Friction measurement in the Spiral Orbit Tribometer

Basic Approach

Friction measurements take place when the ball contacts the guide plate (this contact region is denoted as the "scrub"). The simplest analysis of the kinematics (Pepper and Kingsbury, Tribology Transactions Vol. 46, p. 57 (2003)) shows that in the scrub

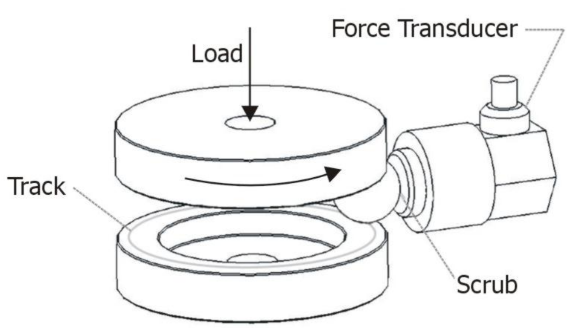
a) the ball slides on the rotating plate.
b) The normal force on the guide plate is twice the friction force of the ball sliding on the rotating plate. This normal force is sensed by the piezoelectric force transducer behind and supporting the guide plate.
c) This friction force divided by the load yields the coefficient of friction (CoF).

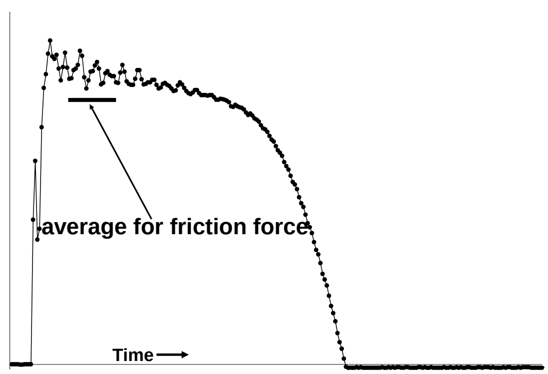
Critique of Kinematics

The normal force of the ball on the guide plate has been identified with twice the sliding friction force of the ball sliding on the rotating plate. But there are other forces on the ball in the scrub; specifically, there are forces that are tangential to the face of the guide plate. The piezoelectric force transducer behind and supporting the guide plate does not sense these tangential forces. A more complete analysis of the forces on the ball in the scrub would reveal these tangential forces that appear as azimuthal forces on the large plates. However, the present use and operation of the SOT does not sense and in fact, ignores these forces.

Critique of the Friction Force Profile

The friction force that is sensed by the transducer behind the guide plate is a function of its position in the scrub as shown below for a liquid lubricated contact:





Two points: a) there is oscillatory force behavior near the entrance to the scrub. This behavior is virtually absent for well lubricated systems with low CoF and extremely pronounced for poorly lubricated systems with high CoF. It is most naturally associated with stick/slip behavior of contacts. For the purpose of the SOT, the friction force is averaged over the indicated region of the scrub to obtain a force that, divided by the load, is taken as the coefficient of friction. b) The friction force profile is not a simple square profile (although we would like it to be). Instead, for liquid lubricants especially (as shown), it drops off gradually to zero at the exit of the ball from the scrub. On the other hand, a contact lubricated with MoS_2, for example, is more of a square profile. This gradual drop-off is not understood, although it appears to be associated with liquids.

Algorithmic Approach

The issues of incomplete kinematics in the scrub and ill-understood behavior of the friction force profile does leave the SOT open to criticism. The approach taken by GRC has been to simply ignore these issues and obtain a CoF as stated by the procedure above. The real justification for this "algorithmic approach" is its quantitative agreement with the CoF obtained for particular systems by other tribometers. Such agreement is found for Fomblin (CoF=.12, Roberts, ESTL, with a pin on disk machine) and Krytox (CoF=.13, Spikes, Imperial College, with a mini-traction machine [MTM]). Another defense of the SOT's algorithmic approach is that of observing the classic response of graphite to water vapor (CoF decreases relative to a dry environment) and MoS_2 (CoF increases relative to a dry environment). Unfortunately, there are no agreed-upon standards of friction to test the SOT's (or for that matter any other tribometer's) ability to correctly measure friction.

Conclusion

Yes, there are basic aspects of the SOT's operation yet to be understood. However, the "algorithmic approach" used by GRC has permitted the SOT to face every situation successfully and no contradictions with the literature have been found.