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GEOMETRICAL CONSIDERATIONS FOR DEBRIS ENTRAPMENT IN CLOSED CONTACTS

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ABSTRACT

Unlubricated contact of metallic surfaces is widely found in everyday applications. In these contacts a part of the wear debris is trapped between the wearing surfaces, creating a wear debris bed. Many researchers have reported that such a bed provides a degree of protection against further wear with wear decreasing with increased debris entrapment and vice versa (1-5). This raises the question of what governs debris entrapment. Zmitrowicz (6) explains entrapment through the disparity of length-scales between the contact (dimensions of order of mm) and debris particles (dimensions order of μm). Given this, it is intuitively expected that entrapment is correlated with the ratio of contact size to average particle size (7). In annular contacts the 'length' in the direction of sliding is infinite. Therefore, it can be hypothesized that the contact width to average particle diameter is likely to govern debris entrapment. Noting the widely accepted notion that 'more entrapment = less wear' it was further hypothesized that wider annuli would wear less, due to improved entrapment, all other parameters being held constant.

To test this hypothesis, 60mm diameter annuli of EN1A steel with width 1-4mm were placed in contact and subjected to oscillating rotation with equal displacement amplitude, frequency, contact pressure and total distance slid. This systematically tested the influence of annulus width on wear. The results showed that the wear mass per unit area of contact was constant to within +/- 20% and showed no trend with annular width.

To explain this observation, the form of the radial velocity profile in the debris flow was estimated by considering mass conservation and the average time from particle generation to ejection from the contact was calculated. This average entrapment time was found to have no direct dependence on contact width. It is concluded that debris entrapment is not dependent on the geometry of the annular contact and correspondingly that mass loss per unit area is independent of geometry, consistent with our observations.

This explains the negative experimental result, but also opens a potential opportunity. If debris ejection does not depend on the contact width to particle size ratio, annular contacts are 'wear-similar' in the sense that the wear per unit area is approximately equal as long as local contact conditions (contact pressure, slip amplitude, and speed) are equal. An annular contact could thus be simulated in a laboratory by a contact of different dimensions, simply by appropriately scaling other parameters.

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REFERENCES

1. *The influence of surface hardness on the fretting wear of steel pairs—Its role in debris retention in the contact.* **Lemm, J.D., et al.** 2015, Tribology International, Vol. 81, pp. 258-266.

2. *Effect of test conditions on the temperature at which a protective debris bed is formed in fretting of high speed steel.* **Hayes, E.K. and Shipway, P.H.** 2017, Wear, Vols. 376-377, pp. 1460-1466.

3. *Fretting wear mapping: the influence of contact geometry and frequency on debris formation and ejection for a steel-on-steel pair.* **Warmuth, A.R., Shipway, P.H. and Sun, W.** 2015, Proceedings of the Royal Society.

4. *Third Particle Ejection Effects on Wear with Quenched and Tempered Steel Fretting Contact.* **Hintikka, Jouko, Lehtovaara, Arto and Mäntylä, Antti.** 2016, Tribology Transactions, pp. 70-78.

5. *Unlubricated reciprocating wear of stainless steel with an interfacial air flow.* **Leheup, E. R. and Pendlebury, R. E.** 1991, Wear, Vol. 148, pp. 351-372.

6. *Wear Debris: A Review of Properties and Constitutive Models.* Zmitrowicz, A. 2005, Journal of Theoretical and Applied Mechanics, pp. 3-35.

7. *Wear modelling and the third body concept.* **Fillot, N, Iordanoff, I and Berthier, Y.** 2007, Wear, Vol. 262, pp. 949-957.

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