Hole Cleaning Performance of Oil Based and Water Based Drilling Fluids – An Experimental Comparison

Transporting cuttings out of the wellbore is an important part of every drilling operation to ensure efficiency and the reduction of non-productive time. The drilling fluids used for this task are complex fluid systems, generally with either oil or water as a base substance. The hole-cleaning performance of these two fluid

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systems is reportedly different from each other. Industry experience indicates that oil-based drilling fluids are performing better than water-based drilling fluids, even when the viscosity is similar. Earlier research results from the 1990s show diverse conclusions with superior behavior for either water-based or oil-based fluids, or findings where neither of the types excelled (Hareland et al., 1993; Pilehvari et al., 1995; Saasen and Løklingholm, 2002). General conclusions have not been made and the reasons for the different behavior are not entirely understood. Drilling fluids are complex fluid systems, exhibiting properties such as yield stress, thixotropy, gel strength and viscoelasticity. These properties can be measured using viscometers and rheometers, and can give insights into their low shear flow behavior.

An extensive experimental study was performed to enlighten the understanding of drilling fluid performance by comparing hole cleaning in the laboratory with the use of field applied drilling fluids from the North Sea area. The approach was to connect the viscoelastic properties with the flow and cuttings-removal properties of drilling fluids. The viscoelastic properties were measured with an Anton Paar MCR (modular compact rheometer) and the cuttings-removal properties with a flow loop. The flow loop (Figure 1) consisted of a 10 m long test section with a fully eccentric, free whirling drill string, a separation unit and several pressure cells. The oil-based drilling fluid (OBM, also referred to as OBM B) of the study is an oil-in-water emulsion containing barite, CaCl2, bentonite, lime, emulsifier and a fluid loss agent. The water-based fluid (WBM) is a KCl/polymer based drilling fluid with glycol, xanthan gum, polyanionic cellulose, starch, soda ash and barite. The densities are 1.26 g/cm3 and 1.19 g/cm3 respectively.

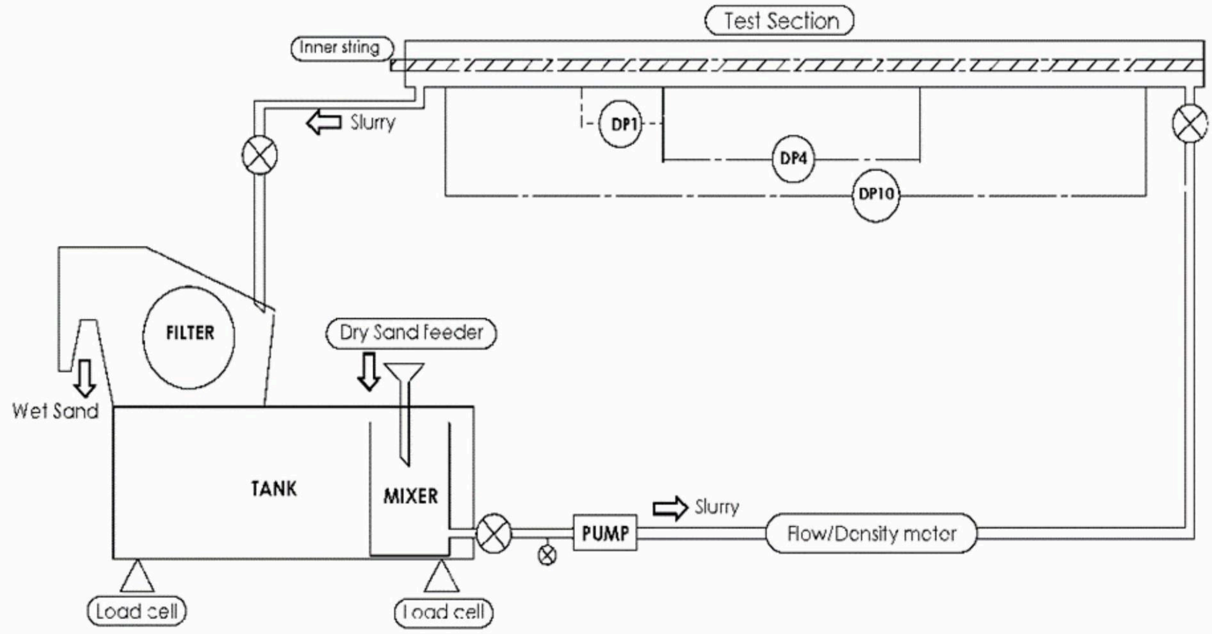

Figure 1. Flow loop setup

"It is also important to improve models for the estimation of cuttings transport"

Results

The comparative cuttings transport study of an oil-based and a water-based fluid with similar viscosity profiles supports the industrial experience that oil-based drilling fluids perform better than water-based drilling fluids. In Figure 4 it is observed that, without drill-string rotation, a significant difference in the hole-cleaning performance of the two drilling fluids occurs. In the absence of drill-string rotation, hole-cleaning performance was significantly better using the oil-based drilling fluid than water-based drilling fluid. For high drill-string rotation rate, the hole-cleaning performance of the water-based drilling fluid approaches that of the oil-based drilling fluid. This knowledge will be helpful in selection of fluids when planning the well construction. It is also important to improve models for the estimation of cuttings transport and this is important for further digitalization of the field operations. Undoubtedly, drill-string rotation has a significant positive effect on cuttings transport. However, drill-string rotation had a greater effect on water-based drilling fluid as compared to oil-based drilling fluid.

The viscoelastic properties were found to rather influence the cutting beds resistance to erosion, instead of affecting the cuttings transport itself. An about 100 times higher strain

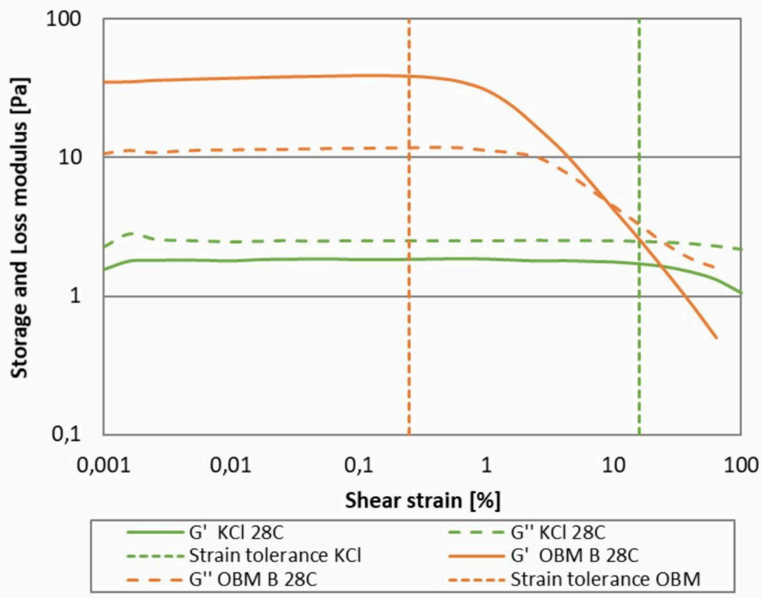

Figure 2. Amplitude sweeps showing the storage and loss moduli of the KCl fluid and the OBM B fluid for temperatures of 28 °C, measured with Anton Paar MCR 302. (data adopted from Werner et al. (2017))

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tolerance was found for the KCl/polymer fluid in amplitude-sweep tests, compared to the OBM (see dashed vertical lines in Figure 2). This higher elasticity increased the cuttings-bed resistance to erosion and created a stronger connection between the cuttings particles. Comparably, the yield stress in the OBM was broken more easily than the elasticity in the KCl fluid, leading to more efficient hole cleaning for OBM B compared to the KCl fluid. However, the storage module (G') in the OBM is about 30 times higher than in the KCl/polymer fluid (see Figure 2). The storage module describes the stored deformation energy in the fluid and is likely to illustrate the apparent yield stress of the fluids.

Figure 3 shows estimated shear rates for various standard borehole sizes and drill-string sizes used in the industry. The relevant shear rate range for the fluids during drilling is in the lower range. The shear rates would still be lower in the presence of a cuttings bed. Typical viscosity models created using the 300 and 600 RPM (511 and 1022 1/s) reading of the VG meter is, by far, outside the correct shear rate range for flow in annuli. Exceptions are flow along the BHA. For flow along the drill pipe the maximum shear rates are in the range as indicated in Figure 3. To be able to correctly estimate the drilling fluid hydraulics and hole cleaning, it is necessary to interpolate viscometer data from the relevant

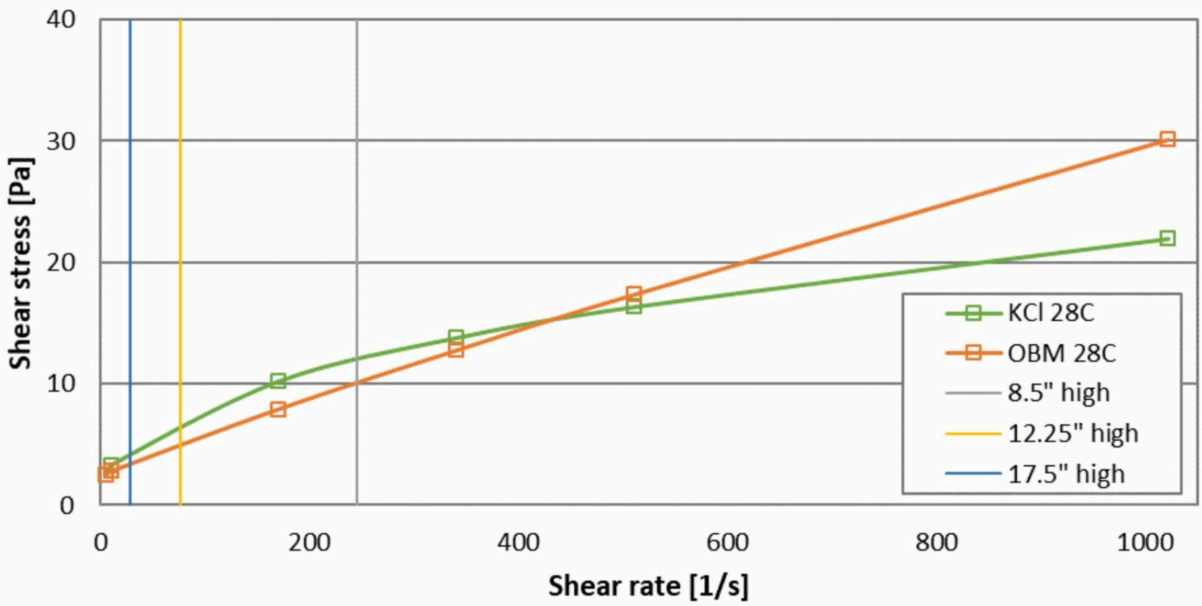

Figure 3. Fann 35 measurements of the KCl fluid and OBM B at 28 °C together with typical maximum shear rates for common borehole sizes. (data adopted from Werner et al. (2017))

"The oil–based drilling fluid used in this study showed a superior cuttings-transport ability"

shear rate to create realistic viscosity predictions independent on the type of applied model.

A CFD model of the horizontal annulus was developed and validated against the flow loop experimental data and data from the literature. The developed CFD model predicts, with acceptable accuracy, the frictional pressure loss in laminar and turbulent flow of non-Newtonian fluid for liquid flow through in horizontal annulus with and without drill string rotation.

Conclusion

An oil-based and a water-based drilling fluid have been compared regarding their rheological properties and their hole-cleaning capabilities. The characterization was done with an Anton Paar rheometer measuring viscoelastic properties. Hole-cleaning capabilities were investigated with flow-loop experiments. The oil-based drilling fluid used in this study showed a superior cuttings-transport ability to the water-based drilling fluid in the presence of drill string rotation. However, cuttings-transport ability of both the fluids was nearly the same in the absence of drill string rotation. The rheological characterization of the tested fluids provided insights into their viscoelastic behavior. The results suggest particle and emulsion based fluids, exhibiting light internal structures at low shear rates and small

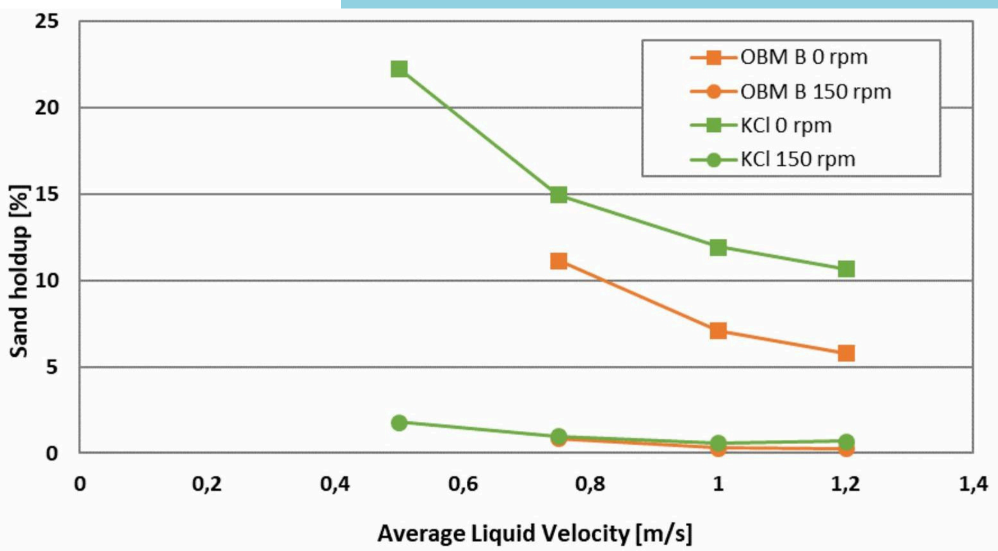

Figure 4 Sand holdup versus superficial liquid velocity for the KCl fluid and OBM B with and without drill-string rotation. (data adopted from Sayindla et al. (2017b))

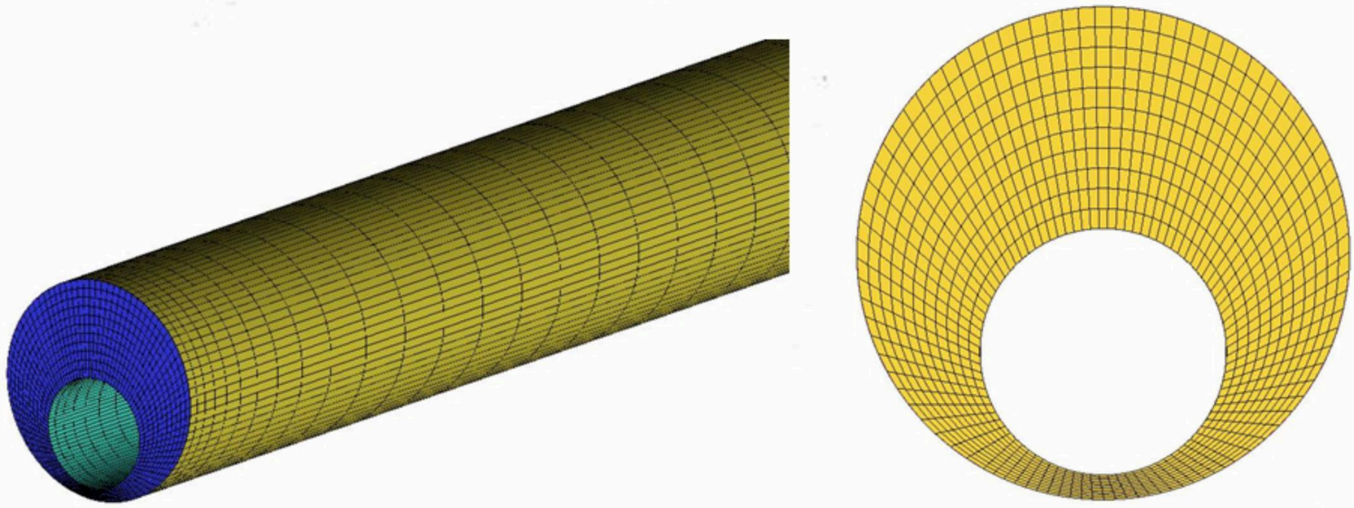

Figure 5 Annulus geometry and computational mesh. (adopted from Sayindla et al. (2017a))

yield stresses being the better option for hole cleaning. This is most likely due to a better suspension capability of the cuttings in the fluid during flow, and due to the absence of polymers consolidating the cutting beds that make these beds difficult to remove.

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