A Field Application of Nanoparticle-Based Invert Emulsion Drilling Fluids

Alexey S. Borisov[1], Maen Husein[1], Geir Hareland[2]
[1]Department of Chemical & Petroleum Engineering, University of Calgary, Calgary, AB, Canada.
asboriso@ucalgary.ca; mhusein@ucalgary.ca
[2]Department of Chemical Engineering, Oklahoma State University, OK, USA 74078. geir.hareland@okstate.edu

ABSTRACT

Application of nanotechnology in drilling fluids for the oil and gas industry has been a focus of several recent studies [1-2]. Zakaria et al. [2] developed a process for the in situ synthesis of nanoparticles (NPs) and reported that calcium-based and iron-based nanoparticles (CNP and INP, respectively) with concentrations of 0.5-2.0 wt% can dramatically improve filtration properties of commercial drilling fluids in a lab environment. A modified process for the emulsion-based synthesis of NPs on a large scale has been developed and a NP carrier fluid was employed in full scale field tests. Results showed that total mud losses while drilling with CNP-based invert emulsion were on average 27% lower than in the case of conventional fluids, which falls within the range seen in the laboratory.

Keywords: nanoparticles, drilling fluid, invert emulsion, field application, oil and gas

1 INTRODUCTION

Invasion of drilling fluid filtrate and suspended solids into a near-wellbore region during drilling operations leads to formation damage and can cause wellbore instability, severe permeability impairment and a substantial decline in production [3]. Recently, several studies have shown that drilling muds that combine conventional LCM with particles in the nanometer domain can dramatically reduce fluid loss and form a thinner filter cake, compared to drilling fluids containing LCM alone [1-2]. In this work, six full-scale field tests were conducted in order to provide reliable observations on the performance of NPs under real-life conditions. Field testing employed a ‘carrier’ approach, whereby a custom invert emulsion of 20 m^3 volume containing 5 wt% in situ CNPs was first prepared in a specialized mixing facility, then delivered to a rig site where it was diluted to the target concentration.

2 MATERIALS AND METHODS

Without delving into proprietary details, industry-scale synthesis of NP-based carrier emulsion followed a bench-scale process developed in our laboratory [4]. Calcium-based NPs (CNP) were produced via a (w/o) microemulsion approach, which served as a mechanism to achieve size control and particle stabilization during chemical co-precipitation of aqueous precursors [5].

In order to determine the performance of the carrier emulsion approach for NP preparation and addition relative to our previous techniques [4], six different virgin and recycled commercial invert emulsion drilling fluids were tested in the laboratory. Drilling fluid testing was carried out using industry-standard equipment and practices [6].
Six full-scale field tests were conducted in horizontal wells in Alberta, Canada in 2014. Upon arrival to the drilling site, 10% vol/vol of carrier were mixed with the circulating drilling fluid to achieve the target concentration of 0.5 wt% CNP, which was maintained thereafter. Mud losses while drilling were estimated via volumetric balance on the total drilling fluid on-site at different depths. The difference between calculated control volumes at a given depth and the initial depth corresponds to cumulative mud losses while drilling. In order to account for differences in measured depth and to standardize the data, cumulative mud losses were converted to losses per 100 m drilled.

3 RESULTS AND DISCUSSION

3.1 Laboratory testing of the carrier emulsion approach

In order to provide a feedback on the effectiveness of the industry-scale mixing and preparation of the carrier fluid, samples from the 20 m^3 carrier fluid were compared with a carrier fluid prepared in the laboratory under controlled environment, e.g. mixing, temperature, etc. The good agreement between the results suggests that the carrier approach was robust even when implemented on a large scale. A laboratory-based carrier emulsion was tested with six commercial invert emulsion drilling fluids to determine its impact on mud weight, electrical stability, plastic viscosity, yield point, gel strength, and volume composition. The results suggested that addition of carrier emulsion did not affect the basic properties of a host fluid significantly.

Once it was established that the carrier approach was compatible with commercial drilling fluids, high pressure high temperature (HPHT) filtration tests at 80 °C and 500 psi were employed to determine laboratory fluid loss in the presence of 0.5 wt% CNP. The results of HPHT experiments are provided in Figure 1 and suggest that CNP reduced the average HPHT fluid loss in virgin Cutter-D and Diesel OBM samples by 52% and 26%, respectively. Filtrate volumes in all three recycled drilling fluids were also reduced in the presence of 0.5 wt% CNP. The respective reduction in HPHT values for the recycled Cutter-D, Distillate 822, and Megadrill samples was 38%, 3%, and 44%, which reproduced previous laboratory results obtained with in situ calcium-based NPs [4].

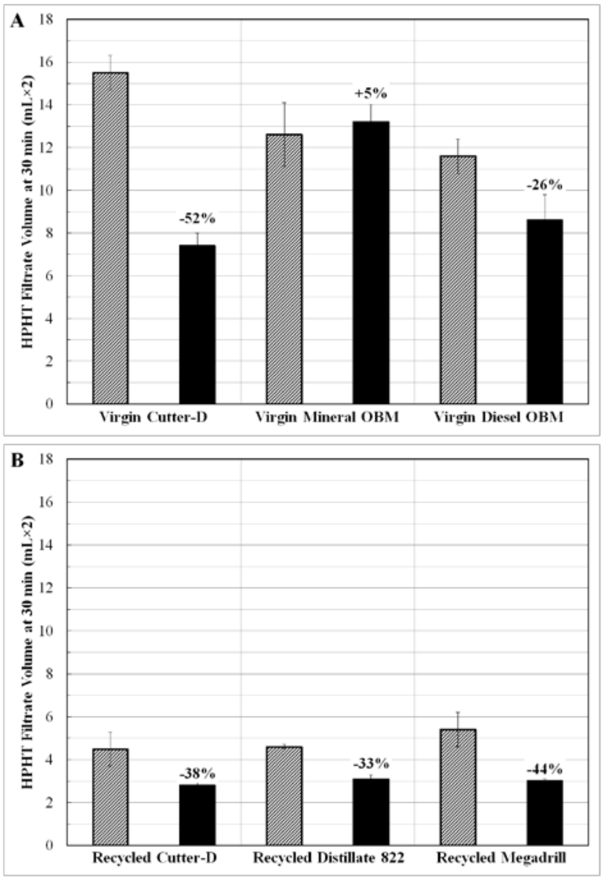

Figure 1: Impact of 10 vol% addition of a carrier emulsion on HPHT fluids loss at 80 °C and 500 psi of commercial virgin (**A**) and recycled (**B**) invert emulsion drilling fluids. Diagonal pattern corresponds to the control samples, while solid black denotes samples with 0.5 wt% CNP.

3.2 Field testing of the carrier emulsion approach

In order to compare the final mud losses in the control and test wells, the average losses per 100 m drilled are plotted in Figure 2.

The average control final losses in groups A, B, and C were in close proximity at 79±3, 77±3, and 82±7 m^3, respectively. Subsequently, same groups showed a 22–34% reduction of mud losses in the presence of 10 vol% carrier emulsion. Group D showed losses of 82 and 72 m^3, which was comparable to the control average. Figure 2-B shows the average mud losses standardized per 100 m drilled. Control wells exhibited losses in the range of 2.5–3 m^3/100 m, which is typical based on mud operator's previous experience in the area. Conversely, losses in the test wells were between 1.9–2.5 m^3/100 m, which again demonstrates reduction in the presence of CNP.

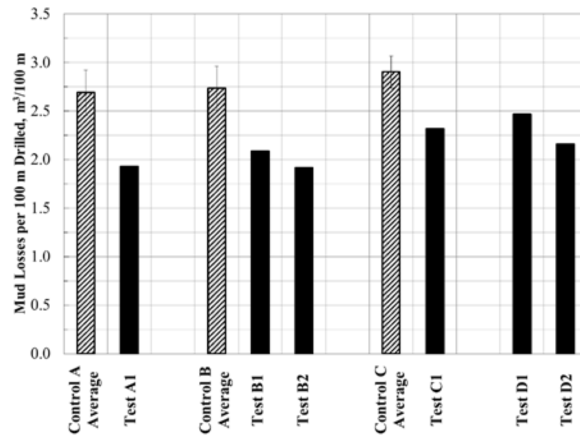

Figure 2: Average losses per 100 m drilled in the control and test wells.

CONCLUSIONS

In conclusion, a novel approach for introducing NPs into drilling fluids using a carrier method was developed and successfully scaled up to an industrial application. Six field tests were conducted using the carrier approach, which was compatible with the existing operations and did not cause any disruptions or drilling problems. The impact of 0.5 wt% CNP on the basic mud properties was within the normal range, while final mud losses in all test wells were 20–30% lower than the control average.

REFERENCES

[1] Contreras, O., Hareland, G., Husein, M., Nygaard, R., and Alsaba, M., "Application of In-House Prepared Nanoparticles as Filtration Control Additive to Reduce Formation Damage", SPE 168116-MS, SPE International Symposium and Exhibition on Formation Damage Control, Lafayette, Louisiana, USA, 26–28 February (2014a)

[2] Zakaria,M., Husein,M., and Hareland,G., "Novel Nanoparticle-Based Drilling Fluid with Improved Characteristics",SPE156992 International Oilfield Nanotechnology Conference and Exhibition, Noordwijk, The Netherlands, June 12–14 (2012)

[3] Jiao, D., and Sharma, M., "Mud Induced Formation Damage in Fractured Reservoirs", SPE 30107, European Formation Damage Control Conference, Hague, The Netherlands, May 15–16 (1996)

[4] Husein, M., Zakaria, M., and Hareland, G., "Novel nanoparticle-containing drilling fluids to mitigate fluid loss", PCT/CA2012/050075 (2012)

[5] Husein, M., and Nassar, N.N., "Nanoparticles preparation using the single microemulsion scheme", Current Nanoscience, 4, pp 370-380 (2008)

[6] API Recommended Practice 13B-2, "Recommended Practice for Field Testing Oil-Based Drilling Fluids", 5th edition (2014)