Applied Rheology | DOI: 10.3933/APPLRHEOL-26-25349 | WWW.APPLIEDRHEOLOGY.ORG

Influence of Vibrations on the Rheological Properties of Drilling Fluids and its Consequence on Solids Control

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Received: 3.11.2015, Final version: 19.2.2016

Abstract:
Removing drilled cuttings from the drilling fluid flowing out of an oilwell is essential for obtaining good drilling conditions. Currently this solids control process is performed by use of shale shakers and vacuum devices. Throughout the last decades, the design and performance of the primary solid control devices have changed significantly. Flow through screens is strongly dependent on the rheological properties of the drilling fluid. Drilling fluids with high extensional viscosity seldom have a very strong gel structure, and are generally not affected equally much by vibrations. This explains why solids control is more difficult using a KCl/polymer water based drilling fluid than using an oil based drilling fluid. This article focuses on describing how the drilling fluid viscous properties alter when being exposed to vibrations like those on primary solids control devices. It is based on theoretical analysis, and rheological studies in the laboratory. The solids control efficiency resulting from using different screen configurations is outside the scope of this article, as this topic requires a higher focus on separation technology.

Key words:
Drilling fluid viscosity, vibrations, shale shaker, oil and water based drilling fluids, bentonite mud

1 INTRODUCTION

In oilwell drilling, one of the scopes of drilling fluid is to transport the drilled cuttings from the drill bit up to the rig. On the rig, the drilled cuttings are separated from the drilling fluid by the use of shale shakers or other devices that all use vibration of screens within their systems. As commented for example by Bouse and Carrasquero [1], correct use of primary solids control equipment is essential to maintain proper drilling fluid properties with the correct particle size distribution of weight material or other added solids. This is crucial to avoid generation of unnecessary waste streams with drilling fluid additives following the drilled cuttings. Since the early 1930s the shale shaker has been the dominating device for this purpose. The general design of these shakers and other solids control devices is presented by American Association of Drilling Engineers (AADE) [2]. Presently, dependent on the choice of correct shaker screens, most shakers have a sufficient capacity to be able to act as the sole solids control device without the use of additional equipment like desanders and desilters that was used in the past.

A combination of shaker and screens applicable for treating water based drilling fluids may not be suitable for treating oil based drilling fluids because these fluids have different extensional viscosities. Extensional viscosity influence the flow typically normal to the shear rate as being the case during flow through irregular flow paths like those of screens. Typically, the extensional viscosity of oil based drilling fluids should be equal to or just above three times the shear dependent viscosity at an extension rate equal to the shear rate. The extensional viscosity may be significantly higher in a water based drilling fluid [3]. In addition, the suitability of the combination of screen and shaker may change during drilling process, because the drill cuttings morphology changes and because the drilling fluid composition changes.

Throughout the last half century, major shaker design improvements have been made. Elliptical motion or linear motion shakers have replaced the older circular motion shakers that typically were used up to the 1980s. These circular motion shakers operated by sending the drilling fluid downhill a vibrating screen. The drilling fluid should flow through the vibrating screen

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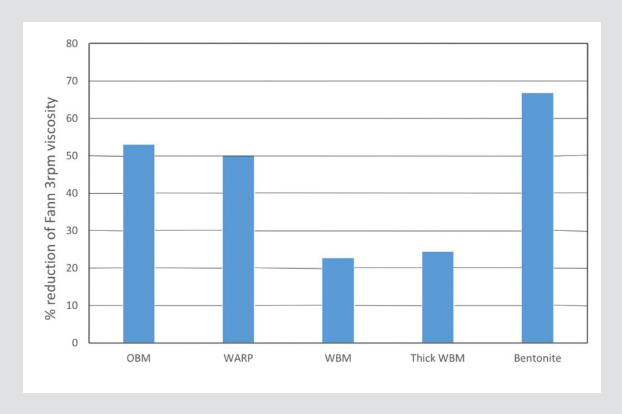

Figure 7: Viscosity reduction at low shear rate (5.11 1/s) for all the fluids.

plausible. This bentonite mud is viscosified simply by clay plate-plate interactions. Vibrations will break any plate network that is being constructed in absence of vibrations and hence, reduce the viscosity.

The oil based drilling fluids is constructed as a combination of emulsion and dispersion. See for example Caenn et al. [16]. Oil is the continuous phase. This phase does not transfer surface charges efficiently. Hence, there is no particle-particle bonding or like in the bentonite mud or any plate-plate interaction creating a gel structure. Therefore, addition of vibration to the sample at high shear rates does not change the structure of the drilling fluid. Any particle-particle bonding is already broken by the high shear rate. At low shear rates, the oil based drilling fluid becomes viscous because of formation of stable geometrical structures built by the emulsion droplets and the organophilic clay particles and other oil wet particles. When vibration is added these stable structures are de-stabilised and the viscosity is reduced. Water based drilling fluids containing particles will contain structural units as defined by Quemada [18]. The structural units are local agglomerations of particles and polymers that build the viscosity of the fluid. The agglomerations are stabilised by the interaction of surface charges of the different particles through the zeta-potential of these particles. When vibrations are added to the fluid, these structural units are partially destroyed such that the viscosity is reduced for all shear rates. The structural units are larger for the lower shear rates. At the very high shear rates these units may have been broken down totally. Hence, the reduction in viscosity must be larger for the smaller shear rates when vibrations are added. The construction of such structural units creates the increased shear stress in the case of absence of vibrations at the very low shear rates for the bentonite mud that is shown in Figure 6. If all the systems are compared, like as shown in Figure 7, it is seen that the effect is biggest for bentonite muds and lowest for polymer containing water based drilling fluids. Here the value is shown representing the reduction in viscosity at a shear rate of 5.11 1/s for the maximum amplitude. This is expected as structural units constructed by particles alone are most common in bentonite muds and least common in the polymer containing fluids like the WBMs. Saasen and Hodne [13] found that in presence of vibrations, no gel strengths exceeding the yield stresses are formed for the fluids evaluated in the present article.

5 THE CONSEQUENCE FOR SOLIDS CONTROL AND DEVELOPMENT OF SOLIDS CONTROL EQUIPMENT

In daily operation it is often argued that high amplitude vibrations are needed to force fluid through the solids control equipment screens and to make sure the drill cuttings particles loose it's affiliated volume of drilling fluid. The current study has shown that the primary function of the vibration is to reduce or to remove yield stresses in the drilling fluids, and hence, make the fluid mobile for flow through the screens. For the oil based drilling fluids it is seen that reduction in yield stress appears immediately when applying vibrations. Only a little reduction in viscosity can be observed when the vibration amplitude is increased further. Hence, in this case, the shale shaker vibrations are needed only to reduce or remove the yield stress and to transport the cuttings particles. Therefore, it is not necessary to use the highest amplitude vibrations in this case.

Vibration amplitude seems to influence the viscosity of primarily polymer viscosified water based drilling fluids only slightly because the vibrations affect only the properties arising form particle-particle interactions. Theoretically, it is anticipated to be important to avoid screens with significant extensional flow paths. The extensional viscosity of the conventional polymer viscosified water based drilling fluids may make solids control more difficult when using water based drilling fluids than when using oil based. Because of it's negligible negative environmental impact, it is convenient to use bentonite muds in the laboratory or in yard tests when developing new solids control devices. Based on the current results, this practice is found to be undesired because the viscosity of bentonite muds are more sensitive to vibrations than other fluids. Solids control equipment must be designed for actual practical types of drilling fluids; both water based and oil based.

6 CONCLUSIONS

An experimental investigation of influence of vibrations on drilling fluid viscosity has verified that Low shear rate viscosity of oil based drilling fluids is significantly reduced by imposing vibrations to the fluid. Furthermore, low shear rate viscosity of water based dril-

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ling fluids is also reduced by imposing vibrations in the fluid, but not as much as with oil based. This is anticipated to be a result of oil based drilling fluids being viscosified with droplets and particles, while the water based drilling fluids are viscosified primarily by addition of polymers. Vibrations have a larger impact on particle-particle bonding than on polymer liquid interaction.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support and data from Det norske oljeselskap and the drilling fluid samples supplied by Schlumberger.

REFERENCES

[1] Bouse EE, Carrasquero JE: Drilling mud solids control and waste management, Paper SPE 23660, The Second Latin American Petroleum Engineering Conference of the SPE, Caracas, Venezuela (1992).

[2] American Association of Drilling Engineers (AADE): Shale shakers and drilling fluid systems, Gulf Publishing Company, Houston, USA (1999).

[3] Svendsen Ø, Saasen A, Vassøy B, Skogen E, Mackin F, Normann SH: Optimum fluid design for drilling and cementing horizontal well technology, 1998 SPE International Conference on Horizontal Well Technology, Calgary, Canada (1998).

[4] ASME Shale Shaker Committee: Drilling fluid processing handbook. Gulf Professional Publishing, Burlington (2010).

[5] Kroken A, Souza E, Martins AL, Vasshus JK, de Vila Panisset CM, Lomba B: Evaluating an alternate cutting separation technology: Is the MudCube a fit for Brazilian offshore drilling? Paper OTC-24405, Offshore Technology Conference Brasil, Rio de Janeiro, Brazil (2013).

[6] Omland TH, Dahl B, Saasen A, Taugbøl K, Amundsen PA: Optimisation of solids control opens up opportunities forddrilling of depleted reservoirs, Paper SPE 110544, SPE Asia Pacific Oil & Gas Conference and Exhibition, Jakarta, Indonesia (2007).

[7] Dahl B, Saasen A, Omland TH: Successful Drilling of oil and gas wells by optimal drilling fluid solids control – A practical and theoretical evaluation, SPE Drilling & Completion 23 (2008) 409-414.

[8] Dahl B, Omland TH, Saasen A: Optimised solids control in arctic environments, Paper SPE 160574, SPE Russian Oil & Gas Exploration & Production Conference and Exhibition, Moscow, Russia (2012).

[9] Larsson A, Blikra H, Florvaag M. Vasshus J.K. Malmin A, Grelland T, Stokknes A, Saasen A: Solids control device optimised for proper occupational hygiene, Paper SPE 164953, SPE European HSE Conference and Exhibition, London, United Kingdom (2013).

[10] Kroken A, Vasshus JK, Grelland T: Drilling waste reduction and improved HSE on Maersk Giant utilizing revolutionary lightweight vacuum conveyor system, Paper OTC-24691, Offshore Technology Conference Asia, Kuala Lumpur, Malaysia (2014).

[11] Børgesson L, Fredriksson A: Influence of vibration on the rheological properties of cement, Proc. Int. Conf. Rheol Fresh Cement and Concrete, Liverpool, UK (1990) 313 – 322.

[12] Barnes HA, Hutton JF, Walters K: An introduction of rheology, Elsevier, Amsterdam (1989).

[13] Saasen A, Hodne H: The influence of drilling fluid rheological properties on primary solids control, Paper OMAE2015-41749, ASME 2015 34th International Conference on Ocean, Offshore and Arctic Engineering, St. John's, Newfoundland, Canada (2015).

[14] American Petroleum Institute: Recommended practice for field testing of oil-based drilling fluids, API Recommended Practice 13B-2, Washington DC (2005).

[15] Fard A-R, Omland TH, Saasen A: Shale shaker's effect on drilling fluids rheological properties, Ann. Trans. Nordic Rheol. Soc. 15 (2007) 227 – 230.

[16] Caenn R, Darley HCH, Gray GR: Composition and properties of drilling and completion fluids, Gulf Professional Publishing, Waltham, Massachusets (2011).

[17] Quemada D: Rheological modelling of complex fluids: 1 – The concept of effective volume fractions revisited. Eur. Phys. J. AP 1 (1998) 119 – 127.

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