

Discussion: “An Application of Dimensional Analysis to Entropy-Wear Relationship,” (Amiri, M., Khonsari, M. M., Brahmeshwarkar, S., 2012, J. Tribol., 134, P. 011604)

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The authors present an interesting thermodynamic interpretation of the Archard wear coefficient. However, their interpretation is confined to the steady state. The purpose of this discussion is, first, to extend the domain of the authors’ derivation to the entire regime of rubbing (running-in to steady state), and, second, to point out a possible thermodynamic functional interpretation of wear rate resulting from the current derivation. The starting point is to represent the hardness of the material as a linear function of the melting temperature T_m , viz:

$$H(T) = H_o \left[\frac{T_m - T}{T_m} \right] = H_o \left[\frac{T'}{T_m} \right] \quad (1)$$

Where T' is the difference between the melting temperature and the temperature rise above ambient, T . Here T' represents a degradation metric that indicates how close the material is to reach the energy barrier needed to degrade the volume active in rubbing from a solid to a liquid state. Substituting Eq. (1) in Eq. (A4) of the authors’ work, and following the authors’ method, we obtain:

$$K = w^o \left[\frac{\mu H(T)}{TS^o + \mu(l.N)T^o/T'} \right] \quad (2)$$

The term T^o in Eq. (2) represents the time rate of change in the temperature rise above ambient. This quantity is a vanishing function in time, and at steady state, the temperature reaches a constant value that does not depend on time, i.e.,

$$T^o \begin{cases} < 0 \text{ running-in} \\ = 0 \text{ steady state} \end{cases}$$

Equation (2) expresses a ratio between two fundamental quantities: the energy barrier to be overcome for complete degradation of the solid state of the active volume, and the net heat transferred away from that volume. The net heat transfer is the balance of the heat transfer (TS^o) and the maximum possible amount of work extracted due to the temperature difference between the various parts of the active volume (i.e., the term $\mu l N T^o / T'$). This latter quantity may be considered as *leakage* from the heat flux transferred out of the active volume. It is of maximum value at the start of running-in and zero at steady state. At steady state, considering the contact is under constant pressure, the heat transfer will equal the enthalpy of the active volume. Thus,

$$K = w^o \left[\frac{\mu H(T)}{E} \right] \quad (3)$$

K in this formulation is interpreted as the ratio of the total energy needed to degrade the wear volume to the enthalpy of the active volume. Noting that T^o decreases during running-in, Eq. (2) may be recast in terms of the first law, viz:

$$w^o = K \left[\frac{Q - w'}{u} \right] \equiv K \frac{\Delta u}{u} \quad (4)$$

with u being the internal energy per unit volume.

Equation (4) interprets the volumetric wear rate as a function of the difference between an activation mechanism (w'), equivalent to the flux leakage term, and a passivation mechanism Q , equivalent to TS^o . The former aims at increasing the internal energy of the solid, whence inducing instability, whereas the latter reduces the internal energy whence induces stability or order. An interesting implication of Eq. (4) is that upon constriction of the heat transfer ability within the active volume, the passivation component Q is minimized and w' , the activation, assumes dominance. This promotes disorder within the material layers. The response of the material in such a case is to increase wear (or to degrade more material to re-establish order within the rubbing zone). Upon reaching a steady state, the activation term vanishes and the volumetric wear rate will be directly proportional to the efficiency of heat transfer away from active rubbing volume.

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