and the fluids don't always flow homogeneously, even when subjected to homogeneous stress.

But simple YSFs have no reason not to flow homogeneously. So Manneville and colleagues didn't expect to see any shear banding. When they set out to study their material's flow under shear stress, they were hoping to get some insight into how a YSF yields, or turns from solid to liquid. More specifically, they wanted to see whether the smoothness or roughness of the container walls had any effect.

The material they studied was carbopol gel, a main ingredient in hair gel and many pharmaceutical gels. Synthesized from carbopol powder and water, the gel itself is an assembly of soft, swollen polymer blobs. The researchers used a rheometer equipped with a Couette cell, shown in figure 1a: A layer of gel filled the 1.1-mm gap between two concentric cylinders, and the inner cylinder was rotated at a constant rate.

To measure the gel's velocity profile, the researchers used ultrasonic speckle velocimetry, a technique Manneville had developed for cheaply studying optically opaque fluids.[3] They seeded the gel with micron-sized glass spheres, which scatter acoustic waves, and aimed an ultrasonic transducer at the sample at an angle to the direction of flow. Every millisecond or so, they shot an ultrasound pulse through the gel and recorded its reflection. From correlations between consecutive shots, they deduced the gel's velocity as a function of position and time.

Not so simple

Figure 1b shows some results from a typical run, during which the inner cylinder rotated once every three minutes. At first the gel flowed only near the moving wall, but with time the flowing band gradually widened and then suddenly gave way to homogeneous flow. That so-called fluidization time was surprisingly long: more than half an hour for the experiment shown.

Manneville and colleagues repeated the experiment, rotating the cylinder at different speeds. Not surprisingly, fluidization happened faster when the cylinder was spun faster. But quantitatively, the dependence took an unexpected form: The fluidization time was inversely proportional to the cylinder's speed raised to the 2.3 power. When the researchers looked at thicker layers of gel, they found a power-law dependence on the shear rate (the inner wall's linear speed divided by the gap width), as shown in figure 2. And it mattered little whether the inner and outer walls were bare plexiglass or whether they were coated with sandpaper to make them rough.

Where the exponent 2.3 comes from is unclear. The researchers think it's a material property, since using carbopol gel from a different batch—which may have had different-sized polymer blobs—was enough to change the exponent from 2.3 to about 3. They're now looking at gels prepared with different concentrations of carbopol powder to better understand the material dependence. Extending the study to different simple YSFs, such as foams, would be more difficult: The high acoustic contrast between a foam's gas and liquid phases makes the ultrasound probe unsuitable.

The observation of transient shear banding shows that nonthixotropic YSFs are not as simple as they've been assumed to be; they don't yield uniformly, even under uniform stress. (The researchers briefly looked at other flow geometries to make sure that the shear banding was not an artifact of the slight stress heterogeneity induced by the circular geometry.) That the power-law relationship is independent of the layer thickness means that the fluid boundary doesn't simply diffuse across the gel. And the long fluidization times point to the importance of distinguishing between steady-state and transient regimes in future YSF models and experiments. **Johanna Miller**

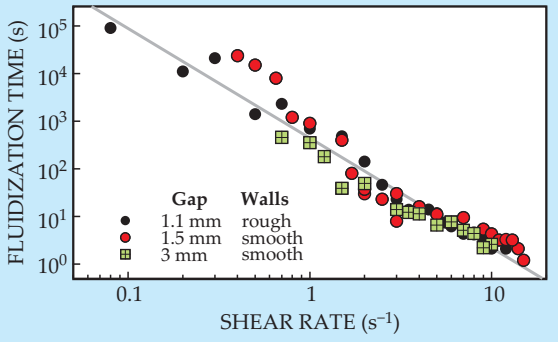

Figure 2. Power-law dependence of the fluidization time (the duration of the transient shear banding) on the shear rate. Symbols represent different gap widths and different boundary conditions, as indicated by the legend. The gray line is a power-law fit with slope −2.3. (Adapted from ref. 2.)

References

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physics update

These items, with supplementary material, first appeared at http://www.physicstoday.org.

A thermometer for modern and extinct vertebrates. Robert Eagle of Caltech and his collaborators have shown that they can determine the body temperature of living and long-dead vertebrates by measuring the abundance of a molecule made of isotopes—an isotopologue—in bones, scales, and teeth. The isotopologue is a heavy version of the carbonate ion CO_3^{2-}. In a typical piece of bone or other biomineral, all but 1.8% of the CO_3^{2-} ions are made of the lightest carbon and oxygen isotopes, ^{12}C and ^{16}O. At around 45 ppm, $^{13}C^{18}O^{16}O_2^{2-}$ is barely present, but its scarcity is made up for by a useful property: The isotopologue's precise abundance depends on the ambient temperature when the biomineral first crystallized. The temperature dependence arises because lower temperatures boost the propensity of a heavy isotope to form a bond with another heavy isotope rather than with a light isotope. Five years ago, Prosenjit Ghosh, who is now at the Indian Institute of Science, and his colleagues extracted CO_2 gas from carbonate crystals they'd made in the lab. From their measurements they derived a robust formula relating the abundance of $^{13}C^{18}O$ carbonate to its formation temperature. By applying the formula to tooth samples, Eagle could accurately predict the body temperature of five vertebrates, including the white rhino (37 °C) and the sand tiger shark (23 °C). From fossilized samples he could also predict the body temperature of the woolly mammoth (38 °C). Applying the paleothermometer to samples of other extinct vertebrates could reveal when vertebrates first became warm-blooded. (R. A. Eagle et al., *Proc. Natl. Acad. Sci. USA* **107**, 10377, 2010.) —CD

An optical speed trap for Brownian motion. One hallmark of Albert Einstein's genius is his 1905 theory that the kinetic energy of pollen grains, dust, and other similarly sized objects in thermal