Energy dissipation network at the interface of sliding metals

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When one solid surface slides onto another, the inevitable response is the heating and subsequent degradation of one or both materials that participate in the mechanical pair. The transformation of frictional energy in mechanical work is essentially a thermodynamic process that involves active and passive processes, since part of the mechanical work that dissipates inside the solids causes the internal energy of the system to increase. The mechanisms that generate work in the dry sliding process between metallic solids and how these mechanisms are responsible for frictional energy surface dissipation are discussed in this work.

Keywords: Friction; dissipation mechanisms; secondary processes, tribology.

1. Introduction

During the last decades a new wear process study area in sliding pairs was proposed. It states that wear rates are caused by the thermodynamic instability generated by the solids friction; this affirms the direct influence of thermal phenomena in the variation of the wear process. It considers the contact process as one of the universal examples regarding dissipative phenomena. As said, friction produces all or most of the energy that leads to irreversible changes associated with oxidation, plastic deformation, phase transformations, etc. This means that frictional forces produce irreversible entropy. This study aims to develop an energy dissipation network, the main dissipation mechanisms in tribological interfaces were quantified; among them, there are: The entropy flow by pure abrasion, the entropy flow by thermal gradient (between Tflash and Tbulk), the entropy flow by heat flow, the entropy flow by phase transformation and the entropy flow by oxidation. Figure 1 shows a flow diagram of the relevant dissipation mechanisms and their relations.

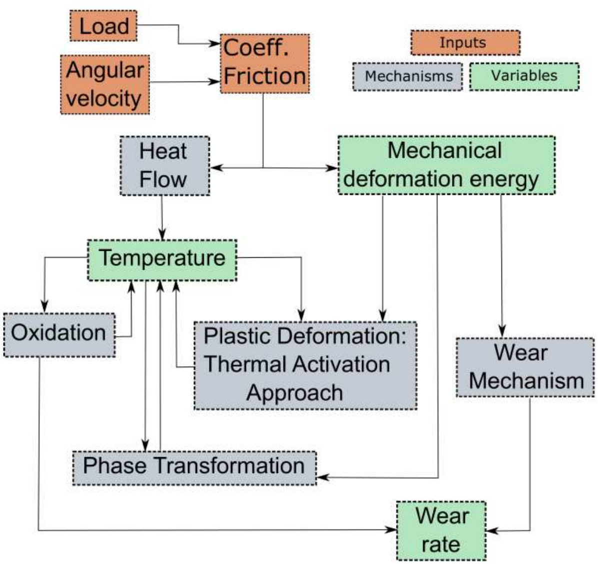

Figure 1. Flow diagram of relevant phenomena/mechanisms considered.

2. Methods

A phenomenological based semi-physical model of the dry sliding process between metallic solids was developed. Using the first law of thermodynamics, the amount of mechanical energy that is transformed into heat during the sliding process was calculated. The second law of thermodynamics was used for analyzing the sliding process in metallic solids and for quantifying the amount of energy that dissipates without generating work in the system. The dissipation mechanisms responsible for generating entropy flows in tribological interfaces has been previously compiled [1, 2]. Equation (1) - (5) represents the entropy flow generated by heat flow, oxidation, phase transformation, thermal gradients and microabrasion, respectively.

$$\dot{S}_f^Q = \frac{\dot{Q}}{T_{bulk}} \quad (1) \qquad \dot{S}_f^{Oxi} = \frac{A}{T}\frac{d\gamma}{dt} \quad (2) \qquad \dot{S}_f^{PT} = \frac{\Delta H_i}{T_i} \quad (3)$$

$$\dot{S}_f^{\Delta} = \left(\frac{1}{T_{flash}} - \frac{1}{T_{bulk}}\right)\dot{Q} \quad (4) \qquad \dot{S}_f^{A} = \left(\frac{U_c}{T_{bulk}}\right)\Delta V \quad (5)$$

3. Discussion

The main mechanisms of entropy generation in tribological interfaces were quantified. The analysis shows that the mechanical and chemical phenomena are the most thermodynamically efficient, i.e., they are the dissipative mechanisms with the lowest entropy flow. This is related to the fact that mechanical and chemical phenomena are the ones that produce structural changes in the system.

4. References

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