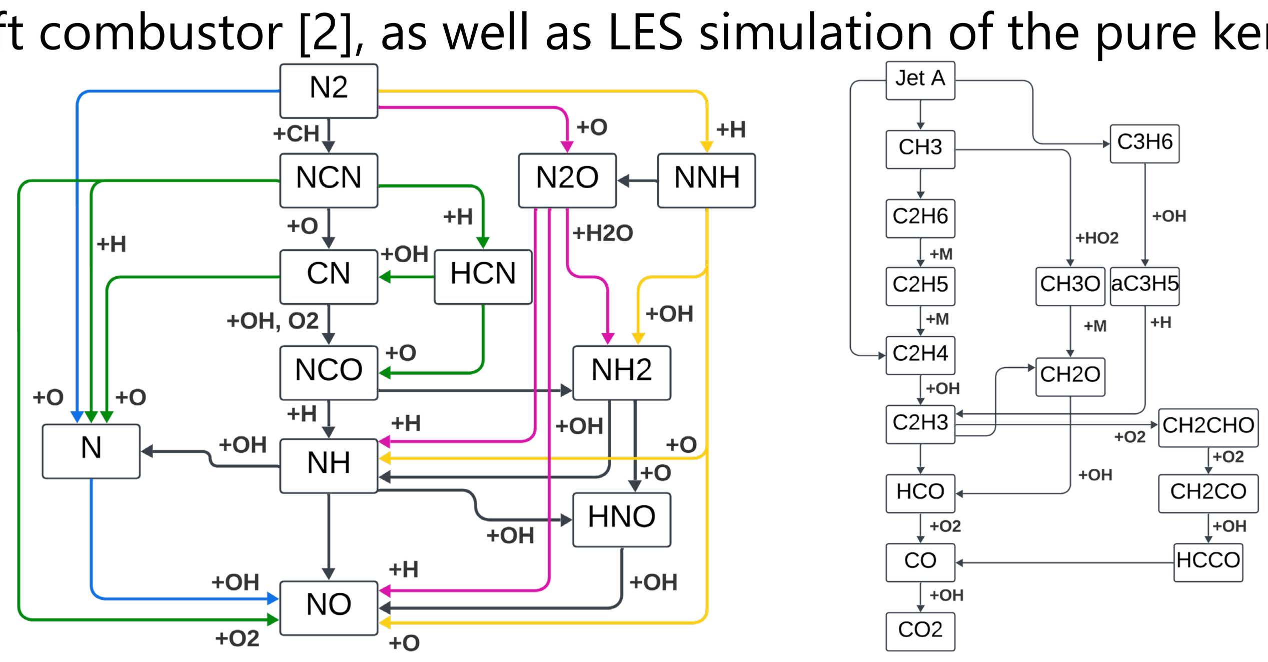
- Hydrogen stands out as a promising solution for sustainable aircraft solutions.
- Fully hydrogen-powered aircraft pose major challenges, both in terms of combustion design and storage systems.
- Hydrogen combustion is characterized by its wide flammability range, very high flame propagation speed, and high diffusivity and reactivity. This makes the hydrogen combustion problematic.
- Storage in aircraft is problematic due to the very high pressures required or the low temperatures needed to keep hydrogen in liquid form.

HOW?

- A mechanism appropriate for kerosene combustion is selected, with a small number of species and reactions, in order to perform high-fidelity CFD simulations.
- Both A (pre-exponential factor) and E (activation energy) of the Arrhenius equation are optimized to better fit experimental data of the blend. Sensitivities coeffiecients of each reaction respect quantities are calculated.
- Experimental Mie-Scattering images are used to determine the particle distribution.
- 3D LES simulations with TFM are used to simulate the TU Delft combustor and analyze the effect on emissions.



TU Delft combustor [2], as well as LES simulation of the pure kerosene case.



NO and CO pathways for kerosene-hydrogen blends.

[1]H. A. Alabaş and B. Albayrak Çeper, “Effect of the hydrogen/kerosene blend on the combustion characteristics and pollutant emissions in a mini jet engine under CDC conditions,”
[2]K. Dave, S. Link, F. De Domenico, F. Schrijer, F. Scarano, and A. Gangoli Rao, “Kerosene-H2 blending effects on flame properties in a multi-fuel combutor,” *Fuel Communications*, 2024.

OBJECTIVE(S)

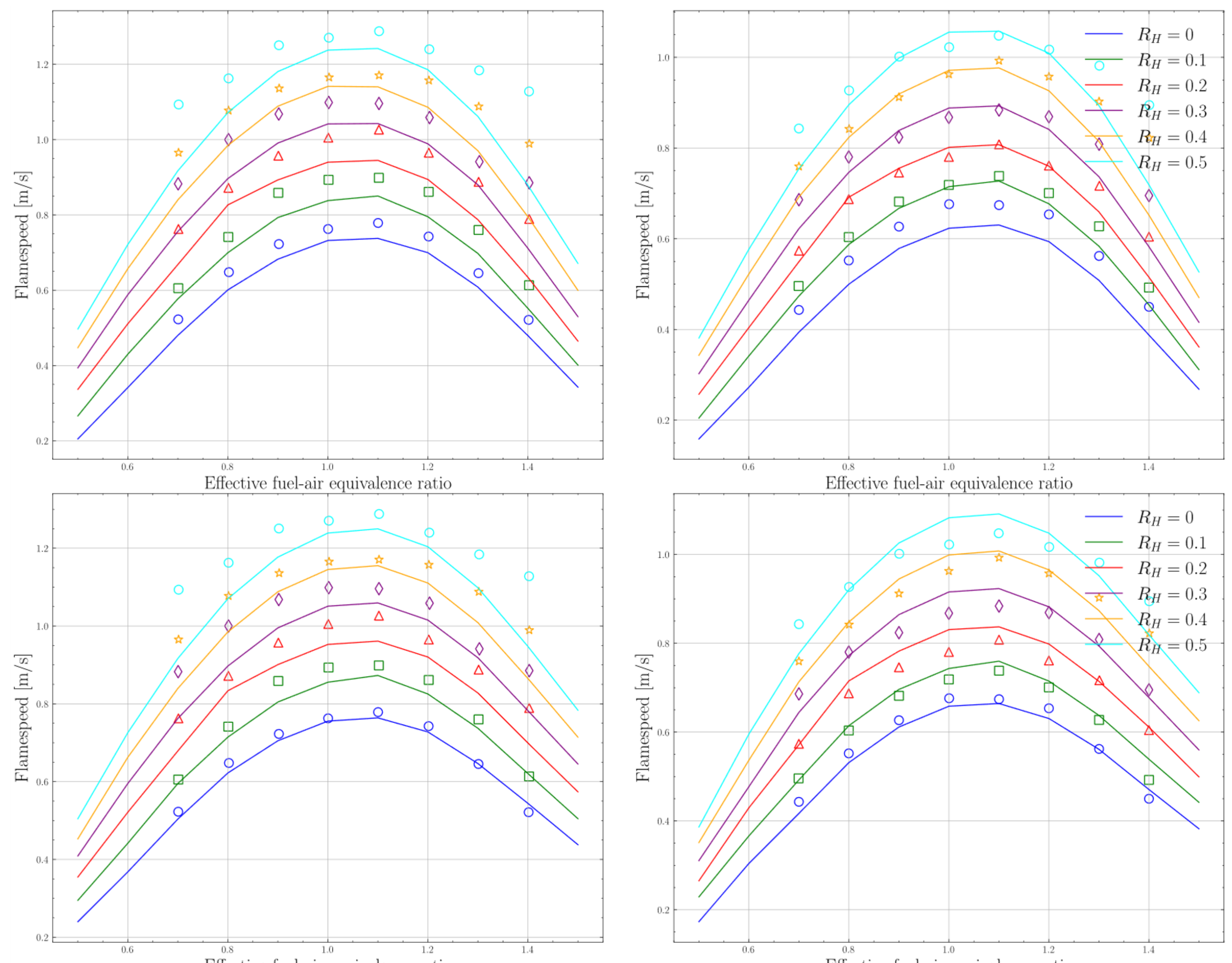
- Understand the mechanisms behind the emissions of this new blend, with particular emphasis on CO and NOx.
- Analyze the chemical kinetics of this mixture and develop a method to optimize the mechanism to better fit the experimental data and to quantitatively determine the main reactions and pathways.
- Design a computational workflow to simulate the TU Delft combustor. Evaluate the effect of pressure and make design improvements.

WHY?

- Blending hydrogen with conventional aviation kerosene offers a practical approach to incorporating hydrogen into aviation fuel.
- Even a small hydrogen addition to kerosene can yield benefits such as reduced fuel consumption and increased range or payload capacity.
- Some studies [1] already show that a small amount of hydrogen can help to reduce the CO emissions.

RESULTS

- The mechanism is modified to better fit the experimental data. The hydrogen oxidation pathways are slowed down, as are the initial kerosene decomposition steps, to account for radical competition.
- NO, CO and flame speed significantly vary as a function of hydrogen content.
- The kerosene spray is modelled according to experimental data. The Rossin-Rammler distribution with a SMD of 25 nm is found to fit the data.
- Future work will analyze the effect of pressure and the emissions on the 3D LES of the TU Delft combustor.



Comparison between the original kerosene mechanism (top) and the tunned one (bottom) at 1 atm (left) and 2 atm (right).

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