

Friction Reduction Technology for Engine Journal Bearings Based on Oil Film Shear Stress

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Friction loss reduction in engine bearings remains an important issue for improving fuel efficiency and contributing to carbon neutrality. In conventional studies, many friction-reduction technologies have focused on mixed and boundary lubrication regimes. In contrast, friction reduction under hydrodynamic lubrication has often been limited to approaches such as the use of low-viscosity oils and dimensional optimization of bearings. However, under typical urban driving conditions of internal combustion engines, engine journal bearings are frequently operated in the hydrodynamic lubrication regime. Therefore, reducing friction loss in this regime is also important.

In this study, friction reduction mechanisms under hydrodynamic lubrication were investigated by focusing on shear stress in the oil film. According to Newton's law of viscosity, the shear stress τ in the oil film is expressed as

$$\tau = \eta \times \frac{\partial v_x}{\partial y}$$

where η is the absolute viscosity, v_x is the fluid velocity in the sliding direction, and y is the coordinate in the film-thickness direction. This relationship indicates that friction loss can be reduced by decreasing the lubricant viscosity or by reducing the velocity gradient in the oil film. Based on this concept, several approaches were evaluated, including oil-repellent surface treatment, control of bearing surface hardness, and reduction of bearing surface roughness.

A newly designed friction test rig was used to measure the small friction torque generated under hydrodynamic lubrication conditions. The housing was supported by a free-rotation structure, and the reaction torque was measured using a load cell. This structure enabled the friction torque between the shaft and bearing to be evaluated while reducing the influence of friction in the supporting components. The test conditions were selected with reference to engine speeds corresponding to urban driving conditions. The rotational speed was varied from 500 to 2000 rpm, the oil temperature was set to 50 °C, and 0W-20 engine oil was used. The bearing specimens were engine journal bearings with an outer diameter of 54 mm. The evaluated specimens included a reference polymer-overlay bearing, an oil-repellent polymer-overlay bearing, a low-hardness polymer-overlay bearing, and a smoother polymer-overlay bearing.

The experimental results showed that the oil-repellent treatment on the shaft surface had a limited effect, whereas the oil-repellent treatment on the bearing surface reduced friction under relatively thin-film conditions. This result suggests that boundary slip at the bearing surface may reduce the shear resistance in the oil film. The low-hardness polymer-overlay bearing reduced friction over the evaluated operating range. This reduction is considered to result from increased surface deformation, which enlarges the load-supporting area, decreases local oil-film pressure, and increases oil film thickness. In addition, reducing the bearing surface roughness also decreased friction. Even when the film thickness ratio was sufficiently large for hydrodynamic lubrication, local film thinning caused by surface roughness may increase shear resistance. Therefore, smoother bearing surfaces are effective for suppressing such local increases in shear stress.

These results indicate that friction loss in the hydrodynamic lubrication regime can be reduced by appropriate design of bearing surface properties. In particular, bearing surface hardness, oil repellency, and surface roughness are important factors for controlling oil-film shear stress. The present study demonstrates that surface-property optimization is an effective strategy for reducing friction loss in engine journal bearings operated under hydrodynamic lubrication conditions.

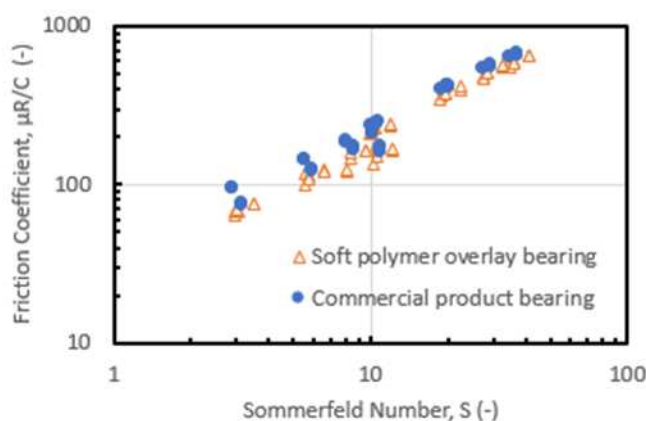


Fig. 1 Stribeck curve of the commercial product bearing and soft polymer overlay bearing.