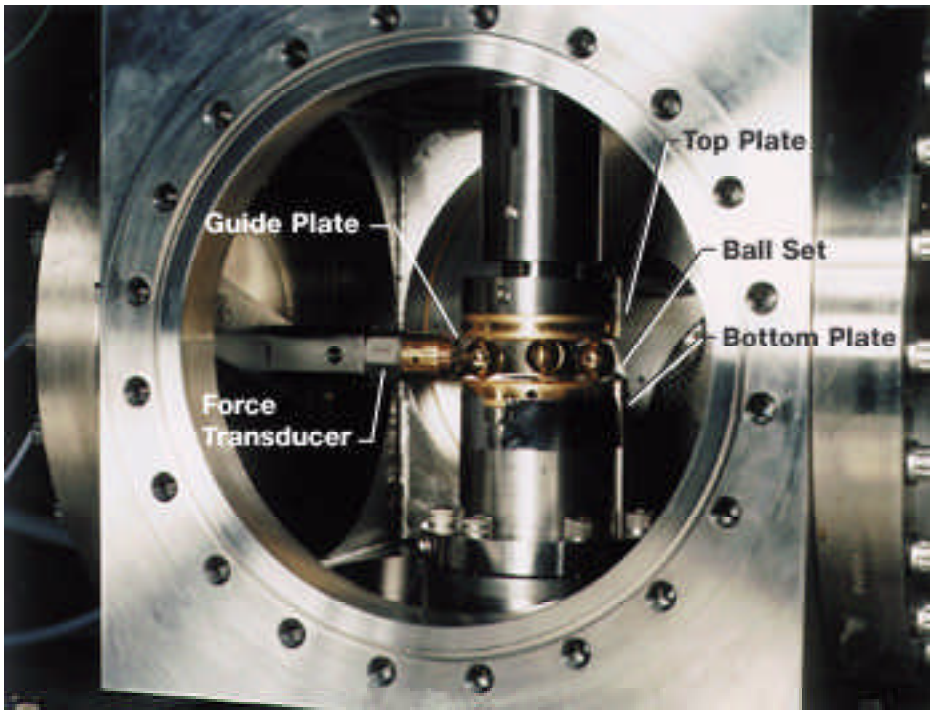
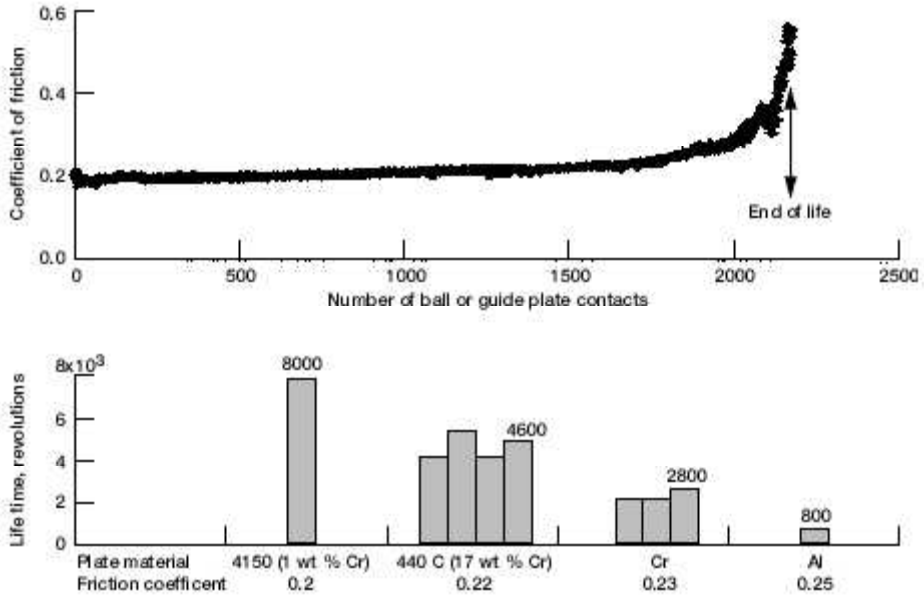
Tribometer for Lubrication Studies in Vacuum



Ball-on-plate tribometer.

The NASA Lewis Research Center has developed a new way to evaluate the liquid lubricants used in ball bearings in space mechanisms. For this evaluation, a liquid lubricant is exercised in the rolling contact vacuum tribometer shown in the photo. This tribometer, which is essentially a thrust bearing with three balls and flat races, has contact stresses similar to those in a typical preloaded, angular contact ball bearing. The rotating top plate drives the balls in an outward-winding spiral orbit instead of a circular path. Upon contact with the "guide plate," the balls are forced back to their initial smaller orbit radius; they then repeat this spiral orbit thousands of times. The orbit rate of the balls is low enough, 2 to 5 rpm, to allow the system to operate in the boundary lubrication regime that is most stressful to the liquid lubricant.



Top: Test of Fomblin Z-25 on 440C steel. Bottom: Response of Fomblin Z-25 showing dependence on plate material.(Fomblin Z-25 is a tradename owned by the Montefluos, Montedison Group, of Milan, Italy.)

This system can determine the friction coefficient, lubricant lifetime, and species evolved from the liquid lubricant by tribodegradation. The lifetime of the lubricant charge is only a few micrograms, which is "used up" by degradation during rolling. As shown in the top graph, the friction increases when the lubricant is exhausted. The species evolved by the degrading lubricant are determined by a quadrupole residual gas analyzer that directly views the rotating elements. The flat races (plates) and 0.5-in.-diameter balls are of a configuration and size that permit easy posttest examination by optical and electron microscopy and the full suite of modern surface and thin-film chemical analytical techniques, including infrared and Raman microspectroscopy and x-ray photoelectron spectroscopy. In addition, the simple sphere-on-a-flat-plate geometry allows an easy analysis of the contact stresses at all parts of the ball orbit and an understanding of the frictional energy losses to the lubricant. The analysis showed that when the ball contacts the guide plate, gross sliding occurs between the ball and rotating upper plate as the ball is forced back to a smaller orbit radius. The friction force due to gross sliding is sensed by the piezoelectric force transducer behind the guide plate and furnishes the coefficient of friction for the system.

This tribometer has been used to determine the relative lifetimes of Fomblin Z-25, a lubricant often used in space mechanisms, as a function of the material of the plates against which it was run. The balls were 440C steel in all cases; the plate materials were aluminum, chromium (Cr), 440C steel (17 wt % Cr), and 4150 steel (1 wt % Cr). As shown in the bar graph, the lifetime is greatest for the plate material with least chromium, thus implicating chromium as a tribochemically active element attacking Fomblin Z-25.

Bibliography

Pepper, S.V.; Ebihara, B.T.; and Kingsbury, E.: A Rolling Element Tribometer for the Study of Liquid Lubricants in Vacuum. NASA TP-3629, 1996.

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