NOX EMISSIONS FROM $NH_3/H_2/N_2$ FUEL BLENDS IN GAS TURBINES: A CHEMICAL REACTOR NETWORK-BASED ASSESSMENT

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Abstract
The decarbonization of power generation systems is increasingly relying on ammonia (NH_3) as a carbon-free energy carrier. However, the use of NH_3 in gas turbines is hindered by challenges related to combustion stability and NOx emissions. This work presents a numerical investigation of $NH_3/H_2/N_2$ blends using a validated Chemical Reactor Network (CRN) approach [1], focusing on the role of the cracking conversion ratio (CR) and equivalence ratio (ϕ) in controlling NOx formation under gas turbine-relevant conditions. The fuel compositions are parametrically varied from pure ammonia (CR = 0%) to fully cracked mixtures (CR = 100%, 75% H_2 / 25% N_2), and analyzed across lean and rich regimes (ϕ = 0.4–1.4). The CRN model, calibrated against CFD simulations and experimental data, consists of a network of PSRs and PFRs that mimic flame stabilization, recirculation, and post-dilution regions typical of Rich-Quench-Lean combustor configurations.
Results show that increasing CR leads to a strong reduction in NOx emissions, especially under lean conditions, due to enhanced pathways for NO destruction involving H and N radicals. At high CR ($\geq$ 80%), NOx becomes almost insensitive to variations in PILOT dilution while for low CR, the pilot zone strongly influences emissions. In rich regimes, NOx formation is intrinsically suppressed by reducing conditions, and further improved by high CR. A detailed Rate of Production (ROP) analysis reveals the dominant chemical pathways responsible for NO formation and destruction in both lean and rich conditions. Specifically, reactions involving NH, N_2O, and the interplay of oxidizing/reducing radicals are shown to govern emission trends.
The study highlights the effectiveness of optimizing CR and equivalence ratios to enable low-NOx operation of ammonia-based gas turbines, supporting their deployment in sustainable power systems.

[1] Christian Romano, Matteo Cerutti, Giulia Babazzi, Lorenzo Miris, Rachele Lamioni, Chiara Galletti, Luca Mazzotta, Domenico Borello, "Ammonia blends for Gas-Turbines: Preliminary test and CFD-CRN modelling", Proceedings of the Combustion Institute 40 (1) (2024) 105494.