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Infrared high-speed thermography of combustion chamber wall impinged by diesel spray flame

- Effects of Wall Surface Roughness on Heat Transfer -

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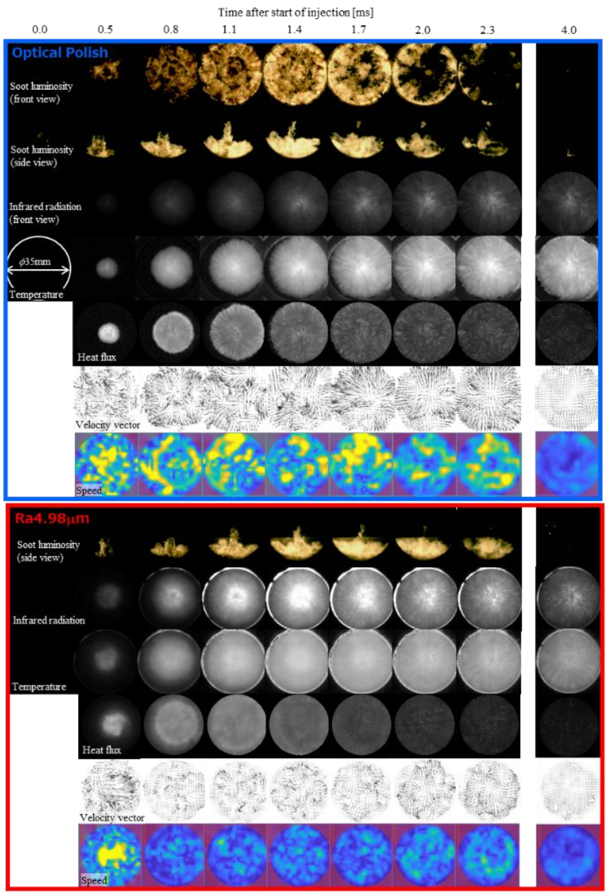
In order to investigate the effect of wall surface roughness on the heat transfer, the inner surface of a quartz window on a constant volume combustion chamber was optical polished or frosted, coated with chromium radiation layer, and vertically impinged by a diesel spray flame. The infrared radiation from the back surface of the coating was visualized with a high-speed infrared camera to obtain temperature and heat flux distributions. The movement velocity of the observed infrared radiation pattern was extracted with FIV (Flame Imaging Velocimetry) analysis.

Figure 1 shows example visualization results of flame luminosity, infrared radiation, temperature distribution, heat flux distribution, infrared radiation pattern moving velocity vector, and moving velocity distribution for optical polished (top, blue) and frosted (bottom, red) wall cases.

The infrared radiation exhibited radially striped patterns extending and waving from the stagnation point, regardless of the wall surface roughness. The emissivity of the coated wall surfaces increased by about 4 times in frosted cases compared to the optical polish case, enabling visualization of the heat transfer phenomena on the wall under more realistic surface roughness conditions and with improved S/N ratio of the imaging.

There was no significant differences in the observed average/maximum temperature and heat flux and general behaviors of the streak patterns between the optical polish and frosted cases. On the other hand, the radially extending high-temperature/high-heat-flux circular regions exhibited unclear contours and flatter distributions around the central stagnation point in the frosted case compared to the optical polish case. The temperature drop and heat flux decay after exhibiting their maximum values were also faster in the frosted case. These results suggest that the frosted wall surface results in a thicker temperature boundary layer near the wall surface and an extended delay from the flame impingement on the wall to the rise in wall temperature.



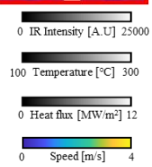


Figure 1 Comparisons of soot luminosity, infrared radiation, temperature, heat flux, infrared radiation pattern movement velocity vector and speed distributions between optical polish and surface roughened wall conditions.

The infrared radiation pattern movement velocity showed a complicated vector distribution and larger velocity around the stagnation point right after the flame impingement likely due to turbulence structure in diesel spray. The turbulence structure dissipated and the velocity distribution converged to an attenuated and smooth radial velocity distribution with the time progress. The attenuation of the velocity was significant in frosted case right after the flame impingement.

The frosted wall firstly promoted stagnation of high temperature flame near the wall surface and heat transfer over larger area, followed by turbulence dissipation and velocity attenuation near the wall resulting in reduced wall heat transfer. On the other hand, the optical polished wall firstly localized the increase in temperature and heat flux by flame impingement around the stagnation point, followed by preserved turbulence and velocity near the wall resulting in enhanced wall heat transfer.