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An Experimental Study on the Effect of Quarl Angle and Swirl Intensity in CH_4/H_2 Co-firing Counter-swirl Injector

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Extended Abstract

The transition to carbon-free power generation is essential to mitigate global warming[1]. Extensive research on hydrogen combustion is currently underway, and the gas turbine industry is also transitioning to hydrogen co-firing and fully hydrogen-fired turbines[2]. While hydrogen combustion as a carbon-free fuel significantly reduces CO_2 emissions, challenges such as flashback caused by its high flame propagation speed, combustion instability leading to nozzle damage, power reduction due to combustion oscillations, and high NOx emissions from elevated flame temperatures must be addressed[3,4]. Applying hydrogen to conventional gas turbines can lead to critical damage, making research on hydrogen turbines indispensable. This study investigated the flame behavior and NOx emission performance under various hydrogen co-firing conditions and parameters related to the geometrical configuration of a combustor, which aerodynamically influence the flow in a counter-rotating injector. The injector used in this study introduces pure hydrogen through an inner nozzle near the dump plane, eliminating the risk of flashback. A 6 mm recess length is employed to partially pre-mix hydrogen, methane, and air, stabilizing the flame. Under conditions where the bulk velocity of the central hydrogen flow is sufficiently high, swirl induction pushed the flame downstream, resulting in flame lift-off. According to S. Marragou's study[5], this phenomenon is influenced by both the swirl of the hydrogen flow and the recess length. Flame lift-off reduces thermal stress on the combustor, thereby preventing damage. Comparing NOx emissions between swirling and non-swirling hydrogen flows, as well as different quarl geometries, it was observed that diverging quarl configurations significantly reduced NOx emissions compared to straight quarls. A study by A.M. Elbaz[6] revealed that quarl geometry affects the lean stability limit, flame structure, and turbulent flow field. In diverging quarls, NO formation at the IRZ boundary was reduced, and the dominant NO formation mechanism shifted from thermal NO to prompt NO. These effects likely contribute to the differences in NOx emission performance, with detailed analysis of the underlying causes being a future research direction.

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