International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

Model validation and numerical analysis of the combustion and NOx characteristics of ammonia/methane-air premixed flames in a model gas turbine combustor

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This research numerically analyzes the combustion and NOx emissions characteristics of ammonia/methane (NH_3/CH_4) air premixed swirl flames in a model combustor for clean energy production in gas turbines. Two equivalence ratios ($\varphi = 1$ and 1.2) were investigated at varying ammonia doping ratios (NH_3% by vol.) of 20%, 30%, 40%, and 50%. The chemistry of the combustion process is comprehensively addressed utilizing a detailed mechanism, featuring 957 reaction steps and 128 species, integrated within the flamelet generated manifold (FGM) model framework. The model was validated in terms of temperature and species fields with very good agreements. The results illustrated that ammonia doping minimally affects the flow field but significantly impacts combustion characteristics. Increasing ammonia fraction lowers peak temperature, CO, and CO_2 emissions, while NOx initially rises and then decreases. Increasing NH_3% from 20% to 40% at $\varphi = 1$ reduced the maximum CO mass fraction by 32.25%. NOx (NO, N_2O, and NO_2) concentrations rose by 9.46% when the ammonia fraction increased from 20% to 30% at $\varphi = 1.0$, but further increasing NH_3% to 40% resulted in a 3.72% reduction in NOx levels. Overall, the highest NOx emissions were consistently observed at 30%NH_3 and $\varphi = 1.0$.