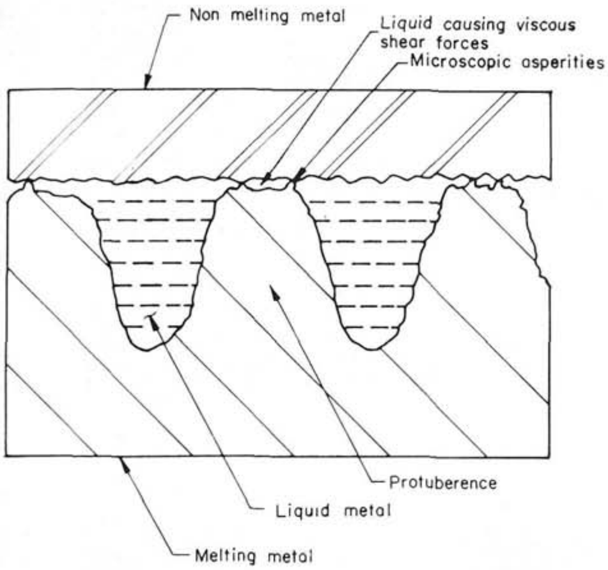

Fig. 8 Interfacial model

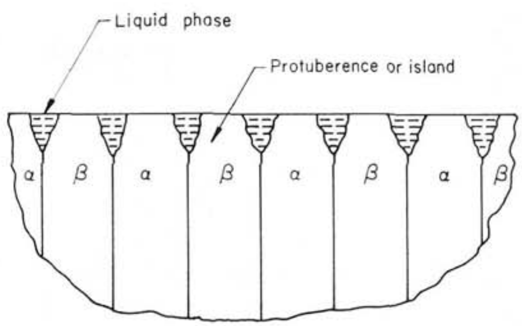

Fig. 9 Model of melting of a binary eutectic

veloped earlier. The results suggest one possible interfacial model as shown in Fig. 8, in which the steel surface consists of the usual microscopic asperities on a nominally smooth surface. The surface model for the melting solid, however, contains severe irregularities (which are given the name "protuberances" to distinguish them from the much smaller microscopic asperities). Superimposed on the protuberances is a second order of roughness, of the same order of magnitude as the asperities on the steel. Molten metal fills the space between the solids, and the greatest portion of the viscous shear occurs between the top of the protuberances and the steel. In this model, wear will be due to melting of the solid, and tearing and breaking away of portions of the protuberances. A basis for the formation of such protuberances may be found in work by Saratovkin [7] in which the melting of a eutectic is attributed to contact fusion, which, in the case of a quaternary alloy, is shown to occur at the point of contact of the four solid phases. This mechanism is illustrated schematically for a binary eutectic in Fig. 9, which shows how the melt can be initiated at the phase boundaries, leaving islands (protuberances) of α and β phases surrounded by liquid. Experiments with macroscopic sections of lead and tin showed that this is indeed the way in which melting occurs.

In all tests the minimum friction always occurred just after the onset of melting, and by the following argument this is the point when conditions most nearly approach the ideal melt-lubrication theory.

During the transition from solid friction, the molten material would be formed at isolated spots, would then form isolated pools, and would finally cover the whole surface, forming a continuous or nearly continuous molten film between the two solids. At this point there would be a liquid film on a substantially flat substrate. However, as melting progressed, deep channels would be formed, thus allowing easy egress for the fluid and preventing support of the load by the fluid film, and the condition portrayed in the interfacial model would be attained and solid-to-solid contact would be present again.

References

1 Siebel, E., "Friction Tests at Higher Temperatures in an Investigation of 'Schmelzflussschmierung'," Translated by E. D. Tingle. Translation No. 391, Ministry of Supply, Millbank, London S.W.1, November, 1951.

2 Gibson, A. H., *Osborne Reynolds and His Work in Hydraulics and Hydrodynamics*, Longmans, Green and Co., London, 1946.

3 Bowden, F. P., and Tabor, D., *The Friction and Lubrication of Solids*, Clarendon Press, Oxford, 1964.

4 Sternlicht, B., and Apkarian, H., "Investigation of Melt Lubrication," *ASLE Transactions*, 1960, pp. 248–255.

5 Sauer, F., "Fundamental Mechanism of Wear and Friction of Unlubricated Metallic Surfaces at High Sliding Speeds," SRI Project No. SU-1494, Stanford Research Institute, December 11, 1956.

6 Allen, C. W., "Melt Lubrication of an Annular Thrust Surface," PhD thesis, University of California, Davis, California, 1966.

7 Saratovkin, D. D., *Dendritic Crystallization*. Translated from the Russian by J. E. S. Bradley, Consultants Bureau, Inc., New York, 1959.

DISCUSSION

H. G. Rylander[3]

The authors are to be commended upon attacking such a proven difficult problem. Even though the theory and experiment disagree, both add to the information on this subject. The authors point toward a more perfect interfacial model and it is in this respect that I would like to make reference back to the theoretical model.

Starting with equation (1), the film thickness h is also a function of both r and θ. Mating surfaces operating with boundary lubrication will wear to exhibit characteristic waviness in the r and θ directions. These characteristic surfaces could be included as a part of the derivation. (Some pictures of the actual surfaces after melt would be helpful in the paper.) Waviness would produce higher theoretical friction due to thinner films at the load support points.

Fig. 2 is interesting in that the data spread is as expected with this type of experiment. It also shows larger differences between theoretical and experimental values as speed is increased which is as expected unless the experimental apparatus is quite rigid and operated below resonant conditions.

Authors' Closure

The authors wish to thank Professor Rylander for his discussion of their paper. There is, of course, a distinct possibility that the film thickness is also a function of θ. However, obtaining accurate data on this waviness during melting is difficult; therefore this was omitted in the first simplified analytical model. As Professor Rylander mentions, waviness could produce higher friction due to the thinner film. However, waviness could possibly introduce a hydrodynamic effect leading to an overall increase in the average film thickness.

An examination of the specimen after the test showed no evidence of large scale circumferential waviness but conditions changed drastically during slider removal and solidification of the surface that any waviness present during melting may have been obscured by the subsequent solidification.

[3] Professor, Department of Mechanical Engineering, the University of Texas, Austin, Texas. Mem. ASME.