CENTER FOR RESEARCH IN SOFT MATTER & POLYMERS

CRiSP SEMINAR

Friday, Nov. 1, 2019

10:00 a.m.

102 Colburn Lab

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“Deformation and Flow of Yield Stress Fluid: Generic Elasto-Plasticity in their Solid Regime“

The transition from a solid state to an apparently liquid state for Yield Stress Fluids (YSF) is intriguing, all the more when one considers that it is reversible after some appropriate relaxation, whereas for standard solids, breakage or irreversible plastic deformations occur. It has even been suggested that the liquid regime would in fact be in the continuity of the solid regime just with continuous plastic deformation, but the mechanical behavior in the solid regime of these materials has not been much explored so far.

First, we follow the structure state of various model YSF (emulsion, gel, bentonite and laponite) during their solid-liquid transition by means of superimposition tests. These tests consist in superimposing oscillations of very small amplitude to creep tests under various stress levels in order to simultaneously measure elastic modulus and the strain. Subsequently, recovery tests are performed to get further information on the elastic and plastic components in the solid regime. We thus show that the solid state of the materials is associated with the persistence of an elastic network of constant elastic modulus up to yielding, while progressively larger plastic events occur. The solid-liquid transition can then be strictly associated with the collapse of this structure. Moreover, the additional elastic component (for larger deformations) and the plastic component appear to be equal and increase as a square of the stress imposed. These observations allow modeling the rheological behavior of all these systems by a basic elastic network plus a continuous series of elasto-plastic blocks with a linear probability density, which appears to be in good agreement with the data for the different systems.

Then we focus on the rheological behavior of a more complex yield stress fluid system, i.e. aqueous Carbon Black (CB) suspensions, which are used as a support of electrolyte solutions in batteries. So far most rheological studies focused on suspensions of CB particles in oil, and original behavior trends were observed: shear thickening at high shear rate, or some kind of anti-thixotropy, associated with the specific morphology and colloidal characteristics of CB particles. We show by means of standard rheometry completed by local rheometry using Magnetic Resonance Imaging (MRI) that these aqueous CB suspensions are basically standard thixotropic YSF. From creep tests, these materials exhibit a solid-liquid transition in the form of a viscosity bifurcation associated with a fast liquefaction of the material beyond a given critical strain. This implies that no steady state flows are possible below a finite critical shear rate.

The behavior of these suspensions in their solid regime is however more surprising, since it appears to strongly depend on the deformation history. The elastic modulus appears to widely increase with the strain applied in creep tests, by up to an order of magnitude (at the approach of a critical deformation), while the yielding conditions remain constant. We suggest that this strain hardening behavior results from the rough aggregates of CB, which tend to interpenetrate for large strains and bring the material into a more jammed state.

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