

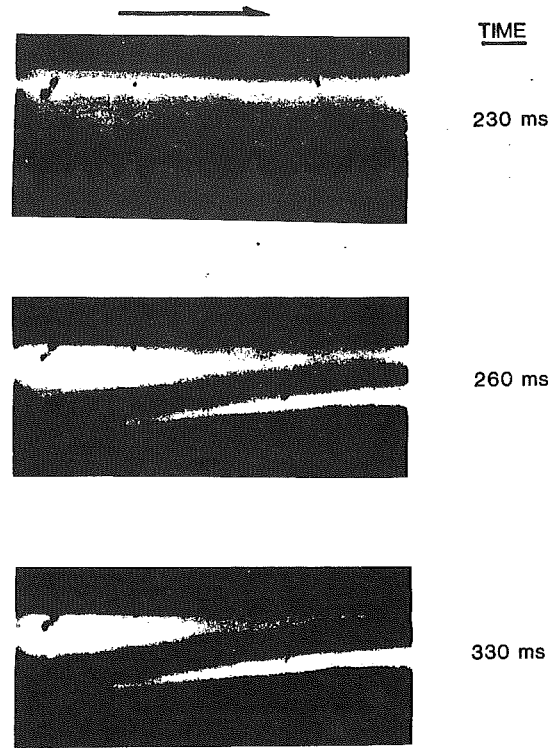
plotted as a function of shear rate $\dot{\gamma}$ and typical results are quoted by the authors in Fig. 1 of their paper. There is some dispute as to whether the behavior is better expressed by an Eyring type relation or by a semi empirical law of the type given in the paper by Eq. (1).

The authors have wisely side-tracked this issue by adopting the approach (much favored by the late Philip Bowden) that direct observation of what goes on in the film during shear may be more important than theoretical modeling. The experiments the authors describe are outstanding in providing direct viewing of the liquid while it is sheared. Ingenious techniques show that there is no slip at the walls. Perhaps the most striking observation is that above some critical shear rate, where the liquid ceases to behave in a Newtonian manner, shear bands are observed in the film implying that the material is below its glass transition temperature. However, this does not agree with quasi-static experiments which show that the glass transition occurs at appreciably lower temperatures than those at which shear bands appear in the film. Evidently the glass-transition depends on shear rate as well as on other variables. This is well known in polymer physics: A specimen subjected to slow deformation flows in a viscoelastic or plastic manner; at high rates of deformation it behaves like an elastic (brittle) solid. The reason is that, in essence, the glass transition marks the stage where large-scale displacement of the molecules is restricted or inhibited and only small portions of the molecule can make very limited movements. High pressures, low temperatures, and high deformation rates are the major factors restricting molecular flow.

The formation of shear bands in a regime which appears to be above the glass transition temperature will undoubtedly attract further study. In particular, those working in E.H.L. will want to know if shear bands may be one mode of failure of E.H. films. For the material scientist the shear band process and the direction of shear demand explanations in terms of material and molecular mechanisms. It might even be possible by "trapping" reflections from the shear bands to apply Raman and similar spectroscopies and so determine the distortional state of molecules in the shear band. In this important paper the authors have opened up a new and exciting field for both lubrication engineers and materials scientists.

Authors' Closure

The authors appreciate the kind comments by Dr. Tabor. Shear bands are observed in glassy polymers when the solid samples are examined after the shearing experiment. It is possible that they have not previously been observed in liquids



5P4E, 22°C INITIAL TEMP, 172 MPa

Fig. 16 Thermally induced shear band in a liquid lubricant under pressure. $B_r = 6.75$, 150 μm film

above the glass transition temperature because of the great difficulty in observing a liquid film at very great shear stress and, of course the bands do not persist for long in the liquid. In any event, we have avoided the liquid/solid issue by modeling the process using the Mohr-Coulomb failure criterion, which provides the explanation for the variation of critical stress for band nucleation with pressure. While investigations into mechanically induced shear localization are ongoing, a very different type of shear band has been observed. For stress controlled high Brinkman number flow ($B_r > 3.5$), at sufficiently long times, a thermally induced band appears near the mid-plane of the film, similar to "adiabatic" shear bands observed during high-rate deformation in metals. See the accompanying figure.