International Journal of
Automotive Manufacturing and Materials (IJAMM)

Editorial

Investigating Hydrogen Jet Ignition Systems for Stable Lean Combustion in Internal Combustion Engines

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Received: 7 March 2026; Revised: 9 March 2026; Accepted: 10 March 2026; Published: 11 March 2026

Given growing concerns about energy security and the need for a cleaner environment, increasing attention is being directed toward the development of highly efficient, clean internal combustion engines. This has led to the emergence and application of numerous innovative technologies across different engine types. In the search for alternative fuels, various efficient and clean energy sources have been investigated. Among them, hydrogen jet ignition systems have emerged as a particularly promising solution. These systems are capable of igniting lean mixtures and addressing challenges such as combustion instability typically associated with conventional spark plugs.

To overcome the ignition difficulties and unstable combustion commonly encountered with spark plugs under lean-burn conditions, and to achieve rapid and stable combustion of lean mixtures, a hydrogen jet ignition device has been developed. This device has been studied through both experimental and simulation-based approaches. Hydrogen, a renewable gas, produces no greenhouse gas emissions upon combustion, further enhancing its appeal as a clean fuel. In recent years, researchers have explored the jet characteristics of outward-opening direct-injection hydrogen nozzles under various injection pressures and environmental conditions. Key parameters influencing combustion propagation—such as optimal jet and background pressures, flame entrainment rate, jet cone angle, and jet pulse width—have been systematically examined.

High-speed schlieren and color imaging, along with advanced image processing techniques, have been employed to investigate the phenomenon of flame spreading rapidly along the wall after the hydrogen jet contacts the surface. These studies have also explored the resulting effects on flame propagation characteristics. The flow behavior and temperature field evolution following flame–wall interaction at different wall inclination angles have been analyzed in depth. Furthermore, the combustion and emission performance of modified internal combustion engines utilizing in-cylinder direct injection and secondary injection strategies has been evaluated through simulation.

Comparative studies between circular nozzles and rectangular nozzles with varying equivalent diameters and aspect ratios have been conducted. These investigations included jet experiments and safety assessments, revealing differences in flow and diffusion behavior. By setting up experimental test benches and utilizing high-speed imaging to capture temperature fields and flame propagation patterns, the effects of varying hydrogen mixture concentrations and contact durations on flame behavior and thermal characteristics were examined. Across multiple studies, a wide range of operating conditions—including injection pressure, pre-chamber fuel concentration, working temperature, ignition timing, and pre-chamber geometry—have been simulated through both experimental setups and computational models. Despite these efforts, further research into jet flame dynamics remains necessary.

In the current issue of the *International Journal of Automotive and Mechanical Engineering (IJAMM)*, a detailed investigation into the flame propagation process of a hydrogen jet ignition system within a constant volume vessel is presented [1]. This study focuses on the underexplored effects of varying injection pressures and working temperatures on jet flame development. A three-dimensional computational fluid dynamics model of a passive pre-chamber ignition device integrated with a constant volume vessel was developed and validated. Simulations were carried out to analyze jet flame characteristics under different injection pressures and subsequently at varying working temperatures, using the identified optimal pressure as a baseline.

The results indicate that higher injection pressures delay the formation of the jet flame but prolong its duration and increase both peak temperature and heat release rate. Conversely, elevated working temperatures significantly accelerate jet flame formation and reduce its duration, while attenuating large-scale roll-up structures and enhancing the heat release rate. This research provides foundational insights into optimizing hydrogen jet ignition systems for stable lean combustion and offers a valuable reference for scholars and engineers in automotive engine research.

Conflicts of Interest: The author declares no conflict of interest.

Use of AI and AI-Assisted Technologies: No AI tools were utilized for this paper.

Reference

1. Gao, Y.; Zhu, G.; Chen, W.; Wang, Y.; Zuo, Q. Numerical Investigation Hydrogen Jet Ignition Process in a Constant Volume Vessel. *Int. J. Automot. Manuf. Mater.* **2026**, *5*, 2. https://doi.org/10.53941/ijamm.2026.100001.