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IDENTIFICATION OF TRIBOLOGICAL PROPERTIES OF SOFT-WET MATERIALS

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ABSTRACT

Stimulus responsive hydrogels are bio inspired polymer materials exhibiting a large change in volume and surface properties during a reversible phase transition. Their characteristics make SRHs suitable for uses as biocompatible devices, actuators, and sensors. In many applications of interest, load transmission occurs through frictional contact and thus surface phenomena play an important role. Previous studies [1] reported that friction between gels or gels and solid surfaces is characterized by very low friction coefficients; experimental data available in the literature describe the dependency of friction on various factors (charge density, chemical structure, degree of swelling, etc.)

Of primary interest is the accurate modelling of the surface phenomena, as it has been observed that the simplified empirical relationships available in the literature do not offer a good approximation for the experimental data obtained in cases when hydrogel–hydrogel friction is present. In this work, we focus our attention on the efficient and accurate identification of tribological properties from experimental data. To describe the bulk behaviour of the hydrogel material, we have adopted a model formulated in finite deformation that accounts for both elastic and viscous phenomena [2]. Material parameters were calibrated based on experimental results. Experimental data obtained in cases when friction is present [3] suggest that the friction coefficient is strongly dependent on the sliding velocity. To account for this behaviour and obtain a good qualitative correlation between numerical simulations and experimental data, we propose the use of a friction law with variable friction coefficient. A robust finite element formulation (using the mortar method) [4] for enforcing the frictional contact constraints defined by this interfacial constitutive model is formulated and utilized for these studies.

The rheometer experimental setup permits for steady state conditions to be reached thus eliminating the role of time dependence in the bulk behavior while rotational sliding occurs on the surface. The configuration allows for the measurement of net torque and normal loads produced by the contact during rotational sliding and proves very useful for tribological studies of soft wet materials. Unfortunately,

since the sliding velocity is non-uniform over the contact surface, direct extraction of tribological properties is not possible; some hypothesis regarding the relationship between frictional force and sliding velocity is required. For instance, previous studies [1] assumed a linear relationship with zero asymptote, along with many other simplifying assumptions to extract the apparent coefficient of friction. A more general (polynomial) dependence can also be assumed. It has been shown [5] that the results obtained from finite element simulations assuming various such dependences are qualitatively similar with the experimental data (normal force is relatively constant when rotation is applied and the torque presents step jumps with the variation of the angular velocity). Quantitatively however, the values are strongly dependent on the choice one makes for the function describing the friction law. These considerations help motivate the need for accompanying numerical studies to investigate the validity of such assumptions and for the development of appropriate techniques to isolate quantitative aspects that are necessary for design.

In this work, an inverse problem is formulated to extract the dependence frictional force–sliding velocity from torque and normal force data. The goal is to develop an effective scheme for the solution of this problem and therefore "synthetic" data from finite element simulations will be used. First, by assuming a friction law with few parameters, a forward problem is solved to obtain the synthetic steady state torque and normal force at a certain level of the angular velocity. The dependence of the torque on the angular velocity is then assumed known and the frictional law is recovered in the inverse problem by means of an optimization method.

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