



Direct Numerical Simulations of Staged Ammonia Combustion at Gas Turbine Conditions

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A challenge for burning ammonia in a typical lean premixed gas turbine combustor is the formation of nitrogen oxides emissions associated with fuel-bound nitrogen. As an alternative to lean premixed operation, a staged combustion approach can be adopted, in which ammonia is consumed in a fuel-rich environment, which favors the formation of stable nitrogen over its oxides. In this study, results from direct numerical simulations (DNS) are presented to elucidate the turbulence-chemistry interaction and the formation of emissions in a novel canonical configuration representative of the lean secondary stage of a staged gas turbine combustor. In this configuration, cold dilution air is injected into a cross-flow of hot hydrogen-containing pyrolyzed ammonia combustion products from the first stage. The first stage is a rich premixed ammonia flame, which is simplified in the DNS setup as a cross-flow of equilibrium products. Three different cases are presented for different air split ratios (i.e., equivalence ratio of the first stage). An additional case with ammonia slip provides insights into changes in flame structure and emissions when unreacted ammonia slips past the first stage. The results are analyzed with respect to general flame behavior, in particular with respect to mixing characteristics. An analysis of flamelets extracted from the DNS data is also conducted, which provides further insights into the complex flame structure. N₂O emissions are analyzed and compared to NO emissions investigated earlier [1]. The results show significant differences in the formation of NO and N₂O. In addition to the analysis of flame structure and emissions, new results are presented that highlight the difference between the equilibrium simplification employed for the cross-flow in the initial set of DNS and a more realistic representation of the first stage.

References

[1] Rieth, M., Gruber, A., Hawkes, E.R. and Chen, J.H., 2024. Direct numerical simulation of low-emission ammonia rich-quench-lean combustion. *Proceedings of the Combustion Institute*, 40(1-4), p.105558.