講演番号	143

Relationship between Wall Surface Roughness and Flow Field inside a Spray Flame after Wall Impingement

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KEY WORDS: **Heat engine, Compression ignition engine, Combustion analysis,** Impingement spray flame, PIV [A1]

This study investigates the influence of wall surface roughness on the flow characteristics of an unsteady spray flame after wall impingement, with particular focus on mean velocity and turbulent behavior. The experimental setup, illustrated in Fig. 1, consists of a high-temperature, high-pressure constant-volume vessel equipped with a fuel injection system and particle image velocimetry (PIV) system. An oxygenated fuel, diglyme, was employed to suppress luminous soot formation and enable accurate velocity measurements inside the spray flame. Two impingement walls with different surface roughness (Ra = 0.4 μm and 6.3 μm) were tested under identical injection conditions.

Time-resolved PIV measurements were conducted to capture the velocity fields of the spray flame after impingement. From these data, ensemble-averaged velocity distributions and turbulent kinetic energy distribution were obtained. The results show that the mean velocity near the wall was found to be nearly identical for both surface roughness conditions, despite slight variations in velocity distribution at different radial positions.

To further assess the impact of surface roughness on turbulence, the nondimensional turbulent kinetic energy was evaluated at a near-wall locZ:\04_Workspace\03 論文\いすゞ中研\20260406_JASEation (H = 0.5 mm). No significant difference in turbulent kinetic energy was observed between the two roughness conditions, regardless of injection pressure. The overall trend indicates that surface roughness does not substantially affect turbulence intensity inside the wall-impinging spray flame.

In order to clarifiy the findings, the thickness of the viscous sublayer was estimated based on the experimental velocity profiles, assuming a 1/7th power law for turbulent boundary layers. As shown in Fig. 2, the comparison between viscous sublayer thickness and surface roughness reveals that the viscous sublayer is significantly thicker than the surface roughness.

In conclusion, within the tested range of surface roughness (Ra ≤ 6.3 μm), the wall surface behaves effectively as hydraulically smooth, thereby the influence of surface roughness on both mean flow and turbulence is negligible

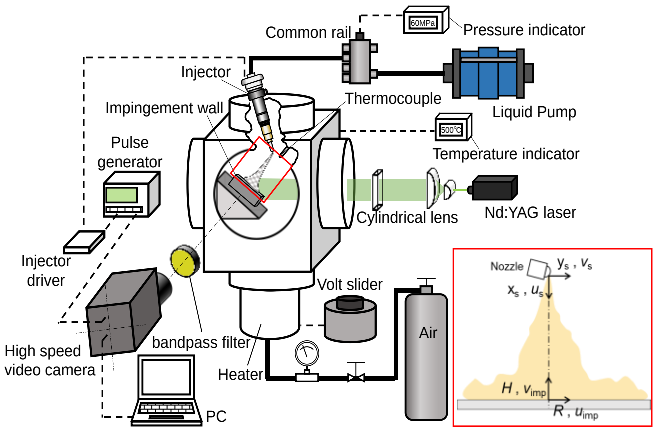

Fig.1 Experimental set-up

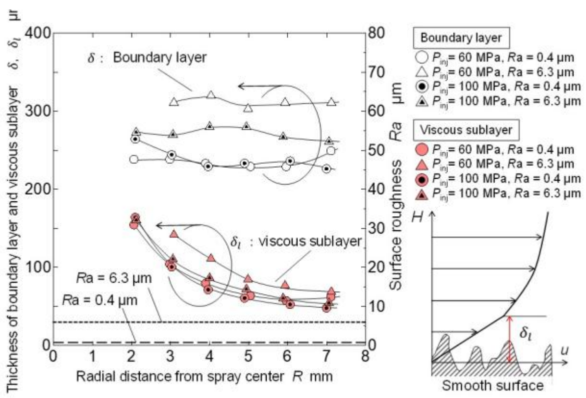

Fig.2 Relationship between viscous sublayer thickness and surface roughness

2026 JSAE Annual Congress (Spring) - Summarized Paper
Issued on May 22, 2026