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Estimating spark channel stretch in a flow via the correlation between spark channel length and discharge voltage/current

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Lean or dilute combustion in the passenger car engine has been widely studied to fulfill stringent regulations on the fuel economy and the emission standards over the past decades. Lean combustion in engine cylinders has advantages such as less pumping loss and heat loss each due to the charged intake and the lower temperature during combustion. However, flame propagation in the lean mixture is slower, thus the combustion is more unstable compared to a stoichiometric condition, which leads to bad performance in the aspect of the engine coefficient of variation(COV). The flame speed and the stability of combustion is strongly related to the initial flame phase, and the energy required to form the initial flame kernel is transferred from the spark channel. Various strategies to reinforce the flow in the engine cylinder are adopted to overcome the slow flame propagation in a lean mixture, but this rather causes blowouts or short-circuits of the spark channel which disturb the energy transfer to the mixture around the spark plug. Therefore, it is crucial from both application and academic perspectives to measure and understand the flow around a spark plug and the resulting spark channel stretch.

In the present study, a flow test rig was constructed which can simulate the environments close to the engine TDC conditions(~30bar, ~20m/s), and spark experiments were conducted in the various test conditions with different air flow rates and pressure. The discharge voltage and current were measured, and the spark channel images were acquired utilizing a high-speed camera while the spark ignites. In the other research, the velocity around the spark plug was estimated with the discharge voltage, current and the pressure by assuming that spark channel is formed with a rectangular shape. However, the shapes of the actual spark channel in the test rig and engine cylinders were wrinkled and showed a random pattern rather than a standardized rectangular shape. Therefore, instead of making assumptions about the shape of the spark channel, the length of the spark channel was directly measured through the captured spark image in this study. As a result, correlations between the discharge voltage, current, ambient pressure and the spark length were always valid although the spark stretch rates were distributed with large variance even in the same flow rate conditions. Consequently, the length of spark channel can be estimated via measuring the discharge voltage, current and the ambient pressure without any optical device in engine cylinders. Since spark channel plays a huge role in an initial flame kernel formation, estimating the spark channel stretch can be a fundamental technique to monitor the stability of the combustion in the lean-burn engine.

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