The influence of strain hardening on contact mechanics

polymer technology

Technische Universiteit Eindhoven University of Technology

The influence of strain hardening on contact mechanics

Vincent G. de Bie, Patrick D. Anderson, and Lambèrt C.A. van Breemen

The properties of polymers make them interesting for many applications. Why some polymers show a low friction property, is not fully understood. As a first step, the role of intrinsic properties of glassy polymers on single-asperity sliding friction experiments is investigated in our group.

Intrinsic response

The influence of the intrinsic polymer characteristics strain hardening on the scratch response is investigated. Experimentally, the strain hardening is manipulated by changing the composition of blends of polystyrene (PS) and poly(2,6-dimethyl-1,4-phenylene oxide) (PPO), as shown in Figure 1.

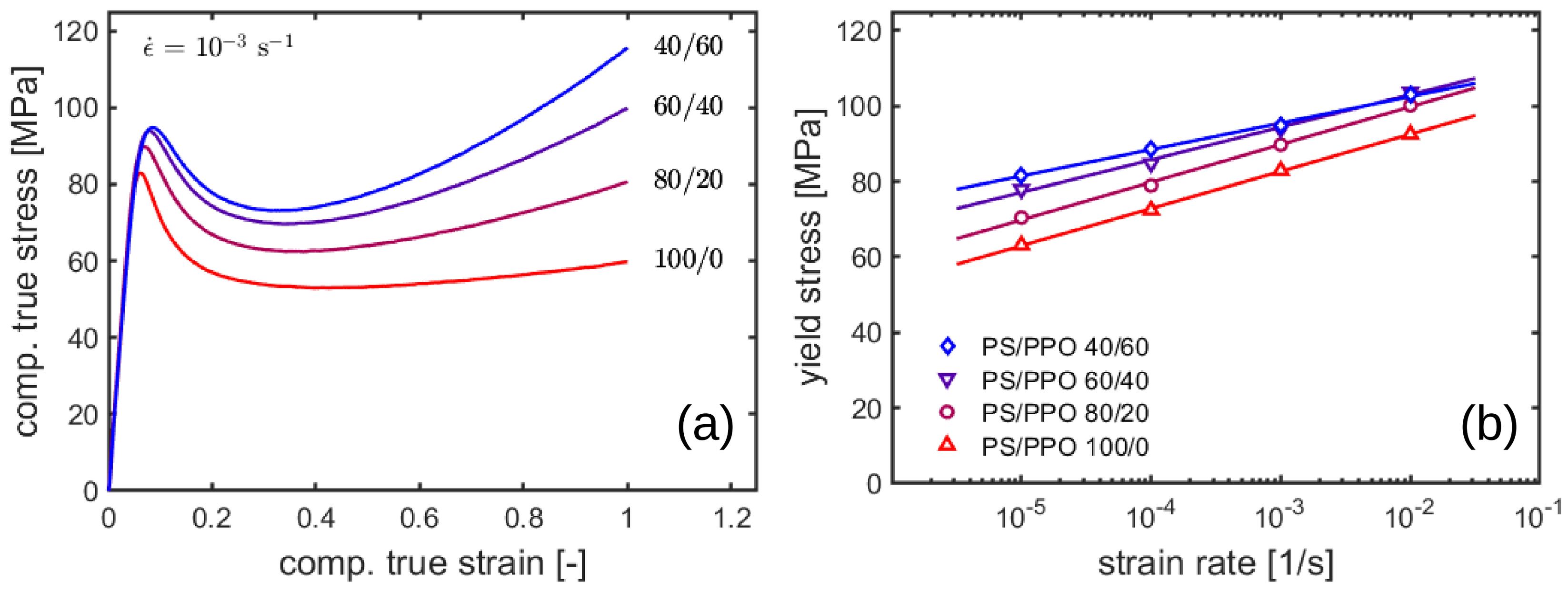

Figure 1: (a) Intrinsic stress-strain response of PS/PPO blends with varying composition, and (b) the strain-rate dependence of the upper-yield stress.

Single-asperity scratching

In single-asperity sliding friction experiments, a scratch is applied with a constant normal force and scratch velocity onto a piece of deformable polymer with a smooth surface by a diamond indenter tip of conical shape (Figure 2). The output is the lateral friction force and the penetration into the surface.

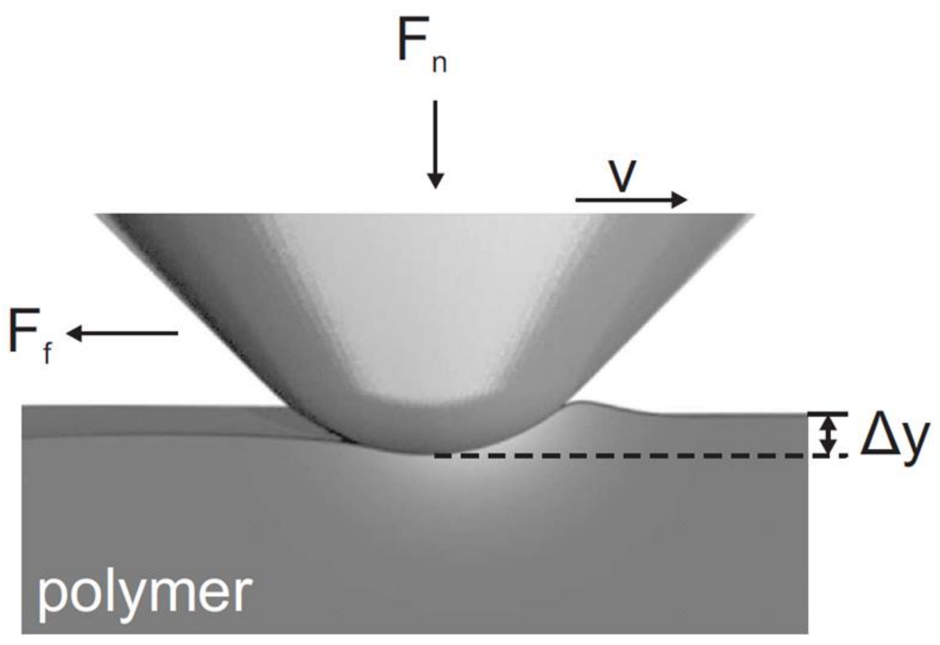

Figure 2: Schematic representation of single-asperity scratching, reproduced from [1].

Sliding friction experiments

The experimental results show that changing the amount of PPO in the blends, and therefore the amount of strain hardening, has a major influence on the lateral friction force (Figure 3b) and almost none on the penetration into the surface (Figure 3a). A decrease in lateral friction force is seen when the amount of PPO in the blend is increased. This decrease is caused by the smaller bow-wave in front of the indenter tip due to the amount of strain hardening.

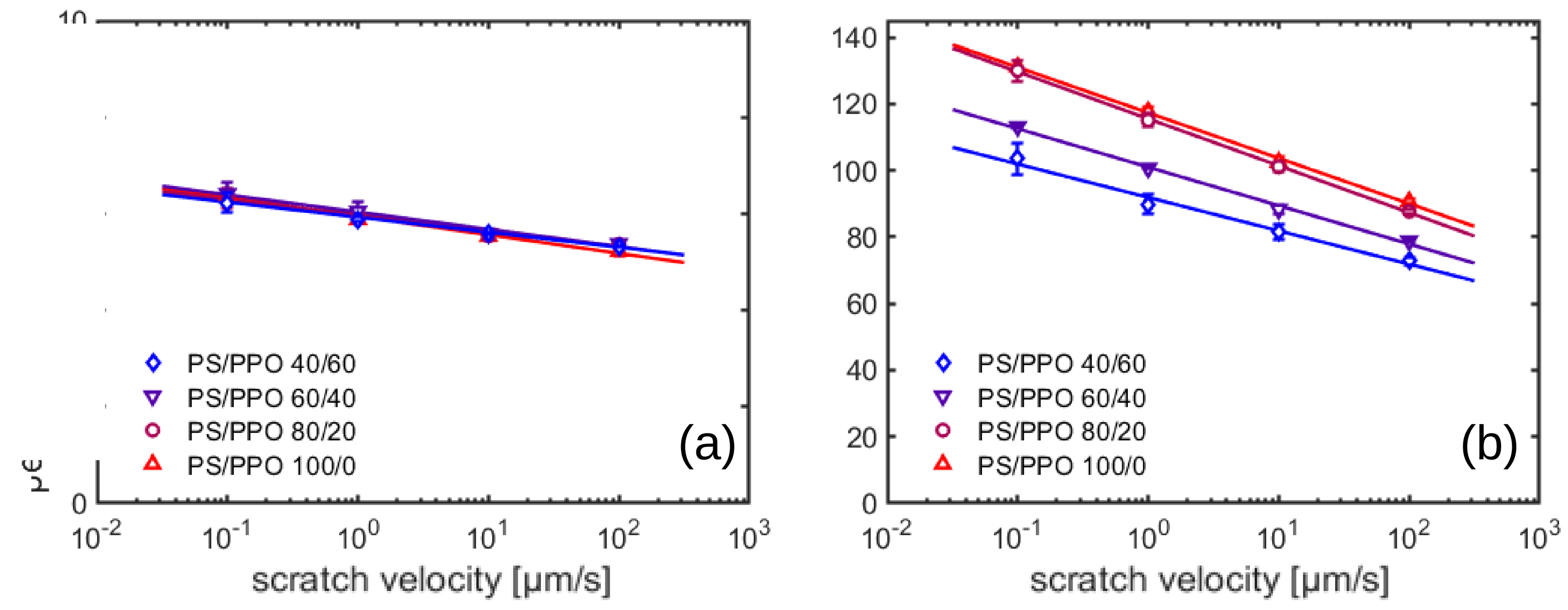

Figure 3: The scratch response for varying PS/PPO compositions at different sliding velocities, (a) steady-state penetration depth, and (b) steady-state lateral friction force.

Scratch simulations without friction show an under-estimation of the velocity dependency and the lateral friction force (Figure 4b). This is the result of a lacking bow-wave in front of the indenter tip. An interaction between the polymer and the indenter tip can be added by incorporating the Coulomb friction model. Increasing the friction parameter results in a bow-wave in front of the tip (Figure 4a). Therefore, the lateral friction force increases.

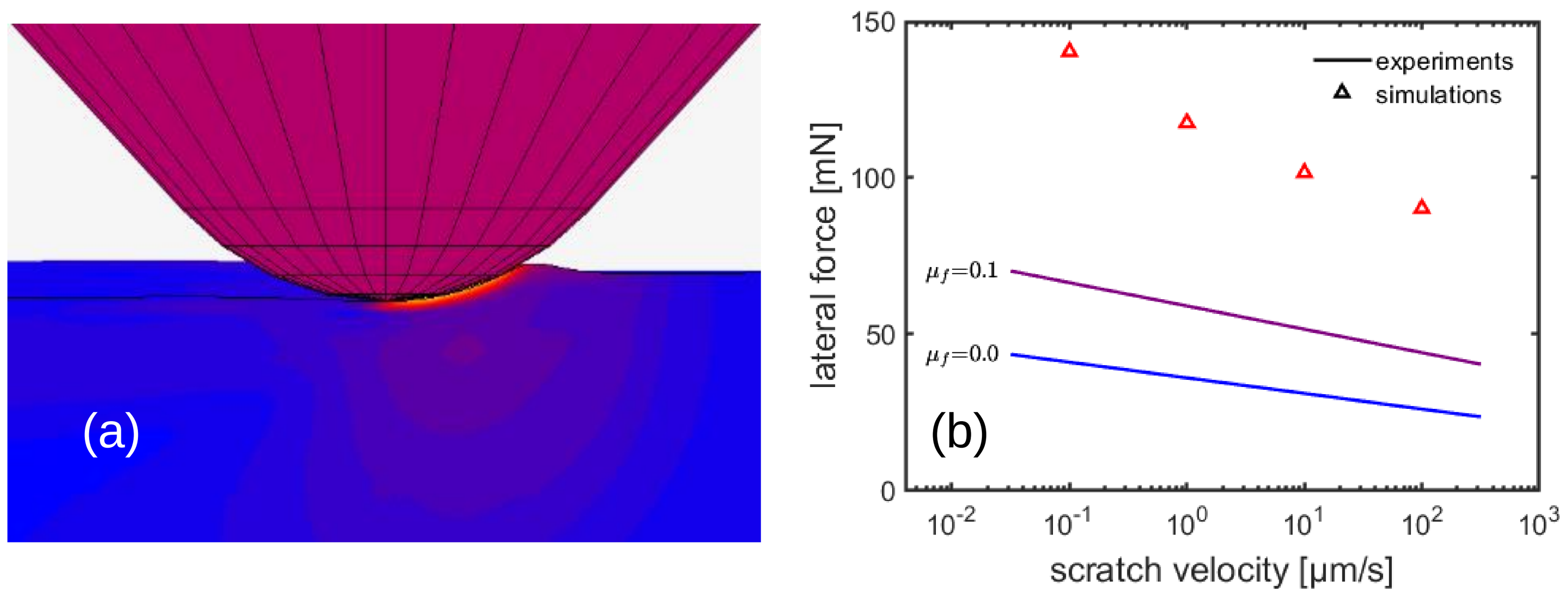

Figure 4: (a) Stress field during scratch simulations, and (b) experimental steady-state lateral friction force of PS for a range of velocities, compared to simulations with a friction parameter equal to 0.0 and 0.1.

Conclusions

The amount of strain hardening does not influence the surface penetration and decreases the lateral friction force due to a change in size of the bow-wave in front of the indenter tip. Friction needs to be added to the simulations in order to also see this bow-wave in the numerical results.

References

[1] Van Breemen, L. C. A.; Govaert, L. E.; Meijer, H. E. H., Wear 2012, 274-275, 238-247.