SHEAR THICKENING AND RHEOLOGICAL SELF-OSCILLATIONS IN DENSE SUSPENSIONS

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Experiments with various highly concentrated suspensions demonstrate that their viscosity increases by several times or even orders of magnitude, when the shear rate/imposed stress in the suspension exceeds some critical value which depends on the concentration, shape of the particles and physical properties of the carrier liquid as well. It is experimentally found that many concentrated suspensions demonstrate N-like dependence of shear rate $\dot{\gamma}$ on applied shear stress σ, the hysteresis dependence of σ on $\dot{\gamma}$. Every point on the decreasing part of this dependence could be detected only if time of the measurements did not exceed several seconds. For longer time the suspension flow was unstable; regular and random rheological self-oscillations arose. In spite of significant efforts, a microscopical theory of the shear thickening effects and the N-like dependence of $\dot{\gamma}$ on σ has not been developed .

We propose a microscopical theory of the N-like dependence and shear thickening phenomena in dense suspensions. This model is based on the idea that the N-curve is explained by the contact friction between the suspended particles. The decreasing part of this curve corresponds to negative sign of differential viscosity of the suspension. Stationary flow of a fluid with the negative differential viscosity can not be stable. Combination of negativity of this viscosity with viscoelasticity of the suspension leads to rheological self-oscillations, which are quite similar to those, observed in experiments.

Fluctuations of the imposed stress are inevitable in any experiments. We have studied effect of these fluctuations on the suspension flow. Our analysis shows that even weak fluctuations can induce to the rheological self-oscillations even when the imposed stress σ corresponds to the increasing part of the N-like dependence of $\dot{\gamma}$ on σ where, in the deterministic approximation, suspension flow must be stable. Amplitude of these oscillations can be high, especially when σ is close to the point of maximum of the N-curve. It should be noted that experiments also demonstrate appearance of the self-oscillations on the increasing part dependence of $\dot{\gamma}$ on σ.

Since the N-or S-like dependences of the shear rate on the applied stress, as well as rheological self-oscillations have been observed for many various complex fluids – polymers, surfactant and micelle solutions, etc., we hope that the proposed model can be considered as a robust background for analysis and explanations of these phenomena in complex fluids.