

The Effect of Substrate Grain Size on Coating Microstructure and Bearing Performance in Multilayer Plating Materials for Engine Bearings

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Engine bearings used under increasingly severe operating conditions require overlay materials that provide both conformability and high fatigue resistance. Bismuth (Bi)-based overlays have been widely applied to engine bearings as lead-free overlay materials, and the addition of antimony (Sb) has been reported to improve fatigue resistance through solid solution strengthening of the Bi matrix ⁽¹⁾. Furthermore, multilayer Bi-Sb overlays have been reported to improve oxidation resistance and fatigue resistance by suppressing the formation of Cu-Sb compounds ⁽²⁾. In this study, a multilayer Bi-Sb overlay was investigated as a means of improving fatigue resistance through control of coating microstructure.

A multilayer Bi-Sb overlay with a two-layer structure was formed on a copper-based (Cu-Sn-Bi) bearing alloy by electroplating. Several samples with different lower-layer plating conditions were prepared, while the plating conditions of the upper layer were kept unchanged. The effect of the lower-layer plating conditions on coating microstructure and fatigue resistance was investigated. The coating microstructures were characterized by cross-sectional scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD). Fatigue resistance was evaluated using a bearing rig test under dynamic loading conditions, and the reliability of the developed material was further confirmed through an engine durability test.

Figure 1 shows the EBSD evaluation results of the overlays. Cross-sectional observations showed that the coating microstructure changed with the lower-layer plating conditions. EBSD analysis also showed that the average grain size of the overall overlay became smaller in the order of Sample 1, Sample 2, and Sample 3. In electric plating, grain boundaries and other active sites on a substrate are known to influence nucleation behavior ⁽³⁾. Therefore, changes in the microstructure of the lower layer were considered to affect the nucleation behavior during deposition of the upper layer, resulting in differences in coating microstructure and average grain size. These results indicate that the coating microstructure and average grain size of the Bi-Sb overlay can be controlled through the lower layer.

Figure 2 shows the mass loss of each sample after fatigue testing in a bearing rig test. The mass loss of Samples 2 and 3 was lower than that of Sample 1, showing the same tendency as the bearing appearance after testing. These results indicate that reducing the average grain size of the overlay suppresses fatigue damage and improves the fatigue resistance of the Bi-Sb overlay.

To confirm practical applicability, the developed Bi-Sb multilayer overlay was applied to a diesel engine connecting-rod bearing and subjected to a durability test. The overlay remained on the bearing surface after testing, demonstrating sufficient reliability under actual engine operating conditions.

These results suggest that controlling the microstructure of the lower layer to influence upper layer nucleation and grain growth provides a new material design strategy for improving the fatigue resistance and durability of the Bi-Sb overlay for engine bearings.

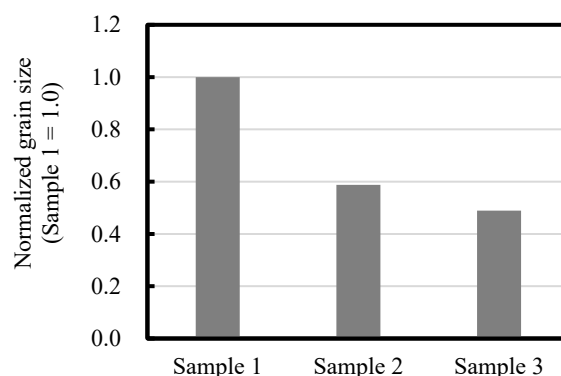


Fig.1 EBSD Evaluation of Grain Size

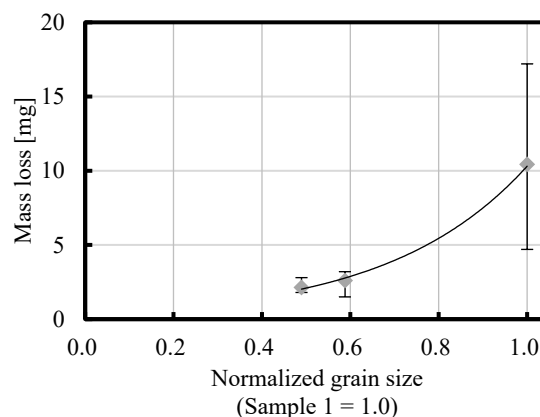


Fig.2 Mass Loss After Fatigue Testing