The rheology of drilling fluids from a non-equilibrium thermodynamics perspective

Drilling fluids are usually suspensions of plate-like (clay) particles, such as bentonite which is largely composed of the mineral montmorillonite. Their use in drilling operations is multifunctional, including removing rock from the hole, cooling and cleaning the bit, etc. For drilling fluids to bear the capacity to perform these crucial functions, their rheological properties should be finely tuned, since the failure to do so results in enormous financial losses. The rheological behavior of drillings fluids is usually described by simplistic constitutive equations, such as the Casson or the Herschel- Bulkley models, and the power-law model. Despite the overwhelming data highlighting the significance of their use in numerous fields, they fail to produce normal stresses, whose importance in drilling operations has only recently attracted attention.

In this paper we introduce a continuum model for predicting the rheological behavior of drilling fluids with plate-like suspensions (Fig. 1), based on the Hamiltonian formulation of transport phenomena for fluids with a complex microstructure. which, by construction, guarantees consistency with the laws of thermodynamics. It allows for the accurate prediction of normal stresses in addition to shear viscosity (Fig. 2). This is the take-home milestone of the present contribution: the model presented allows for non-vanishing predictions for both normal stresses, a feature that makes it unrivaled to all other constitutive models routinely employed in the field. If we aspire to optimize drilling operations, the successful prediction of normal stresses for drilling fluids is paramount. It is therefore expected that its use in CFD calculations, instead of the aforesaid simplified models, will certainly allow for a more reliable and accurate (i.e. closer to actual borehole conditions) optimization of drilling operations.

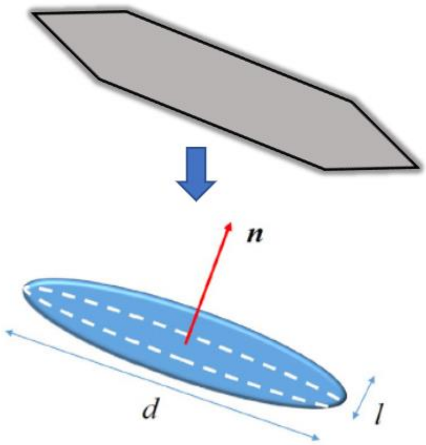

Fig. 1: We treat a montmorillonite platelet (up) as an oblate particle with thickness l and diameter d (below)

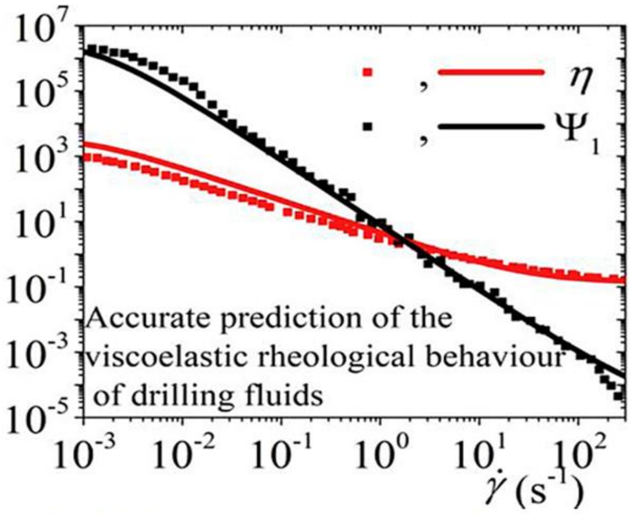

Fig. 2: We manage to accurately predict the viscoelastic rheological behavior of drilling fluids

Reference

P. S. Stephanou, "The rheology of drilling fluids from a non-equilibrium thermodynamics perspective", *J. Pet. Sci. Eng.* 10.1016/j.petrol.2017.11.040 (**2017**).