Contact Temperatures During Tribotesting and Their Influence on Wear

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1. Introduction and Background

When considering materials for use in a sliding component, it is often desirable to subject them to tribotests to determine their wear behavior under conditions similar to those they will encounter in service. It is well known that frictional heating and the resulting increase in contact temperatures can have a significant influence on the friction and wear of many materials, including polymers, metals and ceramics. For this reason, it is important to consider contact temperatures when developing friction and wear tests for potential tribomaterials and when analyzing the results of those tests. In many of the most commonly used tribotests, such as the pin-on-disk or sphere-on-flat test, one component of the sliding contact couple (e.g., the pin) is held stationary while the counterface (e.g. a flat disk) slides continuously against it. The purpose of this paper will be to present some of the most useful analytical and numerical methods that can be used to predict surface temperature rises in dry or boundary lubricated tribotests similar to pin-on-disk sliding contacts.

Although the pin-on-disk or sphere-on-flat test is one of the most common tribotest configurations, there have been few published studies of contact temperatures specifically for that configuration [1]. However, there has been a lot of research on frictional heating that can be applied to contacts between a stationary body and a moving counterface [e.g., 2,3]. The methods used in those earlier studies include transform-based analytical techniques, finite element numerical models, and hybrid or semi-empirical methods. This presentation will build on that previous analytical work and will present equations and models that are valid for a variety of geometries and kinematic operating conditions used in pin-on-disk and similar tribotest configurations. Results of the methods will be compared for several different cases, and experimental verification of the predictions will also be presented. Predictions of those models will be compared with finite element models of sliding contacts and experimental data in order to select the most appropriate and accurate predictive model.

2. Results and Discussion

The models for contact temperature are applied to several pin-on-disk test geometries used for studying wear of tribomaterials; one of the applications considers oscillatory sliding contact while the other considers unidirectional sliding. In the first application, a predictive model of the contact temperature in an oscillatory contact between a flat-ended pin made from ultra-high molecular weight polyethylene (UHMWPE) and a flat metallic or ceramic counterface is developed. The temperature predictions are compared with measured temperatures for the same configuration and it is shown that the measured surface temperature rise at the contact interface agrees well with the model's predictions. Those temperature predictions are then correlated with measured wear of the UHMWPE polymer. The results can be used to provide guidance for the testing of polyethylene bearing materials used in hip and knee prostheses.

In a second application, the surface temperature prediction methods are used to better understand the wear process of zirconia ceramics in pin-on-disk testing. Zirconia is a relatively hard, chemically inert ceramic that has been used in a variety of applications ranging from artificial hip joints to hard counterfaces for wear tests. However, recent studies have shown that the wear rate of zirconia is quite velocity-dependent [4,5]. The pin-on-disk temperature model was applied to the case of dry sliding contact between a metallic pin and a yttria-stabilized zirconia disk. Wear of the zirconia disk in that configuration proved to be quite low at low sliding speed (0.1 m/s) but very high at higher speed (1 m/s). Comparison between predicted contact temperatures and the phase diagram of zirconia shows that the contact temperatures were sufficient to cause the phase transformation that was most likely responsible for high rates of zirconia wear at high sliding speeds. This points out an unforeseen danger in selecting a supposedly wear-resistant material such as zirconia for use in tribotests or applications in which the contact temperatures could be sufficient to cause the material's structure and wear resistance to change dramatically.

3. References

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