order to better understand the emulsion EHL mechanisms. It was found, as a result of our first attempt in this direction, that the destabilized emulsions at lower pH values can form significantly larger and more stable oil pool as well as thicker films in all of these three regions.

Acknowledgments
The authors would like to sincerely thank many of our colleagues, especially S. Sheu and R. A. Reich, for their valuable discussions during the present study. Also, we would like to acknowledge R. A. Trottier of our Analytical Chemistry Division for his contribution in measuring the oil droplet sizes.

References
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DISCUSSION

S. R. Schmid and W. R. D. Wilson

The authors are to be congratulated on a fine piece of experimental work, which adds greatly to our stock of information on the film forming capability of emulsions. While we agree that further efforts are necessary to understand lubrication by emulsions, we believe that we can go a long way towards explaining the present data by using existing theoretical models.

At low speeds the present system apparently relies on a plated out pool of oil in the inlet region to supply essentially pure oil to the conjunction. The pool of oil is partly pushed to the sides of the contact zone, as it passes, so that the film at the trailing edge appears as a valley bounded by two ridges. The amount of lubricant which returns to the inlet zone is determined by the ability of the oil to flow back into the path of the bearing, and depends upon a number of properties including surface tension and speed. At low speeds there is sufficient time for the pool to completely reform before the next passage of the contact. The result is that the system is flooded and the film thickness is close to that formed by pure oil. In this regime the film thickness increases with speed as expected from EHL theory.

As the speed is increased there is less time for the pool to reform and thus the inlet becomes starved of pure oil. This is a well known problem in high speed bearings which has been analyzed by Chiu (1974). As speed is increased, starvation also increases and the film thickness decreases. Figure D1 compares the predictions of Chiu's theory with selected point contact results from the present paper. It is evident that there is rather close agreement, at least at a qualitative level. The theory also explains why there is a range where the film thickness is greater for point contacts than for "line" (actually highly elliptical)
contacts. It is more difficult for the lubricant to flow back in a highly elliptical contact.

At even higher speeds, the contact can no longer rely on the oil pool to recover and to provide essentially pure oil. Thus, it must turn to the jetted-on emulsion. This is where the dynamic concentration model originally proposed by Sakaguchi and Wilson (1984) and developed and refined by Wilson, Sakaguchi and Schmid (1993) should be applicable. Contrary to what is stated in the paper under discussion, this does not treat the case where an oil pool is present. Rather it treats the case where the emulsion is concentrated by the action of viscous forces as it passes into the high pressure conjunction.

It is difficult to apply the dynamic concentration model directly to the point contact case but we can apply it to the line contact case. Figure D2 compares its predictions with some of the present measurements in line contact. A capture coefficient $C$ of 0.2 was used in making these predictions. It is evident that there is substantial agreement between the dynamic concentration theory and the film thickness data at high speeds.

We can also apply the theory to point contact if we assume that the starvation factor to be applied to the film thickness is the same in line contact for the same droplet size and concentration. The result is also shown in Fig. D1. Again there seems to be reasonable agreement.

The most important application of emulsion lubrication theory is to metal rolling. This normally takes place at speeds above 1 m/s where it is not unreasonable to expect that the dynamic concentration process is the active lubrication mechanism. This is supported by film thickness measurements by Schmid and Wilson (1993) in rolling aluminum.

### Additional References


### Authors' Closure

The authors greatly appreciate the comments and discussion by Dr. Steven R. Schmid and Dr. William R. D. Wilson, who have extensive knowledge and experience on emulsion lubrication. Emulsion lubrication is a very complicated problem involving chemical and physical interaction at the interfaces among fluid phases and solid surfaces. Although this makes modeling work very difficult, continuous efforts have resulted in significant progresses recently. The numerical results presented in the above discussion are very interesting and show great potential for further development. The authors believe that direct collaboration between experimental and theoretical modeling work is needed in order to develop better understanding and predictive models for industrial applications.