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Laboratory Products

Yield Testing by Two Methods as a Practical and Convenient Analysis

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Yield testing can be a practical and convenient method for QC/QA testing, as well as for R&D. This paper discusses two rotational shear methods: (1) testing a material at multiple shear rates and extrapolating the yield stress with a math model, and (2) testing the sample at one speed and finding a peak-stress reading, and the corresponding strain. These will be referred to as Methods 1 and 2, respectively. The yield stress is the stress at which a solid-like material starts to flow like a liquid. The corresponding deformation is the yield strain. The two methods provide different complementary information about the material behaviour. The multi-speed/shear rate data provide a more complete picture for process equipment designers. However, the single-speed test does provide useful data, related to the product's end-use, in even less time than the other method.

Strictly speaking, Method 1 is appropriate for materials exhibiting structural recovery; that is, the sample recovers its structure after the shearing stops. Hair gels are one such example. Method 2 is most appropriate for materials that do not recover, such as certain mayonnaises and cold creams, for example. However, Method 2 may also be used with materials that can be analysed with Method 1.

An aloe vera gel was tested, using both methods. A Brookfield RVDV-III Ultra Rheometer, used with Rheocalc™ software, provided multi-shear rate data. *Figure 1* shows a DV-III Ultra Rheometer with EZ-Lock™. The EZ-Lock coupling allows easy attaching and detaching of spindles without screwing them on and off. The spindle was immersed directly in the container. A custom spindle setting was created in Rheocalc™, storing the Shear Rate Constant for the cylindrical spindle immersed in a cylindrical container.

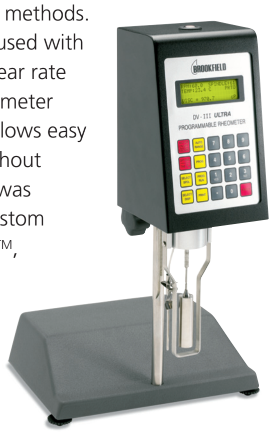

Figure 1. Brookfield DV-III Ultra Rheometer

Figure 2 shows a graph of viscosity and torque vs. speed. The viscosity decreases significantly with increasing speed; this material is highly shear-thinning. *Figure 3* is a log-log plot of viscosity vs. shear rate. It shows the high degree of shear-thinning and that, under these test conditions, the material exhibits Power Law behaviour. These data are useful in designing processing equipment.

Figure 4 shows a fit of the Herschel-Bulkley model to the data. The Coefficient of Fit or "COF" is 99.9, indicating an excellent fit. The calculated yield stress is 666.1 Dyn/cm², or 66.61 Pa, a significant value. In fact, bubbles are easily seen trapped in the gel, through the transparent bottle. The yield stress is high enough to overcome the buoyancy of the bubbles.

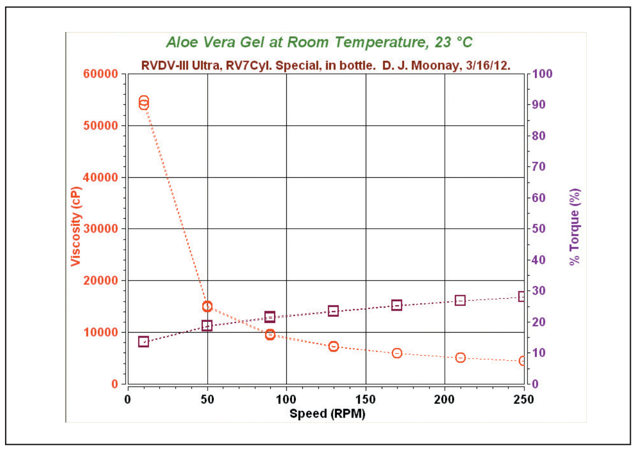

Figure 2. Viscosity and Torque vs. Speed, for Aloe Vera Gel

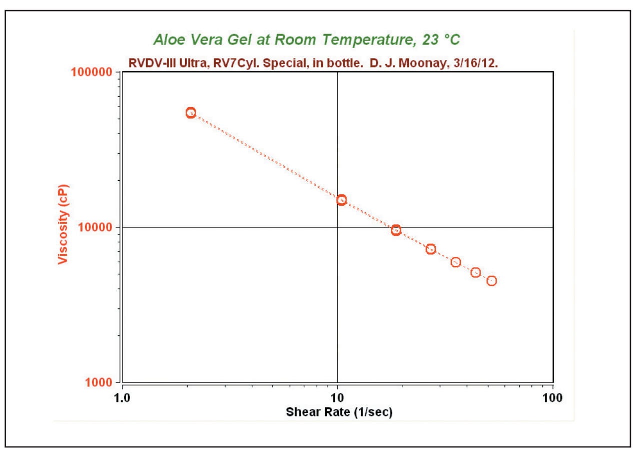

Figure 3. Log (Viscosity) vs. Log (Shear Rate) for the Aloe Vera Gel

The gel was analysed using the same rheometer, but using the Yield Test mode, with Brookfield EZ-Yield™ software. Tests were performed with a V-73 vane spindle at 1 RPM.

The yield stress was calculated from the peak torque, during each run, by the software. *Figure 5* shows typical data from five runs. There is good agreement among the results – approximately 81 to 85 PA as the yield stress. Each run took only 21 to 32 seconds to complete.

This is certainly reasonable for a QC test in a busy lab. The yield stresses from Method 1 and Method 2 differ. This is as expected for different test modes on a complex material.

However, 66.61 and [approximately] 83 Pa are similar, easily the same order of magnitude. The higher value from Method 2 may be expected, because it is from a test at a single, lower speed, compared to a value extrapolated from testing at multiple, higher speeds in Method 1.

In conclusion, yield testing provides useful rheological information for understanding and describing material behaviour. Two methods, (1) yield extrapolation for multi-shear rate testing, and (2) yield determination from single-speed vane tests, provide complementary data for the user. The data may be used to optimise both product formulation and process design.

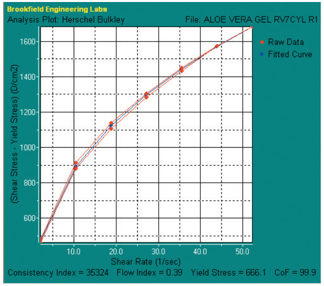

Figure 4. Plot of Herschel-Bulkley Model Fit to the Gel Data

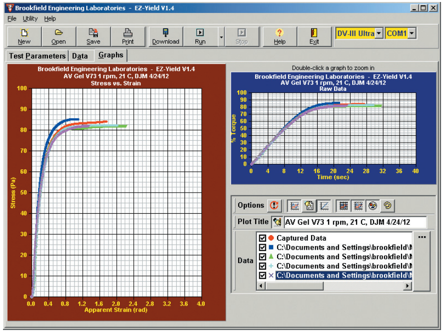

Figure 5. Stress vs. Strain for an Aloe Vera Gel