CFD Investigation of Hydrogen-Enriched LPG Combustion in a Swirl-Stabilized Burner for Aero-Thermal Applications

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Abstract

The shift toward low-carbon propulsion has increased interest in hydrogen-enriched fuels for aero-thermal combustion. Liquefied petroleum gas (LPG) remains common for its high energy density and stability but produces considerable CO_2 and CO emissions. This study employs computational fluid dynamics (CFD) to examine hydrogen enrichment effects on flame behavior and emissions in a swirl-stabilized burner. Simulations were performed under stoichiometric conditions with hydrogen blending ratios of 0–50 %, using the RNG k–ε turbulence, Eddy Dissipation Concept (EDC) combustion, and Discrete Ordinates (DO) radiation models. Results show that hydrogen addition strengthens the central recirculation zone, yielding a shorter and more stable flame. The maximum temperature increased from 2066 K for pure LPG to 2378 K at 50 % H_2, while CO_2 and CO emissions decreased by about 43 % and over 90 %, respectively. These improvements stem from hydrogen's high diffusivity, flame speed, and rapid oxidation kinetics, which enhance fuel–air mixing and combustion completeness. Although hydrogen enrichment raises flashback risk, the optimized swirl geometry maintained stable, confined flames. Overall, hydrogen-LPG blending enables compact, efficient, and low-emission combustion, offering a viable transitional approach toward cleaner aero-thermal propulsion and energy systems.

Keywords

Hydrogen-enriched LPG, CFD, Swirl burner, Flame stabilization, Emission reduction, Aero-thermal systems.