and Gerby, 1955) has been cited simply to substantiate the statement that it is the least refractory of the ceramic counterfaces investigated. No implication regarding the activation of another potential wear mechanism is intended. Thirdly, it follows from first principles arguments that adsorbed species would tend to desorb at increasingly elevated temperatures and could result in the transition from one active wear mechanism to another or from a regime of mild wear to one of severe wear. As noted in the paper, a mild to severe wear transition has been documented by Ishigaki et al. (1986) for self-mated Si$_3$N$_4$. While monolithic Si$_3$N$_4$ is known in general to be a highly plastic-strain-intolerant material, the sliding conditions imposed during the reported investigation are believed to have produced multiaxial compression as well as elevated temperatures which, in combination, could lead to plasticity. Therefore, it is believed that, for the stated materials and conditions, the principal wear or material degradation mechanism is that of plastic deformation due to the combination of thermal softening and a multiaxial, compressive stress state.

The motivations for choosing 28 wt pct ZrO$_2$ in Al$_2$O$_3$ are twofold. First, it represents a level which is more than sufficient to accomplish the desired dispersion toughening (Heuer et al., 1982). Second, it is a commercially available composition which is obtainable readily in the form of the 6.35 mm spheres used as the counterfaces in this investigation.

Finally, self-mated, diffusion-borided alloy 6B was investigated but not reported. Compared to the sintered Al$_2$O$_3$ counterface, the ball wear scar diameters for the self-mated, borided 6B were a factor of approximately 2× larger (2× poorer performance). Compared to the hot-pressed Si$_3$N$_4$ counterfaces, however, the diffusion-borided 6B was a significantly inferior counterface, being a factor of approximately 5× larger in wear scar diameter. Moreover, the reported study was intended to be a basic study to determine the wear behavior of the wrought alloy 6B against a common class of counterfaces.

Additional References


S. Bair and W. O. Winer

The author is to be congratulated on another contribution to the understanding of lubricant rheology at very high pressures and shearing rates. It is particularly interesting to see the agreement in results between our experiments and the author’s, where both observation times and pressurization rates differ by eight orders of magnitude. Apparently, compressional viscoelasticity has little effect on the limiting shear stress at pressures above the glass transition pressure.

The author may have misinterpreted our data on temperature sensitivity of limiting stress (Bair and Winer, 1979a, Fig. 14(a)). Our data indicate a lower temperature sensitivity of $T_u$ above $T_g$ than below $T_g$. However, the ultimate shear strength (Fig. 11 of the reference) of the solid was shown to rapidly decrease as temperature increased to $T_g$ in a constant shear rate experiment due to viscous effects. Since the author’s results were obtained at temperatures well below $T_g$, the low rate viscosity must be in excess of $10^7$ Pa·s (Yasutomi et al., 1984). For the shear rates reported by the author the dimensionless shear rate is over 10$^4$ (Bair and Winer, 1979b), indicating that the limiting shear stress has been obtained and that variations in viscosity with temperature will have no effect on the stress obtained. Our limited data on this lubricant indicates that the limiting shear stress will decrease by 20 to 50 MPa for the temperature increases reported here (50°C), easily explaining the small differences between the author’s results and others.

Author’s Closure

The author would like to express his appreciation of this very interesting discussion by S. Bair and W. O. Winer. In responding to the discussers’ comments, the author will treat the second paragraph of the discussion first, since this is the main point.

The author wishes to thank the discussers for pointing out the misinterpretation of their data on the temperature sensitivity of the limiting stress of the traction fluid. They clearly demonstrate an increased temperature sensitivity of the limiting shear stress for this material below $T_g$. The author further agrees with the discussion in that the limiting shear stress has been attained during the plate impact experiments at these high strain rates, and that therefore the temperature sensitivity of viscosity has no bearing on the measured stress levels. Finally, it is gratifying to note that the discussers’ data on the temperature sensitivity of the limiting shear stress indicate that the difference in stress levels between the author’s results and those of other workers may be adequately explained in these terms. Such an explanation then reinforces the statement in the original paper and in the first paragraph of the discussion that compressional viscoelasticity appears to have little effect on the limiting shear stress at these pressures.

On the Rheology of a Traction Fluid

Scott Bair and W. O. Winer

Drs. Jacobson and Hoglund have presented a device for imposing a shear deformation on a sample of liquid lubricant at very high pressures (up to 2.2 GPa) and reported the shear