

A unified approach for analysis of wear and fatigue

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ABSTRACT – Control and quantification of friction, as a ubiquitous phenomenon, has been of significant priority in numerous practical applications involving contacting bodies. Economic implications ensuing from the loss of material, energy and functionality caused by friction and wear further underline the need for robust modeling techniques. While attempts to afford the development of comprehensive wear models have been profuse, the degree of their success has been limited owing, in large part, to the variegated nature of friction and wear. Today, in light of the existing body of knowledge, it is acknowledged that wear of materials involves a variety of complex and physically diverse phenomena that often occur in an inextricably intertwined fashion. It is, therefore, of no surprise that there exists a scarcity of predictive models to realistically account for the multifarious processes involved. Accordingly, the development of approaches that can properly unify the processes underlying wear and friction is an important scientific endeavor.

Friction, wear, and fatigue are examples of dissipative processes in tribology wherein the system's free energy, Ψ , responsible for doing useful work, decays with time. That is, if Ψ_i denotes the initial free energy of a pristine tribosystem, then after completion of the dissipative process its free energy decreases to Ψ_f such that $\Psi_f < \Psi_i$. This decay in the free energy continues until the system attains a minimum at the equilibrium state in accordance with the principle of minimum free energy. Thus, the system's path to the minimum free-energy is always accompanied by increasing entropy until it reaches its peak value at the equilibrium state. The increase in entropy is a consequence of increasing disorder in the system with time. Therefore, notwithstanding the multiplicity of underlying dissipative processes involved, they all share one unique feature: they all produce entropy. Therefore, thermodynamic entropy production is believed to be a propitious measure for a systematic study of wear and friction.

In this lecture, I present results of a series of recent experimental and analytical development associated with surface degradation such as adhesive wear as well as fatigue fracture within the framework of irreversible thermodynamics. This view offers a potentially transformative path forward for the development of predictive methodologies for variety of applications.

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