Simulation of the Dynamic Wetting Process of Droplets

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Abstract Spreading of liquid droplets on a rigid flat surface is universal and usually happens in a time scaled from milliseconds to seconds. To explain the effect of viscosity on the initial spreading of droplets, simulation of the shear rate distribution of droplets at the spreading front was carried out.

Figure 1. Typical side view of droplets during spreading.

Method We build a two-dimensional axisymmetric model and used a level set method to simulate the dynamic wetting process. The two phase fluid flow interfaces are based on an incompressible Navier-Stokes equations. The correlation of dynamic contact angle and contact line velocity with the effect of viscosity of liquid is expressed as:

$$cos\theta_D = cos\theta_0 - \frac{2k_B T}{\gamma l^2} \operatorname{arcsinh}\left[\left(\frac{\eta V_m}{h}\right)\frac{v_{cl}}{2\kappa_s^0 l}\right]$$

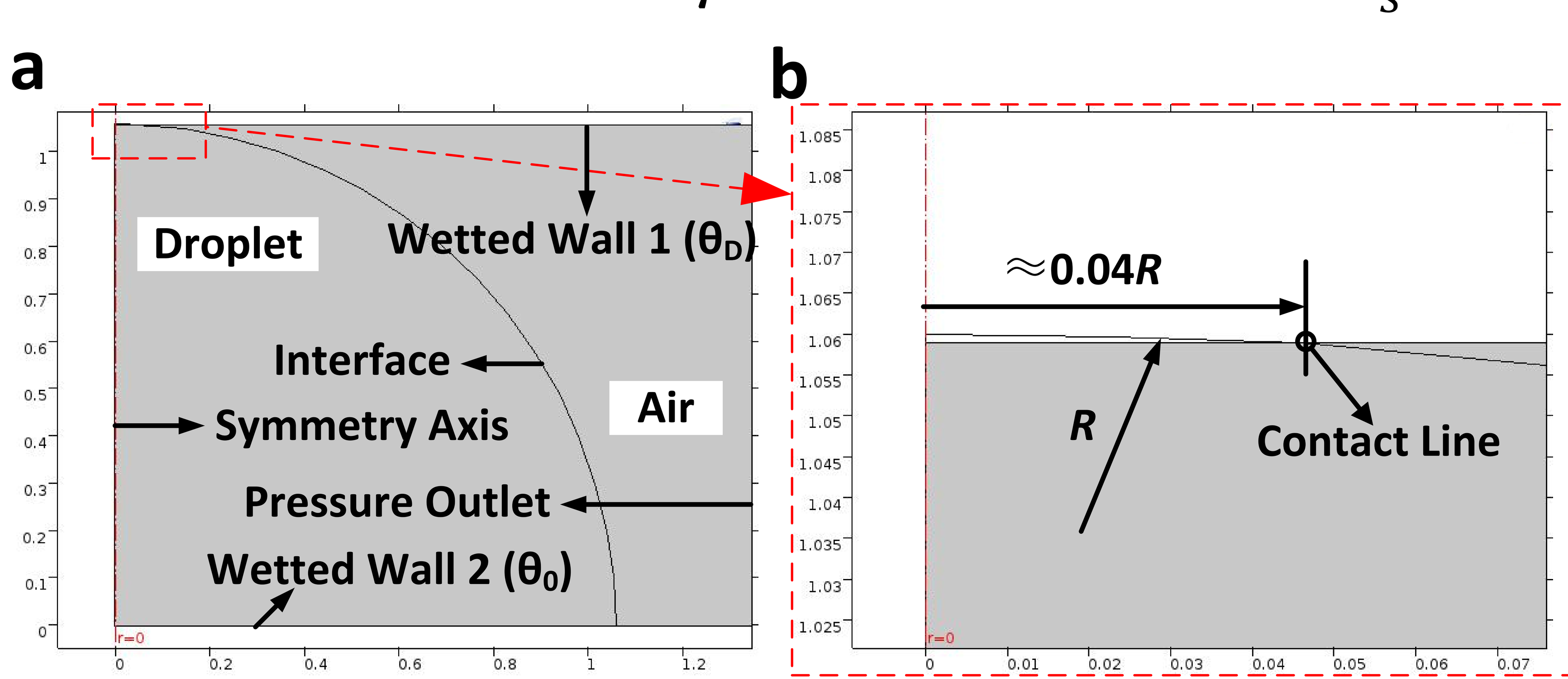

Figure 2. Simulation model and boundary conditions.

Results The simulation results show that the viscous force is high at beginning of spreading even for low-viscosity liquids due to the high local shear rate at the spreading front.

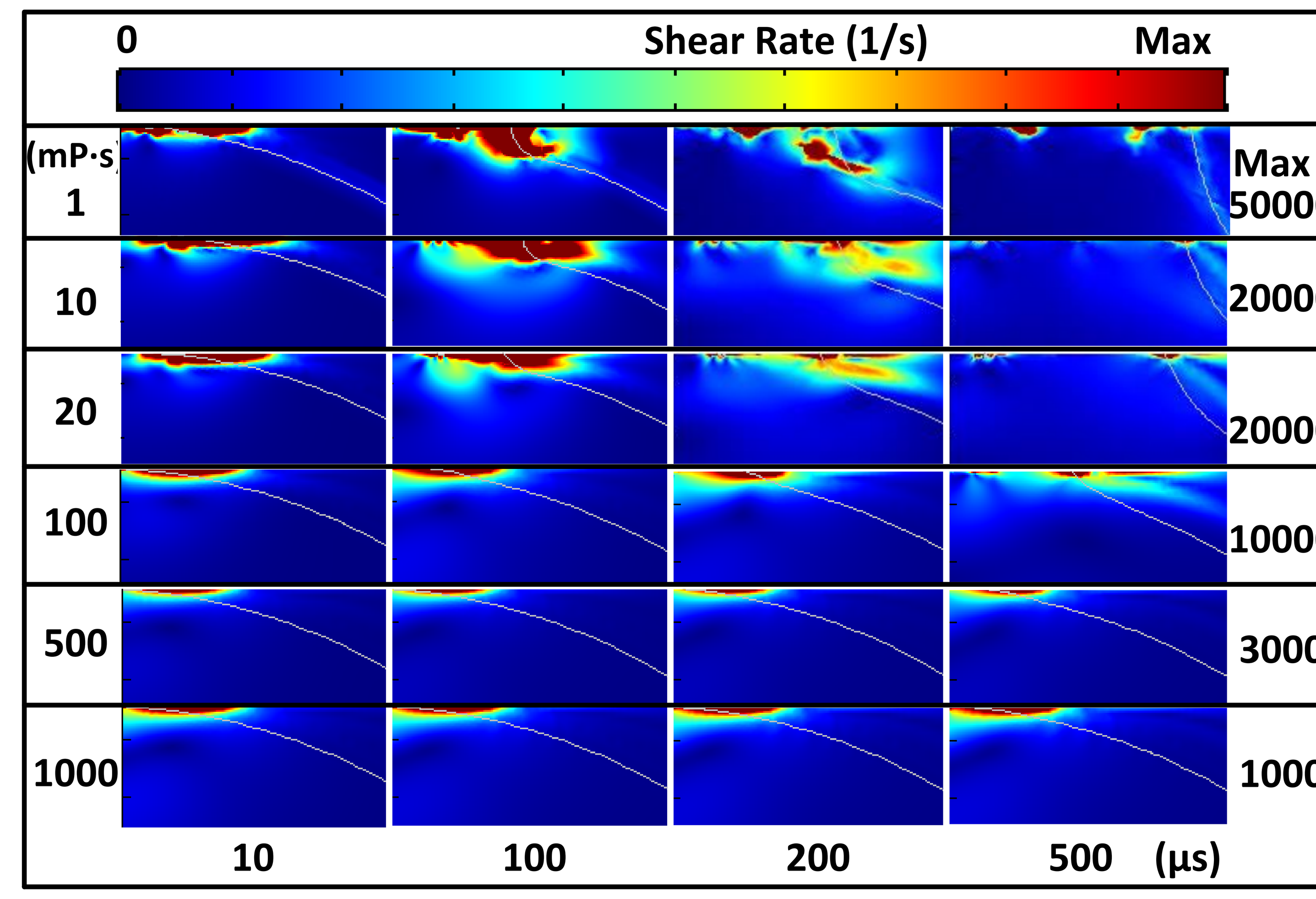

Figure 3. Evolution of shear rate contour of different viscosity liquids as a function of spreading time.

The viscous force is defined as:

$$F_{vs} = \eta \dot{\gamma}_{\text{ave}} L$$

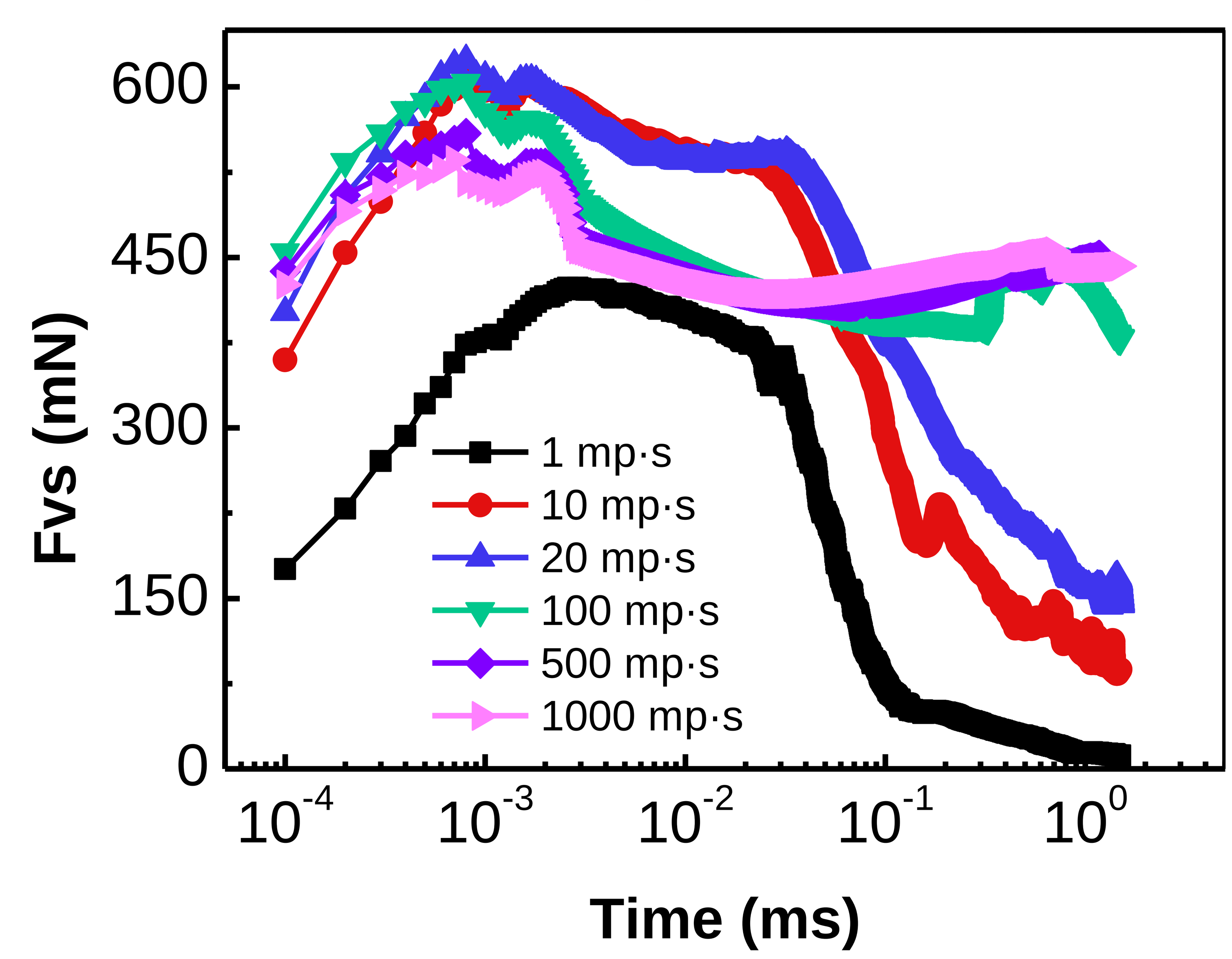

Figure 4. Comparison of qualitative viscous force for liquids with different viscosity.

Conclusions The viscous force could retard droplet spreading at the beginning of liquid/solid surface contact. The viscous retardation could be ascribed to the real high local shear rate along the contact line at the spreading front.

References

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2.Blake, T. D.; De Coninck, J. The Influence of Solid-Liquid Interactions on Dynamic Wetting. Adv. Colloid Interface Sci., 96, 21-36(2002)