DISCUSSION

J. W. Kannel[2]

Since the foundation for the authors' analysis is the assumption that the rate of energy dissipation is constant across the film (Assumption 10), I would appreciate it if they would give us some rationale for this conjecture. Also, I get lost between Assumption 10 and equation (2) for the temperature distribution in the film. Some details of the logic there are also in order. In analyses conducted at Battelle, we have found it convenient to assume that the viscosity of the lubricant is related to the average temperature across the film (as opposed to the authors' Assumption 10). This assumption yields film-thickness predictions that are in very good agreement with more exact types of solutions.

The authors' equation (1), is, of course, an inadequate model for lubricant temperature effects, especially for a wide range of temperatures. Traction predictions using this model [9] (see Fig. 7) show a considerably different dependence on sliding speed than do predictions using the more common model

$$\mu = \mu_0 \exp\left(\gamma p - \alpha T\right) \qquad (51)$$

which causes a peak to occur in the traction slip curve. Table 1 illustrates the difference between predictions of the author and our predictions using the equation (51) model. At low values of L the two predict the same effect. However, for very high values (i.e., high temperature variations) errors of nearly a factor of two may occur.

Additional Reference

9 Kannel, J. W., and Walowit, J. A., "Simplified Analysis for Traction Between Rolling-Sliding Elastohydrodynamic Contacts," JOURNAL OF LUBRICATION TECHNOLOGY, TRANS. ASME, Series F, Vol. 90, No. 1, Jan. 1971, pp. 39–46.

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Table 1 Comparison between author's prediction and prediction using viscosity model of equation (1) for $G = 4$

Thermal Loading (L)	H_0 (Fig. 5)	H_0 [using equation (2)]
0	4.	4.
1	2.6	2.6
3	2.	1.9
5	1.6	1.4
10	1.3	1.1
30	0.8	0.5
100	0.5	0.27
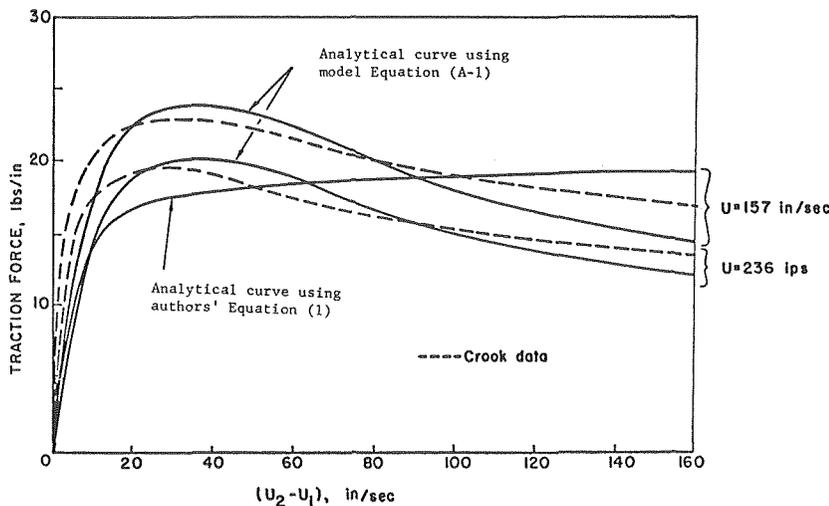
Authors' Closure

As mentioned in the paper, the assumption of uniform energy dissipation across the film simplifies the derivation of the thermal Reynolds' equation substantially. The distribution of energy dissipation across the film does not appear to have a major effect on the calculated pressure gradients. The approach used in the present work yields film thickness predictions which are in close agreement with more exact analyses. This is evidenced by the excellent agreement between the elastohydrodynamic analysis of Murch and Wilson [10] (which uses the present approach) and the analysis of Cheng [11].

The temperature distribution of equation (2) follows directly from assumptions (10) and (11). The rate of energy dissipation E is constant across the film and conduction along the film and convection are neglected. Thus the temperature T is given by

$$\frac{\partial^2 T}{\partial z^2} = -\frac{E}{k} \qquad (52)$$

Double integration of equation (52) with substitution of the boundary conditions $T = T_s$, $z = \pm h/2$ yields equation (2).

The authors agree with Mr. Kannel as to the unsuitability of their viscosity model for large temperature ranges. The exponential model he proposes is much better for practical lubricants. Wilson and Wong [11] have developed the thermal Reynolds' equation for the exponential viscosity model in the case of no sliding. Mahdavian [12] has extended this work to include the effects of sliding. Wilson and Mahdavian [13] have used Mahdavian's equation in a plastohydrodynamic inlet analysis and obtain results very close to those given by Mr. Kannel. This is further proof of the validity of the energy assumption.

In conclusion the authors would like to thank Mr. Kannel for his thoughtful discussion of their work.

Additional References

10 Murch, L. E., and Wilson, W. R. D., "A Thermal Elastohydrodynamic Inlet Zone Analysis," to be published in JOURNAL OF LUBRICATION TECHNOLOGY.

11 Cheng, H. S., "A Refined Solution to the Thermal E. H. L. of Rolling and Sliding Cylinders," Trans. ASME, JOURNAL OF LUBRICATION TECHNOLOGY, TRANS. ASME, Series F, Vol. 95, No. 4, Oct. 1972, pp. 417–426.

12 Wilson, W. R. D., and Wong, C. J., "Analysis of the Lubricant Film Formation Process in Plane Strain Forging," ASME Paper No. 74-LubS-13, presented at the Lubrication Symposium, Key Biscayne, Fla., to be published in JOURNAL OF LUBRICATION TECHNOLOGY, 1974.

13 Mahdavian, S. M., "A Refined Thermal Reynolds' Equation," submitted to JOURNAL OF LUBRICATION TECHNOLOGY, 1974.

14 Wilson, W. R. D., and Mahdavian, S. M., unpublished work, see also discussion of "A Hydrodynamic Lubrication Theory for Strip Rolling including Thermal Effects," by Dow, T. A., Kannel, J. W. and Bupara, S. S., ASME Paper No. 74-LubS-8, presented at Lubrication Symposium, Key Biscayne, Fla., to be published in JOURNAL OF LUBRICATION TECHNOLOGY, 1974.

Fig. 7 Comparison of Crook data with simplified traction calculations