Transient slip at the solid wall for flow of viscoelastic polymer solutions

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Abstract

Identifying the molecular mechanisms of friction at solid-polymer interfaces is a key question in polymer rheology and polymer extrusion processes. It is also of fundamental interest since it provides a unique access to the chains dynamics close to the interface. Slip mechanisms of polymer melts are now well understood due to recent experiments based on dewetting, step leveling or direct slip length measurements [1]. On ideal non-adsorbing surfaces, it was clearly established that the friction between the melt and the surface is a local process, ruled by the friction between monomers and surface [1]. It was also shown that friction is a thermodynamically activated process, characterized by an activation energy, $E(\text{friction})$, different from that of the melt viscosity $E(\text{viscous})$. A s a result, depending on the sign of the difference between these activation energies, the slip length can either increase, decrease or remain constant with increasing temperatures [2].
The case of polymer solution is more complex since it involves a priori a competition between the frictions of the solvent and the polymer at the interface. The friction mechanism on ideal non-adsorbing surfaces can be potentially affected by the existence of a depletion layer or can be described in terms of the friction of blobs (which are the hydro dynamically decorrelated units) sliding on the solid surfaces for semi-dilute solutions... No clear picture of the mechanisms involved in this friction as measured by slip length measurements has emerged in the recent years, due to a lack of systematic measurements on controlled surfaces.

We have undertaken an investigation of slip length dependences on polymer on two different well controlled surfaces, for polystyrene in diethyl phthalate solutions, for different shearing times. These measurements exhibit first a transient behaviour for the slip when the shear solicitation is turn on, and then a steady state slip. We analyse this transient slip that can be rationalized thanks to a simple model for a viscoelastic fluid slipping on a substrate. The steady state slip shows that the slip length scales as 3. Thanks to this scaling, we have a better understanding of the molecular mechanisms of friction of polymer solutions.

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