

Analysis of the Effect of Hydrocarbon-Hydrogen Mixture on Flame Propagation Characteristics Using In-Cylinder Visualization

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A Hydrogen engines have drawn significant attention as a promising technology for achieving carbon neutrality in internal combustion engines. However, hydrogen exhibits fundamental combustion characteristics distinct from conventional gasoline and is highly susceptible to abnormal combustion. In this study, fundamental combustion characteristics of hydrogen-hydrocarbon blended fuels were investigated through in-cylinder optical visualization experiments using an actual engine.

An air-cooled, 4-stroke single-cylinder engine with a side-valve configuration was employed for optical diagnostics. An optical head equipped with a quartz window was installed at the top of the cylinder head, and a high-speed camera was mounted above the window to capture the in-cylinder flame propagation behavior.

The experimental conditions were fixed at an engine speed of 1,200 rpm, a heat input of 712.2 J/cycle, an ignition timing of ATDC -25 deg, and an initial in-cylinder temperature of 473 K. Primary Reference Fuel (PRF90) and hydrogen were used as fuels, with hydrogen mass fractions set to 0%, 15%, 30%, 45%, and 100%.

High-speed flame visualization and in-cylinder pressure analysis revealed the following key findings:

1. **Accelerated Flame Propagation:** Increasing the hydrogen blend ratio significantly increased the flame propagation speed and enhanced early flame development.
2. **Enhanced Combustion Stability:** Due to the high reactivity of hydrogen, the heat release timing was advanced, and cycle-to-cycle variations were markedly reduced, resulting in improved combustion stability.
3. **Requirement for Dedicated Control Strategy:** Hydrogen addition drastically alters combustion behavior and heat release patterns, indicating that distinct combustion control strategies from pure hydrocarbons are required.

The fundamental combustion characteristics of PRF90-hydrogen blends were clarified through optical diagnostics in an operating engine. Hydrogen addition was shown to effectively increase flame speed and suppress cyclic variation. Future work will involve installing a supercharging system to observe abnormal combustion phenomena under boosted conditions. Additionally, data for hydrogen mass fractions that could not be obtained in this study due to injector sensitivity limitations will be acquired.

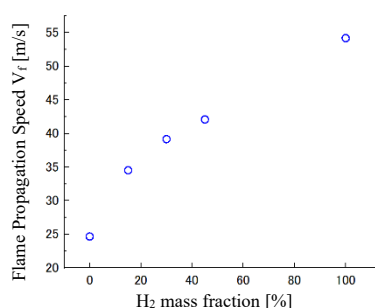


Fig.2 Relationship between hydrogen mass fraction and flame propagation speed

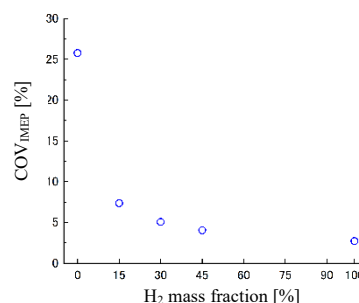


Fig.1 Relationship between hydrogen mass fraction and COV_{IMEP}