Friction of complex fluids: from slip length to Navier's friction coefficient.

Elisabeth Charlaix and Benjamin Cross

Laboratory of Interdisciplinary Physics, Université Grenoble-Alpes, France
*Corresponding author: elisabeth.charlaix@univ-grenoble-alpes.fr

We discuss the dynamics of complex liquids at interfaces from the point of view of their slippage and friction properties. Building on the case of polyelectrolyte solutions, we show that in contrast to the slip length, the Navier friction coefficient is a local property of the interface, whose value can be related to the interfacial structure thanks to high resolution measurements resolving the hydrodynamics in the depletion or adsorption layers. We discuss in this perspective, recent results in the literature, bridging the friction of complex fluids on surfaces to the friction of complex fluids lubricated solid/solid contacts.

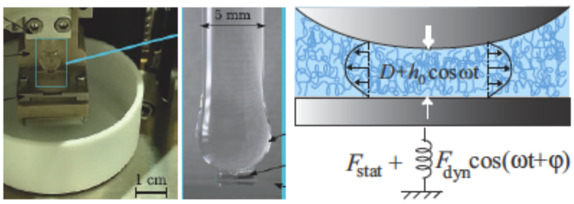
Keywords : liquid-solid friction, complex fluids, slippage, poly-electrolytes

1. Introduction

The friction of complex fluids on solid surfaces is important in many environmental and industrial processes, due to their lubricating properties. More fundamentally, complex fluids have bulk properties intermediate between solids and liquids, and so are their friction properties. Early work of de Gennes on polymer melts discussed their friction on surfaces in terms of the Navier's coefficient relating the slippage velocity to the shear stress. But later work on the slippage of simple liquids at interfaces characterized their so-called slip length, i.e. the ratio of the slippage velocity to the shear rate. Subsequent work on complex fluids essentially continued this approach. We discuss these notions for the friction of complex liquids at solid interfaces, illustrating them in the case of viscoelastic polyelectrolyte solutions.

2. Methods

Using high resolution hydrodynamic measurements performed on the Surface Force Apparatus, we investigate the flow of thin films of polyelectrolyte viscoelastic solutions, bridging 5 decades of length scale for the film thickness from the Angstrom to tens of micrometers, and 1 decade in frequency. DLVO interaction forces give access to the Debye's length and surface charge of the adsorbed layer, while nano-elasticity measurements in the adsorbed layer unravel its organization, modulus and thickness. Far-field hydrodynamic measurements give access to the bulk viscoelastic modulus of the solutions as well as their slip length on the adsorbed layer. Near field measurements resolve the flow in the depletion layer and give access to its thickness.



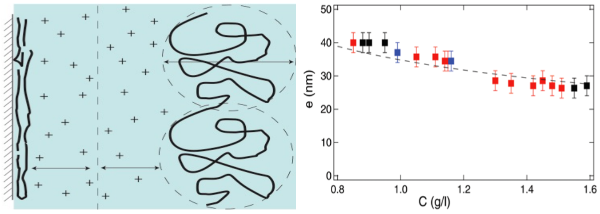


Figure 1: Dynamic SFA measurements give access to the thickness, charge and modulus of the adsorbed layer, the thickness of the depletion layer, and the slip length of the solution flowing on it.

3. Discussion

On this example of viscoelastic fluid, we show that the slip length is a complex quantity reflecting the bulk response of the complex fluid. In contrast the Navier's friction coefficient is a local property of the interface, accounting accurately for the complex hydrodynamic force up to scales of tens of micrometers, with a simple Newtonian-like interfacial friction whose value is related to the interfacial structure.
We discuss in this perspective recent results in the literature obtained in different complex fluids, bridging the friction of complex fluids on surfaces to the friction of complex fluids lubricated solid/solid contacts.

4. References

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