Development of a High-Pressure Counterflow Combustor in Additive Manufacturing for Non-Conventional Fuels

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Abstract

A flexible, high-pressure counterflow combustor has been developed to enable advanced studies on next-generation fuels, including hydrogen, ammonia and their mixtures under realistic conditions of practical systems. This apparatus is designed to operate up to 20 bar with air preheating up to 1200 K, offering a unique platform for investigating key laminar flame properties (laminar flame speed, laminar flame thickness, major species formation, flame temperature, etc.) in both premixed and non-premixed configurations. Computational Fluid Dynamics (CFD) simulations with detailed chemistry have demonstrated the formation of stable, nearly one-dimensional flame structures, confirming the effectiveness of the combustor design and validating its ability to stabilize flames across a wide range of operating regimes. An innovative wall-cooling system, integrating internal heat exchange channels, provides sufficient heat transfer to keep wall temperatures below critical thresholds, even under high thermal loads, with minimal pressure losses. The combustor is manufactured using the Selective Laser Melting (SLM) process, an advanced Laser power bed fusion. This 3D printing industrial process (widely used and qualified by *Sòphia High Tech*) enables the production of monolithic metal components with intricate geometries through a layer-by-layer material deposition approach, in contrast to traditional subtractive methods such as milling or turning. This work lays the foundation for future experimental campaigns, providing a rare high-pressure dataset essential for validating kinetic mechanisms and CFD models, and supporting the development of low-carbon combustion technologies.

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