

# Smoothing of Anodic Oxide Film on Piston Top Ring Groove

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In recent years, direct-injection gasoline engines have been required to achieve both improved fuel economy and reduced exhaust emissions. Although gasoline particulate filters are effective for PM reduction, further reduction of PM and PN emissions is still required from the viewpoint of the overall engine system.

Oil behavior around the piston ring and ring groove is considered to be one of the important factors affecting PN formation. In this study, special attention was paid to oil intrusion from the top ring groove into the combustion chamber and the effect on reducing particle number (PN) emissions immediately after engine start was investigated in a direct-injection gasoline engine. The top ring groove is subjected to high contact pressure and high temperature due to sliding against the piston ring, and anodizing is generally applied to suppress aluminum adhesion (Fig. 1). However, the anodized surface tends to become rough after film formation. It was hypothesized that this rough surface promotes oil retention and oil movement within the groove, thereby contributing to the increase in PN emissions immediately after engine start. Based on this hypothesis, the present study examined whether smoothing the anodic oxide film in the top ring groove is effective for reducing PN emissions.

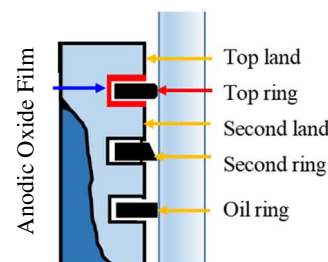


Fig. 1 Schematic of piston and ring

PN measurements were carried out using a four-cylinder direct-injection gasoline engine, K14C-DITC. Surface roughness was evaluated in terms of Ra, Rz, Rpk, and Rk. In addition, rig tests were conducted using piston-material specimens and piston rings to evaluate the wear resistance of the anodic oxide film. As anodizing methods, the conventional DC method and the AC-superimposed method were compared. Furthermore, very-low-pressure shot blasting was also investigated as a post-treatment for further smoothing of the anodized groove surface.

Engine tests under WLTC operation showed that PN emissions were high in the low-mileage range and then rapidly decreased toward a stable level. Oil-drip tests confirmed that PN emissions increased as the amount of oil introduced into the combustion chamber increased. Furthermore, PN emissions tended to decrease as the surface roughness of the ring groove decreased (Fig. 2). Among the roughness parameters, Rpk showed the largest change during the running-in process, suggesting that the peak portion of the surface profile strongly affects oil behavior and PN formation. In this study, Ra 1.0  $\mu\text{m}$  and Rpk 0.5  $\mu\text{m}$  were considered desirable target values.

Rig test results showed that anodizing effectively suppressed aluminum adhesion even after 100,000 impact wear cycles. Compared with the DC method, the AC-superimposed method produced a smoother and more uniform film with lower initial Rpk and superior wear resistance. Furthermore, examination of film thickness and surface roughness suggested that reducing film thickness could further reduce the post-anodizing surface roughness.

Among the several smoothing methods examined, very-low-pressure shot blasting was found to be the most practical. Under optimized conditions, it reduced Ra to 0.71  $\mu\text{m}$  and Rpk to 0.75  $\mu\text{m}$  while causing only a slight change in film thickness (Table 1). These results indicate that smoothing the anodic oxide film, particularly reducing Rpk, improves oil behavior in the top ring groove and contributes to reducing PN emissions immediately after engine start.

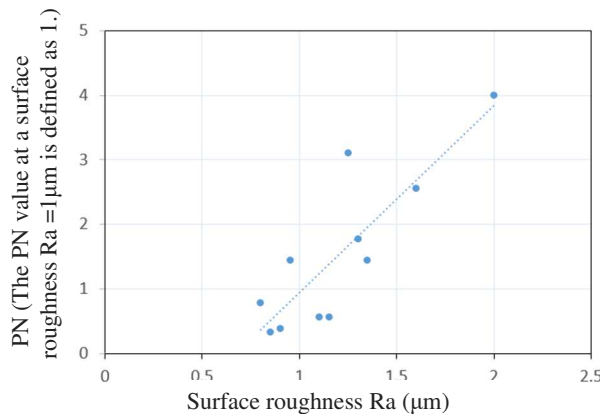


Fig.2 PN emissions vs. surface roughness (Ra)

Table 1 Surface images before and after blasting

