Insights into Hydrogel Friction

CATEGORY OR KEYWORD

Hydrogels, Friction, Colloidal probe atomic force microscopy

AUTHORS AND INSTITUTIONS

Rosa M. Espinosa-Marzal, University of Illinois at Urbana-Champaign, Urbana, IL

INTRODUCTION

Biological tribosystems, including the respiratory and gastrointestinal tracts, the oral cavity, the corneal epithelium and the cartilage, enable diverse functions of the human body by maintaining extremely low coefficients of friction via mucous gel layers and a water-based lubricant. Their tribological properties are often investigated using structurally similar hydrogels, which also consist of crosslinked polymers that contain large quantities of water, so that they are soft and viscoelastic.

ABSTRACT

Hydrogels offer the advantage that their microstructure can be easily modulated to enable systematic studies of the effect of microstructure on frictional properties. We have studied the (dynamic) frictional response of poly(acrylamide) hydrogels with varying microstructure over a wide range of loading conditions by colloidal probe lateral force microscopy. The experimental results show that the dynamic friction between hydrogel and colloid can increase, decrease, or remain constant with normal load and with sliding velocity, and that these trends are strongly dependent on the hydrogel's microstructure. A comprehensive model for dynamic friction has been developed based on the viscoelastic behavior of hydrogels that accounts for the energy dissipated through the rupture of the transient adhesive bridges across the interface and the viscous dissipation upon shear of the near-surface hydrogel film (1). Interestingly, this work has also suggested contact ageing, which has inspired our more recent studies of the effect of hydrogel's microstructure on static friction. Hydrogel's static friction and contact ageing stems from the adhesion of the polymer to the colloid, which strengthens the interfacial energy, and from the drainage-induced increase in contact area. We propose a phase diagram for static friction and contact ageing, which should be universal for hydrogel-like materials, like those present in biological tribosystems. The hydrogel's microstructure dictates the dominant mechanism based in the polymer relaxation at the confined interface and on the poroelastic relaxation. The characteristics of the phase diagram can be modulated by varying the duration of the static loading, load and velocity. We believe that this knowledge will help understand the relation between wear of mucous gel layers and their microstructure in future.

REFERENCES

(1) Shoaib T & Espinosa-Marzal RM (2018) Insight into the Viscous and Adhesive Contributions to Hydrogel Friction. *Tribology Letters* 66(3):96.