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The origin of two-step yielding in natural mud: wall slip or structural reorganization?

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1. Introduction

Natural mud typically consists of clay minerals, water, sand, silt, and a small amount of organic matter of different origin and composition. Yield stress has been found to be an important parameter to define navigable fluid mud layers for ports and waterways. Recently, (Shakeel et al., 2020) examined the rheological characteristics of mud samples collected from different locations and depths of Port of Hamburg, Germany. From the extensive study, a two-step yielding phenomenon was found for the mud samples collected at the top of the water/bed interface. A similar two-step yielding for mud samples was reported by other researchers as well (Nie et al. 2020, Mehta et al. 2014). In literature, this two-step yielding has been correlated either to the structural rearrangements (Nie et al., 2020) during shearing or to the wall slip artefact (Barnes, 1995). Therefore, the objective of the present study is to explain the origin of this two-step yielding in mud.

2. Experimental

Natural mud samples were collected from Port of Hamburg, Germany using 1 m core sampler. The Thermo Scientific HAAKE MARS I rheometer was used to perform the rheological measurements. Three different geometries, including smooth and grooved concentric cylinders (Couette & Couette-G), parallel plates (PP), and vane were used to perform rheological tests. Stress ramp-up and amplitude sweep tests were carried out to analyse the two-step yielding behaviour of mud samples. Modified form of RheOptiCAD was used to analyse the structural changes during shearing action.

3. Results and discussion

Different methodologies are reported in literature, in order to investigate the wall slip artefact, such as (i) by varying the gap, (ii) by using roughened or grooved geometry and (iii) by using vane-in-cup geometry.

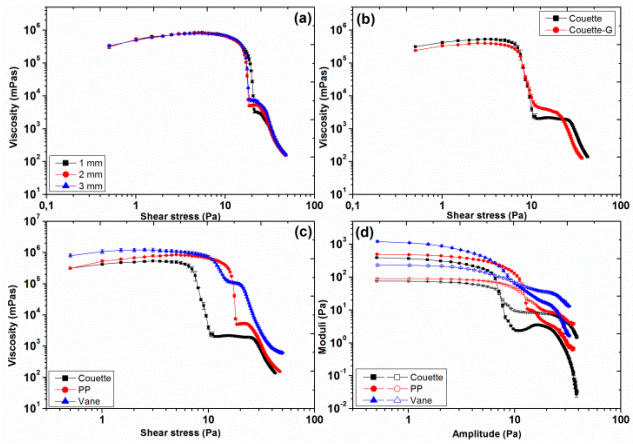

Figure 1: Apparent viscosity as a function of stress for (a) PP with varying gap, (b) Couette and Couette-G, and (c) Couette, PP and vane, (d) storage (filled symbols) and loss (empty symbols) moduli as a function of amplitude for Couette, PP and vane.

The outcome of different methodologies, mentioned before, is shown in Figure 1. It is quite clear from Fig. 1a-1c that all these approaches with different geometries verify the existence of two-step yielding (i.e., two declines in viscosity) for mud samples. Furthermore, in literature, the two-step yielding behaviour is typically investigated by performing amplitude sweep tests and the outcome of this test for mud sample is shown in Fig. 1d. This result again verifies the existence of two-step yielding (i.e., two declines in moduli) for mud. In order to identify the origin of this two-step yielding behaviour in mud, rheo-optical analysis of samples was performed. This analysis confirmed the reorganization of mud flocs during shearing as: (i) breakage of interconnected network of flocs (first yield point), (ii) formation of cylinder-like structures (plateau after first yield point) and (iii) breakage of these cylinder-like structures (second yield point) (Fig. 2).

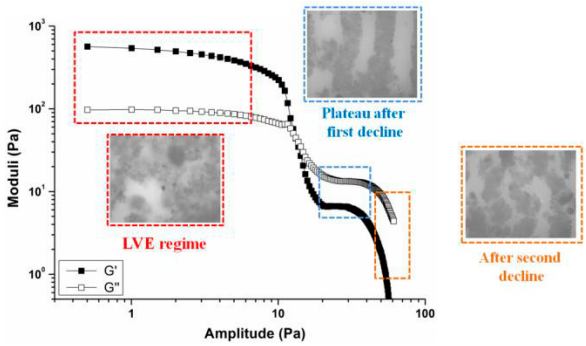

Figure 2: Schematics of the two-step yielding observed by amplitude sweep tests for mud samples, verified by RheOptiCAD analysis.

4. Conclusions

This study confirms that the two-step yielding in mud samples is not because of wall slip but due to the structural reorganization during shearing action. However, this rearrangement is because of the presence of narrow gap between the geometry and cup wall. Therefore, the existence of the first yield point may not be observed in *in-situ* conditions.

References

Shakeel, A., Kirichek, A., & Chassagne, C. (2020). Yield stress measurements of mud sediments using different rheological methods and geometries: An evidence of two-step yielding. Marine Geology, 427, 106247.

Nie, S., Jiang, Q., Cui, L., & Zhang, C. (2020). Investigation on solid-liquid transition of soft mud under steady and oscillatory shear loads. Sedimentary Geology, 397, 105570.

Mehta, A. J., Samsami, F., Khare, Y. P., & Sahin, C. (2014). Fluid mud properties in nautical depth estimation. Journal of waterway, port, coastal, and ocean engineering, 140(2), 210-222.

Barnes, H. A. (1995). A review of the slip (wall depletion) of polymer solutions, emulsions and particle suspensions in viscometers: its cause, character, and cure. Journal of Non-Newtonian Fluid Mechanics, 56(3), 221-251.