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Reducing NOx Emissions in Hydrogen Combustion by Fuel Pipe Diameter Adjustment and Secondary Air Cooling

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Hydrogen (H_2) is a promising zero-carbon fuel for gas turbines, but its high flame temperature can lead to excessive nitrogen oxide (NOx) emissions. This study investigates strategies to reduce NOx formation in a micro-mixing combustor when operating on hydrogen, by adjusting the fuel pipe (nozzle) diameter and employing secondary air injection for flame cooling. A validated computational fluid dynamics (CFD) model (ANSYS) of a 1.15 MW micro-mixing gas turbine combustor is used, based on a reference methane-fueled design. The model is applied to compare combustion of H_2 versus methane (CH_4), H_2 cases with and without secondary air injection, and H_2 cases with varying fuel nozzle diameters (0.125 mm to 2 mm) under the same heat release. Flame temperature distributions, flame propagation characteristics, and NOx emission levels are analyzed for each case. The results show that switching from CH_4 to H_2 increases flame peak temperature and NOx production, but these effects can be mitigated through design modifications. Introducing secondary air (cooling air) lowers the flame temperature and slows flame propagation, leading to a significant reduction in NOx emissions. Furthermore, reducing the fuel nozzle diameter enhances fuel–air mixing, shortening the flame and suppressing peak temperatures. The combination of a small fuel nozzle and secondary air injection yields the lowest NOx emissions among the cases studied. This work demonstrates that appropriate fuel injector sizing and staged air injection are effective in controlling NOx emissions in hydrogen combustion while maintaining combustion efficiency and flame stability.