

Flame structure and combustion mode of ammonia/hydrogen flames in hot and low-oxygen coflows

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In this study, large eddy simulations (LESs) are performed to investigate the flame structure and combustion mode of ammonia/hydrogen flames in hot and low-oxygen coflows. The detailed reaction mechanism developed by Tamaoki et al. [Combust. Flame 2024, 259, 113177] is used to account for gas chemistry, and the Partially Stirred Reactor (PaSR) model is employed to describe the turbulence/chemistry interactions. The LES/PaSR method is first validated on the Lund University Pilot Jet burner (LUPJ) burner [Combust. Flame 2022, 241, 112090]. Good agreements of temperature and major/minor species can be achieved between the LES predictions and experimental data. Subsequently, three oxygen concentrations (3%, 6%, and 9%) and two hydrogen heat fractions (10% and 20%) are considered for the coflow and central fuel streams, respectively. As the oxygen concentration increases from 3% to 9%, the flame structure changes from lifted flames to attached flames, and the lift-off-height decreases with the increase of oxygen concentration. The premixed mode dominates in the lifted flame, while the attached flame is dominated by the non-premixed mode. This is also valid for heat release rate contribution. As the hydrogen concentration in the fuel stream rises, the flame structure transitions from a lifted flame to an attached flame, and the predominant combustion mode shifts from premixed to non-premixed. This is because the addition of hydrogen can greatly increase ammonia's reactivity and markedly reduce the auto-ignition time.

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References

- [1] Tamaoki K, Murakami Y, Kanayama K, Tezuka T, Izumi M, Nakamura H. Roles of NH₂ reactions in ammonia oxidation at intermediate temperatures: Experiments and chemical kinetic modeling. Combustion and Flame. 2024; 259: 113177.
- [2] Fan Q, Liu X, Cai X, Brackmann C, Alden M, Bai XS, Li Z. Structure and scalar correlation of ammonia/air turbulent premixed flames in the distributed reaction zone regime. Combustion and Flame. 2022; 241:112090.