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Numerical investigation of flow characteristics on flame dynamics and NOx emission in non-premixed ammonia/high-temperature air combustion using a double-swirl burner

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Ammonia is a promising carbon-free fuel that can reduce greenhouse gas emissions and serve as an energy carrier in a hydrogen-based economy. However, its practical use is hindered by low reactivity and high NOx emissions during combustion [1]. In practical industrial applications, high temperature environments are usually used to increase the reactivity of ammonia, and NOx emissions can be reduced by utilizing flameless and moderate or intense low-oxygen dilution (MILD) combustion. Studies on such flameless combustion mode have primarily focused on optimizing the ammonia injection locations or pilot flame configurations [2, 3]. Nevertheless, the influence of flow characteristics, including swirl parameters or turbulence effects in abovementioned high-temperature environments are considered critical to NOx emissions and the mechanism remains insufficiently understood. In this study, non-premixed, ammonia-air combustion has been investigated using large eddy simulations of a double-swirl burner. This study mainly focuses on flame dynamics and NOx formation pathways in ammonia combustions under varying bulk flow rates and preheated air temperatures. Large eddy simulations reveal that the swirler recess length significantly influences the location and strength of recirculation zones, and that the low reactivity of ammonia necessitates a shorter recess compared to burners designed for more reactive fuels. Additionally, it was demonstrated that flow characteristics influence flame characteristics, and these changes impact the NO pathway even at a constant equivalence ratio. Finally, the role of NH and NH2 as heat release rate markers at different flow rates has been discussed.

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