Barite Sag in Drilling Fluids

Carsten Ehrhorn and Arild Saasen

Høgskolen i Stavanger, P.O.Box 2557, Ullandhaug, N-4004 Stavanger, Norway

ABSTRACT

The influence of drilling fluid rheology on the barite sag potential is discussed. The problem with barite sag in oil based drilling fluids is emphasized. Sag can not be totally avoided in these fluids as a result of the lack of a real gel structure.

INTRODUCTION

Advances in drilling technology the last decades have resulted in drilling of many deviated and extended reach wells. A number of unexpected operational problems have been observed in such deviated wells. Some of these problems can be related to barite sag, the settling of weight material in drilling fluids. In the late 80s, the problem was identified and adressed to the suspension properties of drilling fluids. Oil companies and drilling fluid contractors have emphasized research to solve the problem with barite sag. The number of incedents and the extent of barite sag have at present decreased to an acceptable level, at least for water based drilling fluids. However, the problem has never been solved.

Barite sag results if the reological properties of the drilling fluid are inadeqate to keep the barite particles suspended. Barite sag occurs more rapidly in deviated wells due to the Boycott effect[1].

Jamison and Clements[1] investigated sag in static drilling fluids. These fluids were based on oil-in-water emulsions. They concluded that sag could not be correlated to the usual rheological parameters measured within the drilling industry. These parameters included the yield point (YP), plastic viscosity (PV), 10 seconds and 10 minute gel values obtained in accordance with the API specifications. Although there seemed to be a tendency towards more sag with lower viscosity and gel strenght, no applicable correlation was found between rheological data and sag.

Hansson et al.[2] tested the hypothesis that a mud with elevated low shear viscosity did not sag. The theory was supported by experimental data, but the tested drilling fluids were too viscous for field use. They also indicated, by warning against exessive thinning, that sag is more probable in a thin drilling fluid than in a viscous one.

Jefferson[3] suggested a field test procedure using a sag index to control barite sag.

Saasen et al.[4] made detailed rheological studies of four polyglycerine based drilling fluids in order to find a relationship between rheology and sag. The drilling fluid samples had been used on the Gullfaks field. One of the fluids had given severe sag, whereas the three others had negligible sag. The rheological studies were carried out on a controlled stress rheometer. Their studies showed that the 3 drilling fluid samples with negligible sag had almost the same low shear viscosity, gel formation and break up of gel structures. They all had a much faster development of gel, than the sample with severe barite sag. The sagging sample also had the most fragile gel structure: the three other fluid samples had a greater resistance towards complete break up of gel structures processes by low shear rates.

Zamora and Jefferson[5] presented guide lines to minimize sag. These included increasing the low shear rate viscosity and improving the suspension properties. Excessive mud thinning and flocculation, which create free water and eliminate low shear viscosity should be avoided.

Saasen et al.[6] investigated 17 water based fluid samples in a laboratory sag cell to evaluate and measure the effect of fluid properties on barite sag. They concluded that sag in a slowly moving fluid (dynamic sag) is partially related to low shear viscosity. However, there are no relationship between static sag and 3 rpm dial reading from the VG viscometer. Dynamic viscosity measurements showed that a gel structure needs to be developed to avoid static sag. This gel does not need to have a high strength, but it needs to be suffciently strong to suspend the barite particles. The ratio of G'/G" was found to give a good indication of static sag potential.

GEL EFFECTS

In order to keep particles, especially barite, under static conditions the drilling fluid needs to have a gel strenght. In absence of a gel structure the barite can not be kept in suspension over a long period without circulation, even if the viscosity is very high. The minimum gel strength can be estimated by requiring the gravitational force to balance the flow resistance force of a non-moving particle. The minimum gel strength to keep a single barite particle in suspension is given by Eq. 1.

$$\tau_{gel} \geq \left(\rho_{particle} - \rho_{fluid}\right)\frac{gD}{6} \qquad (1)$$

With a particle diameter equal to 100 μm, a particle and fluid density equal to 4.2 and 1.0 SG, the necessary gel strength is 0.5 Pa to keep the barite particles suspended.

The API yield point and plastic viscosity and the ratio between them are widely used to characterize the drilling fluid rheology. They should not be used in order to prevent barite sag, since their values normally are correct only at shear rates above a few hundred reciprocal seconds.

WATERBASED DRILLING FLUID

The gel formation in water based drilling fluids is normally controlled by the type and content of clay. The clay particles can come from the drilled formation or it can be added to the drilling fluid to control gel properties.

The gel formation is a result of the interaction between electrical charged edges and faces of the clay particles.

OIL BASED DRILLIG FLUIDS

The viscosity of oil based drilling fluids iscontrolled by emulgating water into the oil. An other additive used to control low shear rate viscosity is the addition of organically modified clay particles. The surface charges of these particles are no longer of importance. Thus, the viscosity is only dependent on the water content in the emulsion, the content of modified clay and the morphology of the droplets and particles. A structure may be formed at low shear rates giving rise to thixotropy. However, no bonding forces exist between the individual particles. Therefore, the oil based drilling fluids do not build a proper gel strenght.

VISCOSITY OF OIL BASED DRILLING FLUIDS

The shear rate dependent viscosity of a selection of oil based drilling fluids was measured using a Bohlin controlled stress rheometer.

The viscosity of oil based drilling fluids is dependent on the water content of the emulsion and the emulsion droplet size. An example is shown in Fig. 1. Here, the shear stress is shown as a function of the shear rate for three emulsions with different water concentrations. The concentration of emulgator in the water phase is equal for all emulsions.

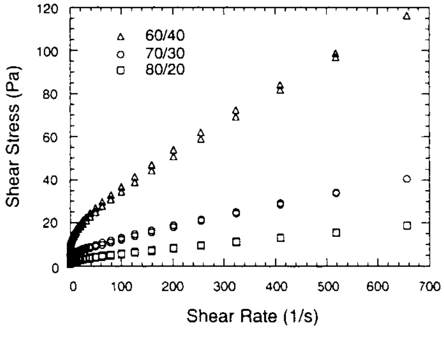

Figure 1. The shear stress as function of the shear rate for oil based drilling fluids with 20, 30 and 40% water emulgated into the oil.

As can be seen from Fig. 2, barite contributes to the viscosity of the suspension in a similar way as when the water content is increased. None of these fluids seem to have any non-zero yield stress value. This can be observed in Fig. 3, where the viscosity of three different drilling fluids is given as a function of the shear rate. The viscosity curves of all the investigated emulsions had a "S-shape" when plotted in double logaritmic plots. The emulsions seem to have a constant viscosity region at very small and very large shear rates.

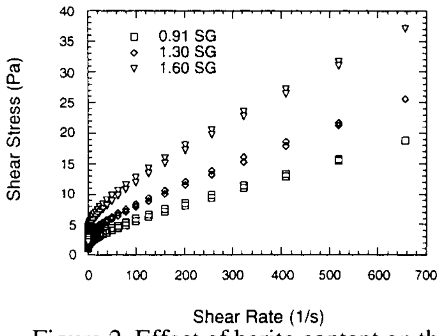

Figure 2. Effect of barite content on the viscosity of a 20% water in oil emulsion.

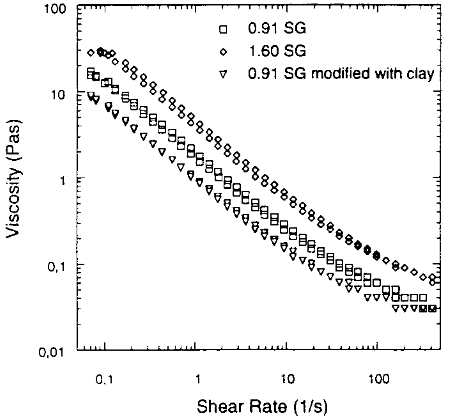

Figure 3. Viscosity as function of shear rate for three emulsions with 20% water.

In Fig. 3, the squares represent a pure emulsion, the diamonds represent an emulsion weighted with barite to 1.60 SG, and the triangles represent a different blend with added organic clays. Note that the emulsion with added organic clays is from a different blend than the two other emulsions. The three curves have a parallel shape.

The measurements indicate that all the emulsions have a constant viscosity at low shear rates. Since no gel stress or no yield stress seems to exist it is not possible to avoid barite sag. Therefore, it is only a question of minimizing the sag to an acceptable level for the drilling operation. The Newtonian low shear viscosity region may be applied to estimate the significance of sag.

CONCLUSION

Earlier studies have demonstrated that static sag may be avoided in water based drilling fluids. Dynamic sag can only be minimized in these fluids. Gel structures will be partially broken in the presence of fluid motion. Therefore, no forces will be present to keep the particles permanently in suspension.

There are no gel structures in oil based drilling fluids. Neither static or dynamic sag can therefore be prevented in these fluids. An increase in low shear rate viscosity is expected to minimize the significance of both types of sag.

REFERENCES

1. Jamison, D.E, & Clements W.R. (1993), "A new test method to characterize setting/sag tendencies of drilling fluids used in extended reach drilling",ASME 1990 Drilling Tech Symposium pp. 109-113.

2. Hanson, P.M, Trigg Jr, T.K, Rachal, G. and Zamora, M. (1990), "Investigation af Barite "Sag" in Weighted Drilling Fluids in highly Deviated Wells", SPE Annual Technical Conference and Exibition, New Orleans, Sept. 23-26, pp. 223-230.

3. Jefferson, D.T. (1991), "New Procedure Helps Monitor Sag in the Field", ASME Energy-Sources Technical Conference and Exibition, New Orleans, Jan. 20-24.

4. Saasen, A, Marken, C, Sterri, N and Jacobsen, J. (1991), "Monitoring af barite sag important in deviated drilling", Oil & Gas Journal, vol. 89, Aug. 26, pp. 43-50.

5. Zamora, M. and Jefferson, D. (1994) "Controlling barite sag can reduce drilling problems", Oil & Gas Journal, vol. 92, Feb. 14, pp. 47-52.

6. Saasen, A, Liu, D, Marken, C.D, Sterri, N, Hallsey, G.W. and Isambourg, P. (1995), "Prediction af Barite Sag Potential of Drilling Fluids from Rheological Measurements", SPE/IADC Drilling Conference, Amsterdam 28 Feb.-2 Mar, pp. 662-670.