Shale Shaker's Effect on Drilling Fluids Rheological Properties

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ABSTRACT

This study describes observations and measurements of viscous properties of different types of model drilling fluids when these fluids are imposed to vibrations of different frequencies and amplitudes. These vibrations simulate the motion on a shale shaker. Our experimental data shows clearly a reduction in shear stress and gel strength caused by vibrations in drilling fluids where particles build the structures in the fluids. For purely polymeric drilling fluids no effect was seen when imposing vibrations.

INTRODUCTION

A shale shaker is the most commonly used device to separate drilled cuttings from the drilling fluid within oil well drilling [1]. The separation capacity of a shale shaker screen is controlled by the shaker design, screen design and the imposed vibration frequency on the shale shaker. The shaker vibrations influence the formation of particle structure in drilling fluids. However, the effects of vibrations on the drilling fluid properties have not been known. Therefore, this effect has not been included in shaker performance analysis.

Although the Bingham model and the "power-law" models are frequently used for modelling the viscosity of drilling fluids, most drilling fluids do not conform exactly to any of these models. However, for hydraulic and displacement calculations, the drilling fluid behaviour can be predicted with sufficient accuracy using the Herschel-Bulkley model. This is a three-parameter model that includes a yield stress and "power-law" behaviour:

$$\tau = \tau_0 + K\dot{\gamma}^n \qquad (\tau > \tau_0) \qquad (1)$$

$$\dot{\gamma} = 0 \qquad (\tau \le \tau_0) \qquad (2)$$

Parameter constraints are $\tau_0 \ge 0$, $K > 0$, and $0 < n$.

Industrial practice is to calculate the yield stress being the interception with the shear stress axis for a straight line fitted to the shear stress data obtained at 5.11 and 10.22 1/s shear rates. Industrial practice may also differ from standard procedures [2] in selecting the shear rates to obtain the Herschel-Bulkley n and K values. In the present work these parameters were modelled using the shear stress data measured at shear rates equal to 170.3 1/s and 340.7 1/s.

Several studies exist on the effect of vibration on the rheological properties of fresh cement pastes or concretes. A series of studies, relevant for drilling fluid analysis [3,4,5], concludes that vibrations reduce the shear resistance of cement significantly if the right combination of frequency and amplitude is applied. The tests show that the stiff non-Newtonian cements, that is cement with a high yield stress, becomes nearly Newtonian when the amplitude is sufficiently high. Vibrations influence the particle structures and gel structures within the fluids.

EQUIPMENT AND PROCEDURE

Laboratory tests with seven different water based drilling fluids and one oil based drilling fluid have been performed. The experimental procedure followed for shear stress and gel strength calculations is in accordance with API RP 13B[2]. A Fann-35 viscometer is used to measure shear stress and gel strength of drilling fluid samples. The viscometer is a simple controlled shear rate type of instrument. Drilling fluid is contained in the annular space between two concentric cylinders. The outer cylinder or rotor sleeve is driven at a constant velocity. Six viscometer readings are measured for shear rates of 1022, 511, 340.7, 170.3, 10.22 and 5.11 1/s.

The sample was placed in a cylinder shaped tank, which was connected to a Dremel Engraver tool shown in Fig.1. The engraver tool's frequency is adjustable. The tool's maximum frequency, $f_{\max}$, was 7200 strokes per minute and displacement amplitude was approximately 0.75mm.

The width of the slot between the cylindrical tank and the bob was fixed to 5 mm. According to Børgesson and Fredriksson [3], who measured viscosity of pure clay water and cement pastes, the width will not influence the viscometer readings.

The preparation of the fluids consisted of an initial 6 minutes period of high speed mixing in a Hamilton Beach mixer. The compositions of the drilling fluid samples are shown in Tables 1 and 2. The volume of each sample was approximately 350 ml and they were all prepared at room temperature. In four of tests we added a Poly Anionic Cellulose, PAC Polymer Regular provided by MI-Swaco, as viscosifier.

For the gel strength measurements, we let the sample rest in time intervals from 10s up to 10 minutes and then recorded the observed peak shear stress following the start up of a shear rate at 5.11 1/s. The gel strength measured at 10s and 10 minutes follow standard procedures [2]. The gel strength measurements with vibrations were conducted by applying vibrations at the same time as the standard required shear rate of 5.11 1/s [2] was applied.

Each sample is subjected to a variable shear rate, starting at 1022 1/s, followed by a stepwise decrement till the lowest shear rate is reached, which is 5.11 1/s. Then the sample was subjected to frequencies at 1/3 f_{max}, 2/3 f_{max} and f_{max} as indicated on the frequency controller. The same procedure was repeated for each sample. For the sample to reach its steady value at the given shear rate, a 10 second measurement time was allowed.

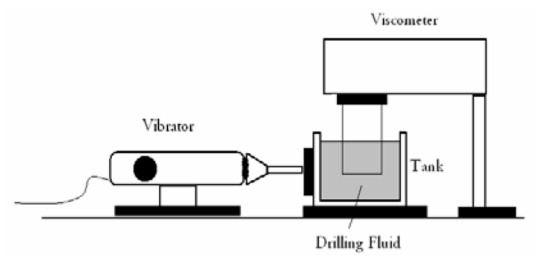

Figure 1: Schematic view of experimental equipment

Table 1: Composition of the water based Drilling Fluids samples

Sample Nr	Water (ml)	Clay (g)	Barite (g)	PAC (g)	NaCl (g)	KCl (g)	pH
1	350			1,5			
2	350			2,0			
3	350			1,0		20	10,65
4	350	25		1,5	9		9,05
5	350	25					10,15
6	350	25	25				10,3
7	350	25	25		9		9,85

Table 2: Composition of Sample 8 consisting of oil based Drilling Fluid. Chemicals provided by MI-Swaco. Base oil delivered by Total.

Mineral oil	Emulgators		$Ca(OH)_2$ (g)
EDC95/11 (ml)	Versa Vert PE (ml)	Versa Vert SE (ml)	
206	9	3	8,5
Organophilic clay Versa Vert Vis (g)	Barite (g)	$CaCl_2$ (ml)	Versa Vert F (ml)
5,5	115	60	2

EXPERIMENTAL RESULTS

Since it is expected that vibrations will only influence particle structures [3,4,5], and thereby yield stress and gel formation, it is necessary to verify that the vibrations have no effect on the viscosity profiles of polymeric liquids. This is verified from the data shown in Fig. 2. As anticipated, there are no differences between measured values of the shear stress versus shear rate in the different cases with and without vibrations. Similar results were also obtained in our experiments on Sample 1, which had lower polymer concentration. Likewise, in the tests with Sample 3, the polymer and potassium chloride formulated fluid; insignificant differences were observed when applying vibrations. Like for the purely polymer based fluids this fluid did not contain any particles.

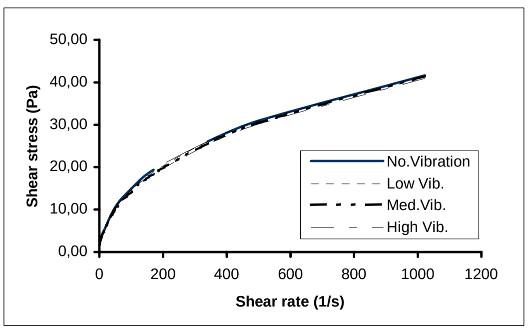

Figure 2: Shear stress as the function of shear rate for Sample 2

Viscosity measurements on Samples 4-8 illustrated in Figs.3-5 show a reduction in shear stress as the frequency was imposed and further increased. Generally, the change of viscosity of the particle loaded drilling fluids was significant for low shear rates when vibrations were imposed. These changes were insignificant and possibly absent at high shear rates. This is illustrated in Figs.3 and 5. In the measurements on Sample 7, however, it was observed that the shear stress was reduced due to vibration intensity over the whole shear rate range. Sample 7 was constructed purely with bentonite, water, barite and sodium chloride. Sodium chloride will partly agglomerate the bentonite particles in the fluid. The fluid may therefore no longer be able to keep the heavy weight barite particles in suspension. It is therefore anticipated that the reduction of shear stress at high shear rates was caused by sedimentation of the coarser barite particles in the fluid.

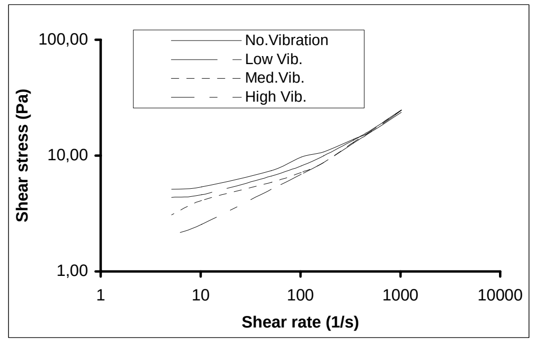

Figure 3: Shear stress as the function of shear rate for Sample 5.

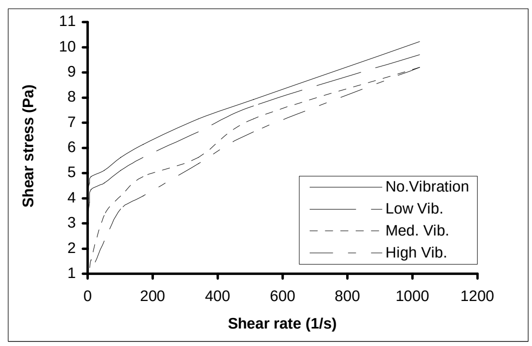

Figure 4: Shear stress as the function of shear rate for Sample 7.

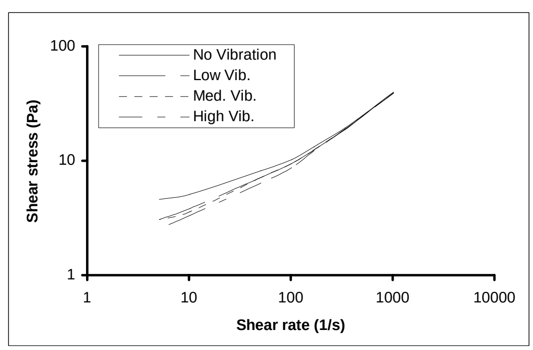

Figure 5: Shear stress as the function of shear rate for oil based drilling fluid, Sample 8.

The viscosity behaviour of the oil based drilling fluid is shown in Fig. 5. The oil based drilling is weighted with barite. The other stable drilling fluid weighted with barite, Sample 6, did show a similar change in viscosity with imposed vibrations.

The viscosity measurements performed with Sample 4 also resulted in a similar behaviour as the measurements with Sample 8 when imposing vibrations. Sample 4 is a water based bentonite slurry containing sodium chloride. There are no heavy weight particles in Sample 4. It is likely that the presence of sodium chloride aid forming bentonite agglomerates and therefore, the bentonite contribution to viscosity development is of lesser importance than in Sample 5.

In order to characterize the non-Newtonian behaviour of drilling fluids for drilling hydraulic calculations, the Herschel-Bulkley model is widely used because of its simple model parameter estimations. In the absence of a yield stress this model degenerates to the two parameter model with consistency index K and flow behaviour index n. The values of the parameters K and n are strongly connected. Therefore it has not been possible to find any systematic change in either K or n by increasing the vibration.

CONCLUSION

Shear stress measurements using a Fann 35 viscometer have been used to study the viscosity of drilling fluids when these fluids are exposed to vibrations simulating the conditions on shale shakers.

The measurements revealed that no reduction in shear stress was observed when vibrations were applied to purely polymer solutions. For the tested fluids where interaction of solid particles is important for building viscosity and forming gel structures, a significant reduction in shear stress was observed when vibrations were introduced. This reduction in viscosity was most significant at smaller shear rates.

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