ParticlesCIC

Application Note 02

Direct Measurement of Yield Stress

Introduction

The yield stress is the minimum stress that must be applied to a sample in order to induce flow. The sauce that refuses to run out of the bottle until a hefty slap is applied? That's due to yield stress. Until the slap is applied, the sauce stays in the bottle – it exhibits elastic (solid – like) behaviour. The slap to the bottle applies enough stress to the sample to overcome its inherent structure and the sample starts to behave like a liquid, and undergoes flow. A similar explanation applies to pump start-ups, toothpaste extrusion and butter spreadability.

Experimental

Two methods are used to directly determine yield stress using a rotational rheometer, termed Stress Growth and Creep/Recovery. A vane tool is used over the more conventional geometries because the vane barely disturbs the sample at all upon insertion prior to testing and it eliminates slippage (figure 1).

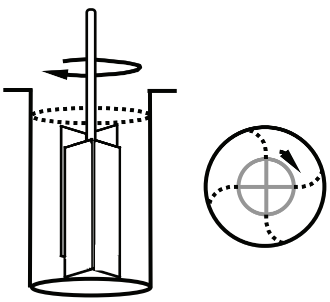

Figure 1: The Vane Tool

In the stress growth method, a very slow constant shear rate is applied to the vane immersed in the sample and the resulting stress is measured as a function of time. Essentially, we are monitoring the build up of stress within the sample. At a critical yield stress, the applied stress overcomes the inherent resistance within the sample and the material flows. The yield stress is then determined as the maximum stress in the stress-time profile (see figure 2), in this case at a value of 134 Pa. This value gives us an indication of the value of shear stress we require for the second technique.

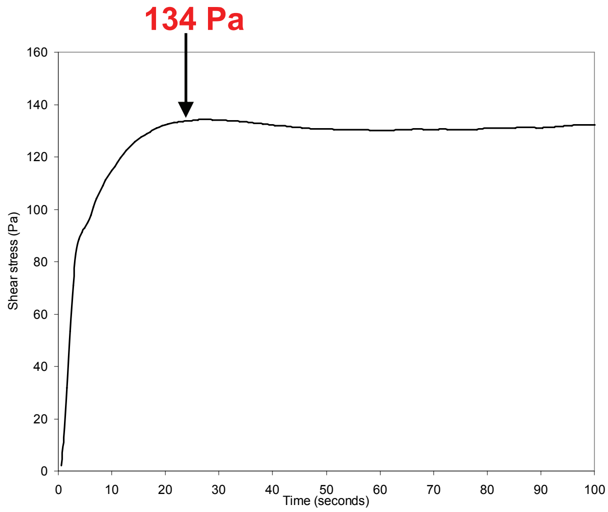

Figure 2: Stress Growth Method

Measurement conditions

Samples: Mineral slurries, sauces, pastes, gels *etc.*
Measurement settings: Rate controlled
Rheology option: Viscometry
Shear rate: 0.01 s^{-1}
Geometry: Vane tool

The second method is a *creep/recovery* technique whereby a constant stress is applied in steps to the vane immersed in the material and resulting strain is measured as a function of time for each stress step. The strain is given by the amount the vane rotates within the material, known as the creep angle, and the yield stress is the point at which the vane will just start to turn. Below the yield stress, the material behaves as an elastic solid so that the strain increases with time towards a constant value. Above the yield stress, the strain increases indefinitely with time, ultimately attaining a steady state of shear indicating viscous flow. The yield stress is then the transition between these two phases and is indicated by the red line in figure 3.

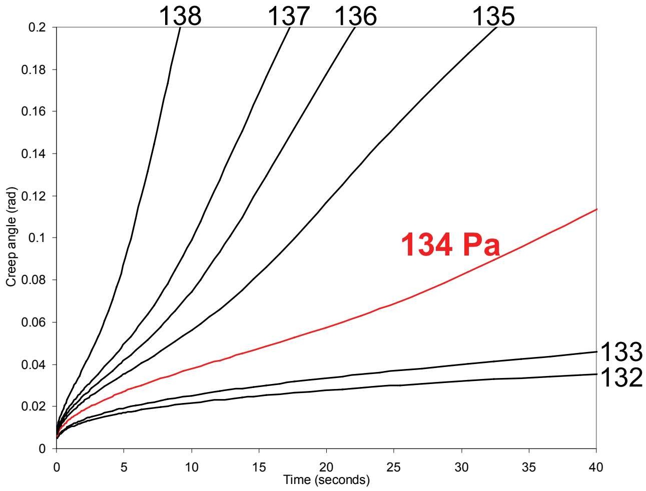

Figure 3: Creep/recovery Method

Measurement conditions

Samples: Mineral slurries, sauces, pastes, gels *etc*.
Measurement settings: Stress controlled
Rheology option: Creep/recovery
Shear stress: Variable around critical stress from method 1
Creep time: Variable, long enough to see yielding occur from method 1
Geometry: Vane tool

Conclusion

The resulting stress is a static yield stress, the stress at which the sample just starts to move. Both methods produce reproducible values of yield stress:

- The stress growth technique is quick and simple and is suitable for most sample types.
- The creep/recovery method is more time consuming but delivers a more precise result.

Essentially, the best method to use will rely upon instrument capability, whether stress controlled or rate controlled.

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