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Numerical simulations of viscoelastic concentrated suspensions in planar elongational flow

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Introduction
Elongational flow experiments show a reduction of strain hardening if particles are added to a viscoelastic fluid [1]. This phenomenon is more pronounced if the particle volume fraction is increased. The reduction in strain hardening seems to be related to hydrodynamic effects. In order to predict and model this phenomenon a suitable simulation scheme needs to be developed.

Model and methods
A suspension of non-Brownian, rigid, inertialess, circular disk particles in planar elongational flow is considered. The particles interact with the fluid (modeled like a Giesekus fluid) and other particles by hydrodynamic interactions. The equations are solved by means of the finite element method. A DEVSS-G/SUPG scheme is combined with a fictitious domain and the particles are described by a rigid-ring [2]. A log-conformation representation for the conformation tensor is also used [3].

Simulation scheme
To manage a many-particle problem computationally, the simulation scheme should use the smallest domain that still has the same average properties as the whole suspension. The basic idea is to randomly relocate a particle on an inflow section of the domain when it crosses the outflow boundaries (see Fig. 1). With this scheme a regular time-independent grid can be used and a steady state is achieved [4]. A three concentric square region domain is considered so that: i) the boundary conditions are imposed far from the particles, ii) the stress has time to relax after the relocation.

Results
Local fields of the trace of the conformation tensor $(trC)$ show the presence of regions (see Fig. 2) where the fluid is more (red zones) and less (blue zones) stretched than the unfilled polymer. Furthermore, for high Weissenberg numbers $(Wi)$, highly oriented regions exist so the polymer molecules are induced to align along these directions.

Conclusions
□ A new simulation scheme for concentrated suspensions in elongational flow has been developed.
□ The local trace of conformation tensor shows increased stretch and reduced stretch regions.
□ Our simulations predict the reduction of the strain hardening in qualitative agreement with experiments.

References:

For $Wi = 0.1$, these regions quickly disappear since the polymer stress relaxes fast. Instead, higher $Wi$ leads to the existence of the stretched zones that survive much longer.

![Figure 1. Scheme of the simulation procedure: (a) initially the particles are randomly distributed; (b) the particles move; (c) the particle “2” is close to the boundary; (d) the particle “2” is relocated.](image1)

![Figure 2. Distribution of $trC$ for $Wi = 0.1$ and $Wi = 1.0$. A suspension of 150 particles in the full domain is considered ($\phi = 0.20$). Only the internal square domain is shown.](image2)

![Figure 3. Average relative bulk viscosities and strain hardening parameter as a function of $\phi$, for different $Wi$.](image3)