

Review of: "Shear stress during the flow of thixotropic and rheopex suspensions"

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Potential competing interests: No potential competing interests to declare.

Review of a paper "*Shear stress during the flow of thixotropic and rheopex suspensions*" submitted to Qeios as manuscript 407WP7

The actual manuscript suggests a semi empirical equation that would describe non-linear stress-strain rate relationship when considering a mixture of non-linear polymers. The suggested equation is based on the Krieger formula (1967) generalized to the case of multicomponent suspensions. It is clearly written that "The equation needs experimental verification".

As it actually stands, the manuscript presents modification of a equation of mixture between two components, which, in addition, interact between them, creating some feedback loops. In that sense, the theoretical approach is a valuable contribution to the understanding of non-linear rheology of mixtures.

BUT

A mixture of two (or more) components, a solid and a liquid to simplify, even if both are viscous, is a mixture, the behaviour of which (the strain-stress response) depends on the amount of each phase (here treated as f_1 and f_2). An additional constrain may be that they do not interact, linking f_2 to $1-f_1$.

When the two phases have a "normal" rheology (pure solid and pure liquid), a mixture equation can be formulated, as done by A. Einstein (1906), later formulate and complexifies by other averaging methods (e.g. Krieger, or Krieger-Dougherty *J. Rheol.* 1959, 3, 137–152. Jinescu, V.V., 1974. The rheology of suspensions. *Int. Chem. Eng.* 14, 397–420. Kröner, E., 1978. Self-consistent scheme and graded disorder in polycrystal elasticity. *Journal of Physics* F8, 2261-2267.). The latter being a full review of averaging processes and self-consistent schemes (SCS). SCS equations with exchange require Kohn-Sham theory, that is much more complex (1965, *Physical Review* 140, A1133).

A good formulation would be adding to the strain-stress curve for each phase $(F)_1$ and $(F)_2$ and a coupling term function of $(F)_1(F)_2$. The problem comes when the strain rates for both components become highly contrasted. In this case the smooth curve at high strain rate (experimental for instance) fits a mixture law. But at lower strain rate, when both components show contrasted relaxation time, the mixing curve adopts a 3 order shape (a cusp), showing a zone of instabilities. It mimics the large interval observed when computing mixture curves (serie and parallel schemes).

A PHYSICAL FLAW

Nevertheless, ALL those averaging methods suffer a physical flaw. They do not take into account strain partitioning that develops between phases, leading to local shear zones. This is one reason for which experimentalists, using gas press apparatus failed (and abandoned) in describing the rheology of partially molten rocks. The imposed strain rate (10^{-4} /s) is too fast, but long enough for experiments.

Consequently

The actual manuscript, in its present formulation is certainly a good approach on a pure mathematical point of view and it should be issued. But physically, it is erroneous, and that should be pointed in the introduction. It certainly forgets implying instabilities. By the way, introducing and justifying a coupling term (reaction between components) should be emphasized. The only problem of a reaction is that it consumes (or release) some energy. It is what is observed during melting (or even dry friction). It produces small scale instabilities that make the bulk flow instable with small spikes like stick-slip motion (alternate periods of sticking and gliding). See our last EPSL paper on that.

In conclusion the manuscript can be **accepted, with some modifications**

Vigneresse et al., Rheological Transitions During Partial Melting and Crystallization with Application to Felsic Magma Segregation and

Transfer <https://ieeexplore.ieee.org/abstract/document/8156683>

Vigneresse, and Cenk. "Multiphase rheology as a cause for stick-slip like melt extraction." *Earth and Planetary Science Letters* 577 (2022): 117269. <https://doi.org/10.1016/j.epsl.2021.117269>

In details

In the introduction, you specify that the Krieger equation is valid for "a structured suspension". This is an important double constrain. Please define what is a structured (shape of grains ?) suspension (< 20-30 % hard phase ?)

You introduce a reversible reaction 2 f1 and f2. I am surprised that you do not consider the rate of the reaction vs the strain rate.

The captions Fig1 and Fig2 poorly illustrate the shear stress and shear rate. Apparently the two curves show hysteresis, which is expected. But not justified. By the way, check the English of the captions (thixotropy, thixotropie)