Influence of Boundary Conditions on Yielding in a Soft Glassy Material

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Outline

1. "Soft Glassy Materials" - Description of fluid/solid behavior, yield stress
2. Gibaud's Paper - Modes of Yielding
    1. *Shear localization* - The "standard" yielding transition
    2. Effect of *boundary conditions*
    3. Explanation of observances

Soft Glassy Materials

Author/Paper	Definition/Characteristics of SGM	Material(s) used
Gibaud, T. "Influence of Boundary Conditions on Yielding in a Soft Glassy Material"	•Transition from solidlike behavior to fluidlike behavior (occuring at yield stress)	Laponite Suspension (3 wt. %)
[5] Coussot P. "Coexistence of Liquid and Solid Phases in Flowing Soft-Glassy Materials"	•Material flows when applied yield stress is greater than a critical value •Under flow, viscosity decreases with increasing shear rate	i.Bentonite/water suspension ii.Mayonnaise iii.Water/silica suspension
[7] Moller PCF. "Shear Banding and Yield Stress in Soft Glassy Materials"	•Yield stress •Aging and shear rejuvenation	Gel formed from suspension of charged colloidal particles (Ludox TM-40)

Experimental Methods

- Laponite suspension in water (3 wt. %)
- Smooth/rough concentric couette cell (transparent 24+1mm)
- Direct ultrasonic velocimetric measurements
- Steplike shear rate imposed & stress is monitored

Smooth cell - "Standard" yielding transition

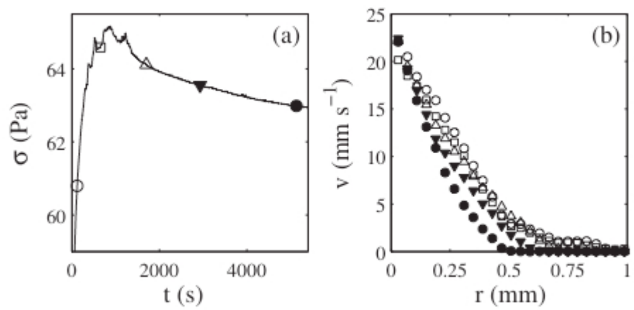


FIG. 1. Flow behavior in a rough Couette cell after a constant shear rate $\dot{\gamma} = 25\ s^{-1}$ is imposed at $t = 0$ s. (a) Stress response σ vs time t. (b) Velocity profiles $v(r)$ at $t = 123$ s (○), 653 s (□), 1702 s (△), 2931 s (▼), and 5137 s (●). r is the radial distance from the inner rotating cylinder. Error bars are of the order of the marker size.

Gibaud, T. "Influence of Boundary Conditions on Yielding in a Soft Glassy Material" *Physical Review Letters*

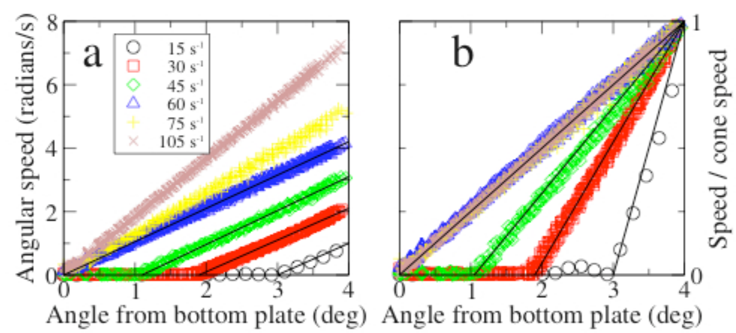


FIG. 1. (Color online) Velocity profiles in a 4° cone-plate geometry for different globally imposed shear rates. Fluid velocity (a) in rad/s and (b) normalized by the cone velocity.

Moller, PCF. "Shear Banding and Yield Stress in Soft Glassy Materials" *Physical Review Letters,*

Effects of Smooth Geometry

- With smooth geometry (15nm vs. 0.6um) yielding transition is much more complex

Evolution of velocity profile

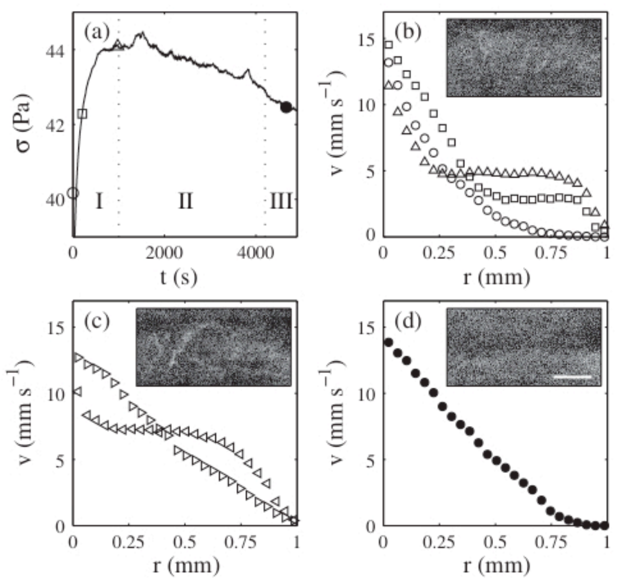
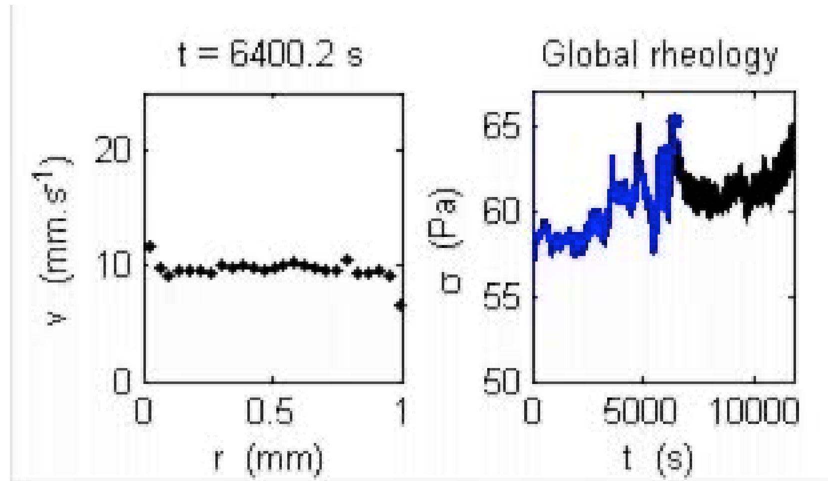


FIG. 2. Flow behavior in a smooth Couette cell after a constant shear rate $\dot{\gamma} = 17\ s^{-1}$ is imposed at $t = 0$ s. (a) Stress response σ vs time t. Velocity profiles $v(r)$: (b) in regime I at $t = 3$ s (○), 205 s (□), and 980 s (△); (c) in regime II at $t = 2235$ s (◁) and 2245 s (▷); (d) in regime III at $t = 4665$ s (●). Insets in (b), (c), and (d): pictures of the sample in regime I, II, and III at $t =$ 874 s, 2236 s, and 4350 s, respectively. The white bar corresponds to 5 mm. See also [19].

Regime II



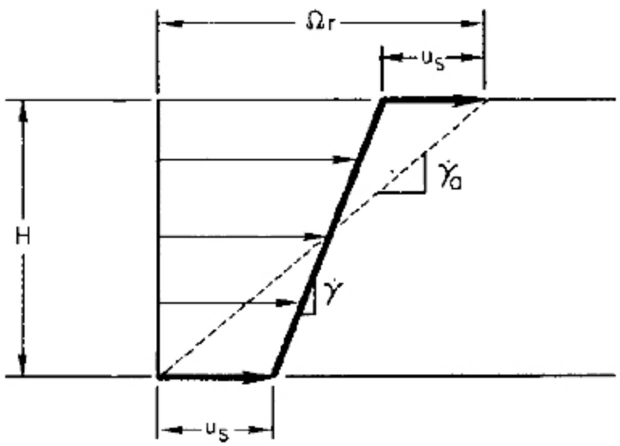
- Velocity alternates between linear/plug flow

Video from:
http://www.aip.org/pubservs/epaps.html

Slip Velocity vs. Slip Length

- We can quantify slip in two different ways, either using a slip velocity, or a slip length:

Yoshimura and Prud'Homme (1988 JOR)



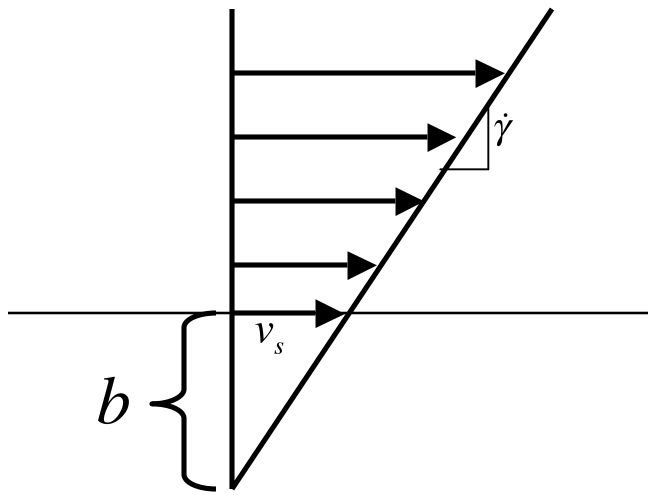
Slip occurs at the top and bottom so:

$$H\dot{\gamma} + 2v_s = H\dot{\gamma}_a$$

We can also write the slip velocity in terms of slip length:

$$v_s = b\dot{\gamma}$$

$$H\dot{\gamma} + 2b\dot{\gamma} = H\dot{\gamma}_a$$



Slip Velocities & Periodicity of Velocity Profile

Normalized Slip Velocities:

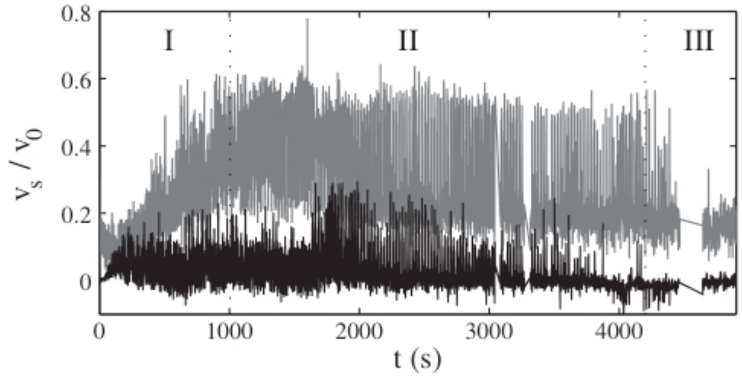
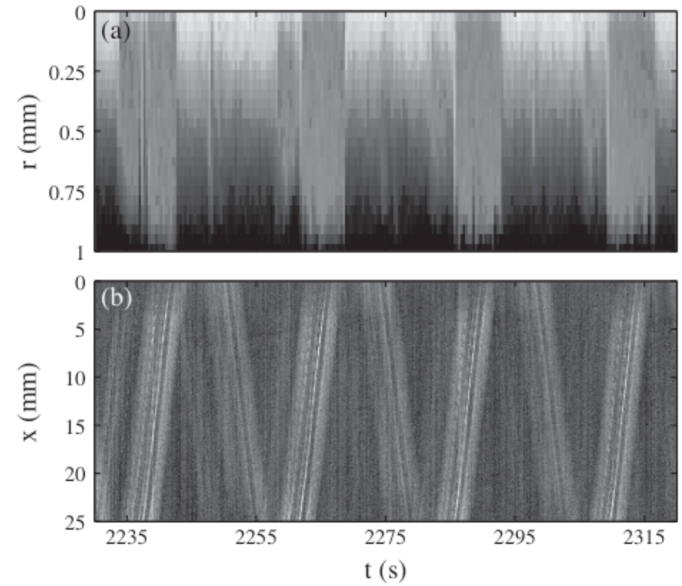


FIG. 3. Normalized apparent slip velocities v_s/v_0 in the smooth geometry derived from linear fits of the velocity profiles over 0.2 mm from the stator (black) and from the rotor (gray), where v_0 is the rotor velocity.

- Variations in slip velocity indicative of unsteady sticking/slipping status of sample on cell wall

Spatial/time variation of velocimetric & optical measurements



$$v_{solid} = 7mm/s$$

$$T = \frac{2\pi R}{v_{solid}}$$

Fragmentation/Erosion

- **Decrease in Φ (fraction of pluglike velocity profiles) with time**

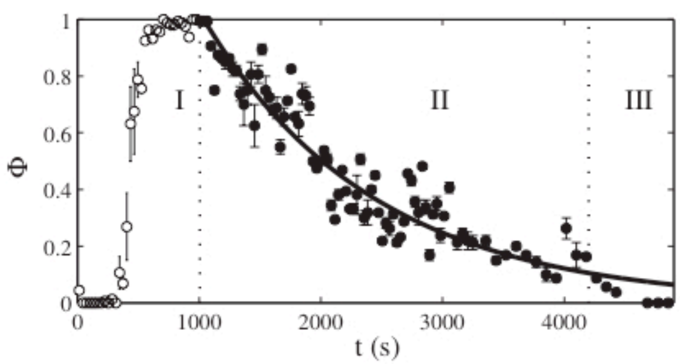
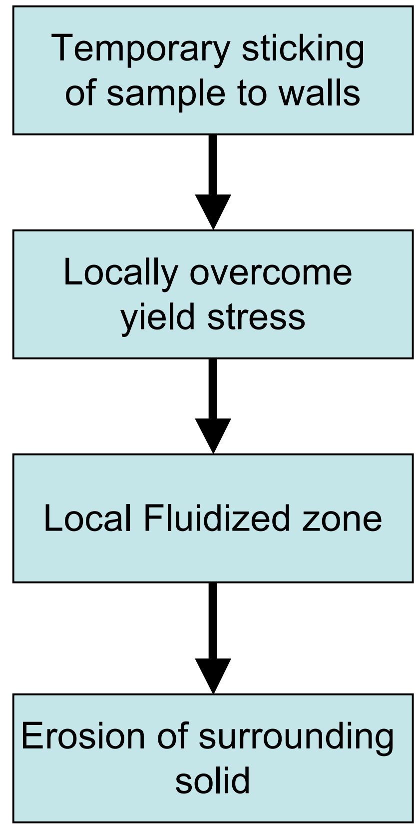


FIG. 5. Fraction Φ of pluglike velocity profiles measured within a constant time window of 50 s during the experiment shown in Fig. 2. A velocity profile is counted as "pluglike" when the local shear rate in the middle of the gap is smaller than the threshold value 8 s^{-1}. The thick line is the best exponential fit of $\Phi(t)$ over regime II which yields a characteristic relaxation time of 1450 s.

Yielding transition for smooth wall



Conclusion

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