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Flame stability of liquid ammonia combustion under intermittent fuel supply condition

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Liquid ammonia combustion has received a lot of attention in recent years [1]. In this study, quasi-direct numerical simulations are performed to investigate flame stability of liquid ammonia/hydrogen combustion when fuel delivery becomes intermittent because of flash boiling in the fuel pipeline. The simulations are treated with the Eulerian–Lagrangian framework, and the interaction between gaseous phase and droplets is considered using two-way-coupled method [2]. The reaction is considered using a detailed reaction mechanism developed by Shrestha et al. [3]. The governing equations are solved in OpenFOAM with a second-order finite-volume scheme on a high-resolution mesh sufficient to resolve the flame thickness [4].

Two operating stages are analyzed. Stage 1 (S1) is a steady liquid spray at global equivalence ratio $\varphi = 1.0$. Stage 2 (S2) represents conditions after flash boiling: all droplets vaporize before entry into computational domain, which raises the inlet mass flow and cools the mixture, creating a clearly intermittent fuel supply while the total equivalence ratio remains unchanged. The results indicate that the rapid liquid-to-gas transition in S2 brings significant instability of fuel supply. Compared with S1, the flame front exhibits larger flame curvature, driven by local temperature drops and fluctuations in equivalence ratio caused by flash boiling. These fluctuations in fresh mixture equivalence ratio can temporarily expand or narrow the reaction zone. As a consequence, changes in heat release rates may require higher total equivalence ratios to maintain sustained combustion, thereby narrowing the stable operating window.

This study delivers a high-resolution simulation of how flash boiling in the fuel pipeline influences liquid ammonia flame structure, flammable regions, and extinction risk. The proposed conclusions could provide practical guidance for designing liquid ammonia gas turbine combustors.

References

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