Sensing of radicals in plasma-assisted NH_3 combustion using laser-induced fluorescence

1. Context

Ammonia (NH_3) is a potential energy source to replace conventional hydrocarbon fuels in high-power applications that cannot employ electricity, e.g., long-distance/air/space transportation and the steel/cement/glass industrial sectors at high temperatures. The complete combustion of NH_3 produces no harmful exhaust and no greenhouse gas: $2\ NH_3 + 3/2\ O_2 \rightarrow 3\ H_2O + N_2$. However, NH_3 flames are prone to extinction and low-temperature kinetic pathways can lead to the emission of NH_3 (unburnt), NO, N_2O, and NO_2, which have a strong environmental impact. Our group at the EM2C laboratory employs nanosecond repetitively pulsed (NRP) discharges to activate new kinetic pathways in NH_3 flames and reduce these emissions. This strategy has been successfully applied in several configurations to stabilize hydrocarbon flames at an industrial power[1] but has been less investigated in NH_3.

2. Objectives

Preliminary results showed that NRP discharges can generate plasmas out of thermal equilibrium, i.e. the temperature of the electrons is significantly higher than the translational temperature of the atoms/molecules, $T_e \gg T_{heavies}$. In this case[2], the translational temperature is $T_{heavies}$ = 1000 – 2000 K. Another regime can be obtained where the temperatures are equilibrated[3], i.e. $T_e \sim T_{heavies} \sim$ 30,000 K. The flame topology is strongly influenced by the plasma regime, which also has a strong impact on pollutant emissions (NO and N_2O). The objective of this internship is to track the formation of radical species generated and transported in the plasma vicinity and their impact on the flame topology. Priority will be given to molecular radicals (OH and NH) which can be measured with laser-induced fluorescence (LIF). The student will also have the opportunity to apply two-photon absorption laser-induced fluorescence (TALIF) to track the formation of atomic species (O and H). The latter is more challenging given the reduced cross-section of two-photon absorption and the lower concentration of atomic species. Still, the development of these diagnostics will pave the way for a PhD thesis which will be proposed in parallel.

3. Organization

The student will work at the EM2C laboratory, CentraleSupélec, primarily under the supervision of Nicolas Minesi. Two PhD students are actively working on plasma-assisted combustion of NH_3 and the intern will conduct this project in close collaboration with them. The internship, initially set for **5 months**, holds the potential for extension into a thesis. For more information, please contact nicolas.minesi@centralesupelec.fr

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2. Rusterholtz, D. L., Lacoste, D. A., Stancu, G. D., Pai, D. Z. & Laux, C. O. Ultrafast heating and oxygen dissociation in atmospheric pressure air by nanosecond repetitively pulsed discharges. *Journal of Physics D: Applied Physics* **46**, 464010 (2013).
3. Minesi, N., Stepanyan, S., Mariotto, P., Stancu, G. D. & Laux, C. O. Fully ionized nanosecond discharges in air: the thermal spark. *Plasma Sources Science and Technology* **29**, 85003 (2020).