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A Study of Extinction, Flame Structure, and Reaction Mechanisms in Methane/Ammonia Counterflow Diffusion Flames

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Ammonia is a promising carbon-free fuel, but its low reactivity presents challenges for practical combustion applications. In this work, the behavior of methane–ammonia counterflow diffusion flames were investigated through combined numerical simulations and experiments, with variations in strain rate (a_g) and equivalence ratio (ϕ). One-dimensional CHEMKIN simulations were performed to evaluate extinction strain rates, flame structure and reaction mechanisms across a wide range of NH_3/CH_4 mixing ratios. Results show that increasing NH_3 content leads to thicker, orange-colored flames and reduced flame stability, particularly at higher strain rates. Compared with pure CH_4/air flames, NH_3/CH_4 blends achieved substantial CO_2 emission reduction with only moderate decreases in stability limits and no significant flame temperature drop, highlighting their potential as low-carbon fuels. Extinction stretch rate increased with CH_4 fraction, with the most stable condition observed at lean operation (ϕ = 0.9). Pathway analyses at different blending ratios further identified the elementary reactions and radical species responsible for heat release and extinction, clarifying the chemical interactions underlying methane stabilizing role in NH_3 combustion.

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