Simulation of strain hardening in particle suspensions

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Particle suspensions exhibit a wide variety of non-Newtonian flow phenomena. One such phenomenon is the so-called strain hardening [1]. In strain hardening an increase in viscosity is observed as a function of induced strain when an initially immobile suspension is sheared. The prevalent belief is that strain hardening results from a microstructural change in the configuration of suspended particles, but so far there has been no direct evidence of this mechanism.

In order to clarify the mechanism of strain hardening, we performed a series of direct numerical simulations by the lattice-Boltzmann method. The studied suspensions consisted of monodispersed spherical particles suspended in a liquid. Simulations were done using a parallel plate geometry: the plates between which the suspension was confined, were started to move with equal speeds in opposite directions. A significant increase in the viscosity of the suspension was observed when its strain reached a value of approximately 0.1 in agreement with the experiments [1]. The change in the viscosity was also found to increase with increasing solid-volume fraction of the suspension. At the same value of strain for which the increase in the viscosity took place, strong cluster formation was also observed. The initial configurations of the particles were always such that no clusters of particles existed when the simulation was started. We could verify that the increase in the viscosity when clustering of suspended particles appears, is caused by enhanced momentum transfer through the solid phase.

References

[1] P.J. Carreau and F. Cotton, in Transport processes in bubbles, drops, and particles, eds. D. De Kee and R.P. Chhabra (Taylor & Francis, New York, 2002).