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DISCUSSION

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The authors have delved into the very interesting, but complex area of the mechanisms involved in self-lubricating bearing materials. These studies have generated additional data that leads to a greater understanding of the strengths and weaknesses of these type materials. The use of the powerful tools such as SEM, EDAX, and ESCA are providing the long needed link between friction and wear tests and the understanding of the fundamental mechanisms that govern the behavior of solid or dry lubricants. I can only urge them to continue these type studies with other dry lubricating materials to determine whether similar mechanisms and behavior are observed that may lay a sound, fundamental basis that all future applications can take advantage of.

Reading and studying this paper has generated some questions in my mind that hopefully the authors have already considered. If not, maybe they will stimulate further studies along these lines that may lead to new conclusions and greater understanding. First of all, the third body formation has been described as the transferring of material from the parent body (Liner) to the counterface and back to the liner surface, or simultaneously. Does this imply that film transfer in solid lubrication may be a self regulating, sacrifical wear process that quickly goes to an equilibrium or steady state? Does the increased concentration of the fluoride ion in the transferred film suggest that degradation of PTFE is necessary for successful lubrication? If so, could this analogy be applied to the lubrication by MoS_2 and the generation of sulfur ions in transfer films? And finally, do the authors feel the behavior found in these studies would be significantly different if less abrasive graphite fibers were substituted for the glass fibers and an inherently better lubricating resin, such as polyimide, was substituted for the phenolic? I would like commend the authors for initiating a very interesting study that has many implications for providing a greater understanding to one of the more intriguing areas of tribology.

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Authors' Closure

We thank Mr. McConnell for his comments and questions on the paper, and would agree with his first point that film transfer does appear to be a self-regulating process which ultimately reaches an equilibrium condition. Whether or not this equilibrium is approached quickly, however, will depend on a number of factors, such as debris cohesion and adhesion, counterface roughness, etc; these are discussed more fully elsewhere [35]. Transfer must obviously occur in the first place from liner to counterface, but whether "back-transfer" is then possible is not known and, without the use of radio-tracer techniques, would be exceedingly difficult to prove.

The suggestion that degradation of PTFE might be a necessary requirement for successful lubrication does not seem to be wholly supported by the evidence presented in the Discussion section of the paper. Further, more recent, unpublished work by the authors has shown that transfer films produced from PTFE-fibre composites which do not incorporate glass fibre in the surface layer, contain greatly reduced amounts of F^-. In the particular conditions of testing which were being used, the friction and wear properties of these composites were virtually identical to those containing glass fibre at the surface and producing F^--containing transfer films. Further work is clearly necessary to establish the precise role, if any, of PTFE degradation in solid lubrication.

We have no direct experimental information, as yet, on what would happen by replacing the glass fibre in the present, complex type of PTFE-fibre composite by graphite fibre. Certainly one would expect differences in friction and wear behaviour if only because the finely-divided degradation products from the graphite are likely to possess some lubricating ability in their own right. As a broad generalisation from previous work with bulk PTFE composites containing chopped fibres [36], it would appear that when using graphite fibres the counterface transfer films tend to be graphite-rich whereas when using glass fibres the films are PTFE-rich. Such differences in composition would be expected to lead, for example, to differences in the environmental sensitivity of friction and wear and unpublished work has, in fact, shown that the wear resistance of PTFE/graphite fibre composites in vacuum is generally inferior to that of similar PTFE/glass composites. The precise part played by the abrasiveness of the fibres is not at all obvious at present and, indeed, it has always seemed somewhat surprising how little metal counterface damage is encountered in practice during the operation of woven PTFE fibre/glass fibre types of dry bearings.

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