

A Study on the Mechanism of Abnormal Combustion Caused by Abnormal Electrical Discharge in a Direct-Injection Hydrogen Engine for Motorcycles

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Hydrogen is a promising carbon-neutral fuel for motorcycle engines; however, its low ignition energy can lead to abnormal combustion phenomena. Furthermore, hydrogen combustion produces fewer ions than gasoline combustion. Consequently, a larger amount of electrical charge remains on the secondary side of the ignition system after combustion because it is not consumed in the flame zone. This residual electrical energy has been reported to induce abnormal electrical discharge, resulting in backfire phenomena. This study investigated the mechanism of abnormal combustion caused by unintended electrical discharge in a direct-injection hydrogen motorcycle engine. Simultaneous in-cylinder visualization from two directions and ignition secondary voltage measurements were conducted to identify the origin and trigger of the phenomenon.

Experiments were performed at 2000 min⁻¹, $\lambda = 1.0$, and advanced fuel injection timing (EOI = -180deg.ATDC). High-speed imaging revealed that pre-ignition originated near the spark plug and propagated throughout the combustion chamber. A brief light emission observed at the spark gap immediately before pre-ignition suggested the occurrence of abnormal discharge (Fig.1).

Simultaneous measurements of ignition secondary voltage showed a sudden drop in residual voltage just before pre-ignition (Fig.2). The results indicate that residual electrical energy remaining in the secondary side of the ignition system after hydrogen combustion caused unintended discharge, which subsequently triggered pre-ignition.

These findings clarify the role of abnormal electrical discharge in inducing pre-ignition in direct-injection hydrogen engines and provide important guidance for improving combustion stability and ignition system design in future hydrogen-powered motorcycles.

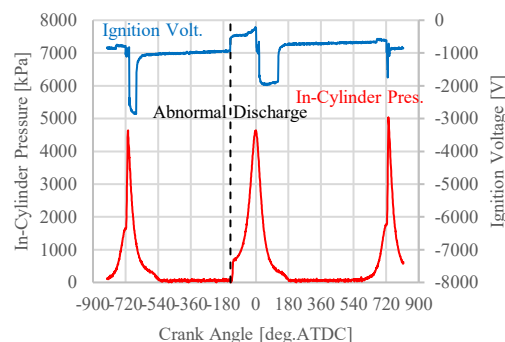


Fig.2 Ignition secondary voltage measurements

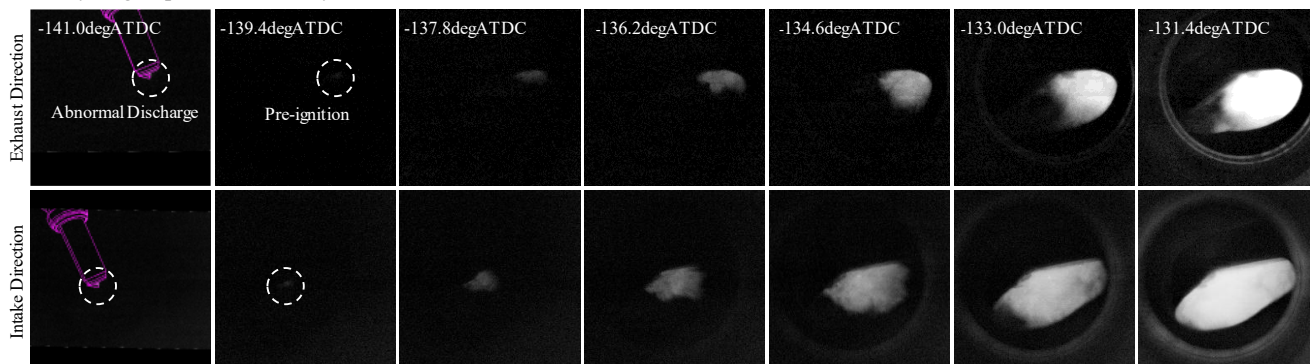


Fig.1 In-cylinder abnormal combustion visualization by simultaneous dual-direction direct imaging