

Research on the Influence Factors of Emulsion Stability of Oil-in-water Drilling Fluid

Xiaoxu Li ^{1,2}, Yuxue Sun ¹, Xiangming Chen ³, Zengkui Wang ⁴, Jianjun Xu ^{1,*}

¹. Department of Petroleum Engineering, Northeast Petroleum University, 163318, China

². Daqing Oilfield Production Technology Institute, Daqing Oilfield Company, 163000, China

³. Engineering and Technology Research Institute, Tuha Oilfield Company. 839000, China

⁴. Daqing Oilfield Co., Ltd. Chuangye Group. Daqing 163000, China

* Corresponding author e-mail : 123939274@qq.com

Abstract. The evaluation standard of emulsion stability of oil-in-water drilling fluid is determined in this paper, based on which an evaluation analysis is conducted for the influence factors of emulsion stability, including the addition of emulsifier, addition of stabilizer, stirring speed, weighing agent, clay, etc. to gain the corresponding regularity understanding.

Keywords. Oil-in-water; emulsion stability; influence factors.

1. Introduction

Oil-in-water drilling fluid is an emulsion that forms via emulsification with water (or brine) as continuous external phase and oil (or diesel oil and white oil) as dispersion phase, and it also includes other treating agents like filtrate reducer, drilling fluid stabilizer, flow pattern regulator, etc.. Oil content in oil-in-water drilling fluid usually used is between 30~60%, the drilling oil has better cuttings-carrying property, filtration reducing property, suspension property and rheological property, and may adjust oil-water ratio within a certain range. This system was applied by Daqing Oilfield for the first time in 2000 for well drilling, and was successively applied in tens of wells with ideal effect obtained, during which the emulsion stability played an important role. Therefore, it is one of the primary work in drilling construction to research the emulsion stability of oil-in-water drilling fluid.

2. Evaluation Standard of Emulsion Stability of Oil-in-water Drilling Fluid

Evaluation methods of the emulsion stability usually used include standing observation, conductivity test, surface tension measurement, determination of dispersion stability, etc., and the resistivity measurement method and standing observation method are mainly adopted in this paper for evaluation.

2.1 Resistivity Measurement Method

Emulsion stability is usually measured with electric conductivity meter. Resistivity is the reciprocal of conductivity, and can also be applied to measure the status of stability. RES2000 resistivity meter is



adopted in this paper to determine the resistivity value of each sample, which can be converted to the value under 17°C automatically while measured at the room temperature for comparison. With smaller resistivity, it is closer to the resistivity of water ($R_s=2\Omega\cdot m$), which indicates that oil-in-water emulsion is more stable. While in actual use, generally the emulsion is stable while its resistivity reaches 1.67~3.3 $\Omega\cdot m$.

2.2 Standing Observation Method

According to the gravity and Stokes' law, the settling velocity formula of spherical particle in the medium is $v = \frac{2r^2}{9\eta}(\rho - \rho_0)$, therefore, standing experiment is the most conventional and most intuitive method to evaluate the stability. Steps of this method: place the emulsified drilling fluid well prepared in the measuring cylinder, let it stand at room temperature from several hours to several days after sealed, observe and record the layering condition or the precipitated amount of water and oil regularly to evaluate the effect of emulsion stability.

Additionally, filtration property is also a sign for stability of oil-in-water drilling fluid.

3. Laboratory Experiment

3.1 Experimental Materials

Clear water, $\rho = 1.00\text{g/cm}^3$; 0# diesel oil, $\rho = 0.84\text{g/cm}^3$; emulsifier (trade name: OW-200); stabilizer (trade name: FRJ-2); bentonite, barite. Drilling fluid composition: 60% of diesel oil+ 40% of clear water+ emulsifier (all are volume fraction, and the volume of emulsifier is included into the water phase) + treating agent.

3.2 Influence of Emulsifier on Emulsion Stability

3.2.1 Selection of Emulsifier Type. According to pertinent literature, HLB of surfactant required while emulsified diesel oil forms oil-in-water emulsion should be between 13.6~14.3, HLB of emulsifier selected in this experiment is exactly within this range, that means it can form oil-in-water emulsion with good emulsion stability, high temperature resistance, good compatibility with various drilling agents. Water-oil ratio of drilling fluid thus prepared has wide range (may reach 1.5:1), which can meet the requirement of the experiment.

3.2.2 Adding Method of Emulsifier. Most emulsifiers used for oil-in-water emulsified drilling fluid are water-soluble, which means the hydrophilic is larger than lipophilicity. While added in water during experiment, emulsifier can dissolve completely; while added in oil, it cannot dissolve completely, and appears residual at the wall and bottom of the container, thus failing to exert its role completely. Therefore, while used, oil-in-water emulsifier should be fully dissolved in water first to reach the best emulsifying effect.

3.2.3 Volume Fraction of Emulsifier. Clear water that accounts for 40% in the total volume of drilling fluid prepared is weighed and poured into the high-speed stirring cup, and the emulsifier can be added into clear water respectively as per 3%~8%, because oil-in-water emulsifier OW-200 is water-soluble. Stir for 5min with GJSS-B12K variable-frequency high speed mixer (at the third gear) ($3\times 103\text{r/min}$) to make emulsifier fully dissolved in water. Then weigh diesel oil that accounts for 60% in the total volume of drilling fluid prepared and add in water-emulsifier system, stir in high speed and measure respectively; the measured value is shown in Table 1.

Table 1 Influence of Emulsifier Volume Fraction on Stability

Emulsifier dosage (%)	Resistivity R_s ($\Omega \cdot m$)	Layering volume after standing for 5d (mL)	FL (mL)
3	6.64	6.3	2.8
4	6.21	5.4	2.8
5	5.65	4.0	2.6
6	5.43	3.2	2.6
7	5.09	2.5	2.6
8	4.92	2.0	2.4

Data in Table 1 show that under the same oil-water volume ratio and the same emulsifier, as the volume fraction of emulsifier increases, the resistivity, layered volume and water loss value will reduce and the emulsifying effect will be enhanced. The emulsion thus prepared is milk white and stable with small particles. In considering the preparation cost, the usage amount of emulsifier in subsequent experiment is set as 5%.

3.3 Influence of Shearing rate on Emulsion Stability

After the emulsifier is fully dissolved in water, diesel oil accounting for 60% of the total volume is added and then is stirred at different rates (the fourth gear: $4 \times 103r/min$; the sixth gear: $6 \times 103r/min$; the eighth gear: $8 \times 103r/min$; the tenth gear: $10 \times 103r/min$; the eleventh gear: $11 \times 103r/min$; the twelfth gear: $12 \times 103r/min$) for 40min respectively.

Stirring in high speed helps disperse emulsifier and two phases of oil and water, but it may lead to foaming during high-speed emulsification. After high-speed stirring, it is stirred for 10min at low speed (at the third gear: $3 \times 103r/min$), which may greatly reduce the quantity of foam, besides, the foam becomes exquisite; this helps that the emulsifier on the interface is adjusted towards the more regular and more compact direction and is convenient for subsequent measurement.

Table 2 Influence of Shear Rate on Stability

stirring rate (103r/min)	Resistivity R_s ($\Omega \cdot m$)	Layering volume after standing for 5d at homoeothermic (mL)
4	6.05	5.5
6	5.83	5.0
8	5.65	4.0
10	5.41	2.0
11	5.35	1.5
12	5.24	1.0

As can be seen from Table 2, with higher shearing rate in stirring, the resistivity of emulsion measured is smaller, is closer to the resistivity value of clear water, and this system has a relatively stronger stability. This is mainly because high shear can make oil-water particles finer and contact with emulsifier in a better way, thus forming more stable emulsion drops.

This point is also verified in the standing experiment, while other factors keep unchanged, with better dispersion, the particle radius r is smaller, the settling velocity is smaller, and it is harder to form settlement and aggregation. While it is discovered through the standing experiment under normal

temperature that four samples showed layering in different degrees after 5d, therefore, it is impossible to completely stabilize the emulsion only by means of high shearing rate, and the emulsifying effectiveness must be enhanced via other treating agents.

According to this experiment, the stirring rate for the subsequent experiment sample is determined at the twelfth gear.

3.4 Influence of Borehole Stabilizer on Emulsion Stability

Borehole stabilizer FRJ-2 used in this experiment is cationic condensate, which has certain inhibiting effect on clay, can reduce the filtrate loss and maintain strong stability of borehole. Borehole stabilizer of different proportions is added into the prepared oil-water emulsion respectively, then is stirred at the twelfth gear for 1h, and is finally measured after stirred at the third gear for 10min.

Table 3 Influence of Shaft Stability on Stability

Composition	Resistivity R_s ($\Omega \cdot m$)	Layering volume after standing for 5d (mL)	FL (mL)
Oil-water-emulsifier	5.24	1.0	2.4
Oil-water-emulsifier+1%stabilizer	3.02	0.2	1.5
Oil-water-emulsifier+2%stabilizer	2.20	0.1	0.8
Oil-water-emulsifier+3%stabilizer	1.81	0	0.7
Oil-water-emulsifier+4%stabilizer	1.67	0	0.7
Oil-water-emulsifier+5%stabilizer	1.52	0	0.7

As can be seen from Table 3, addition of stabilizer can decrease the resistivity and filtrate loss quickly, reduce the layering volume obviously, and thus improve the emulsion stability to a great extent. Stabilizer particle has a good stability in water, and can gather on the oil-water interface to form another layer of solid film, to enhance the strength of the original interfacial film and protect the dispersed droplets, thus making the emulsion more stable. With increase of stabilizer addition, the resistivity value constantly decreases, but the decrease degree is constantly reduced. When the addition exceeds 3%, it is discovered via the standing observation that no layering happens after 5d, and the stabilizer addition in subsequent experiment is determined as 3% in consideration of the stability and cost.

4. Conclusion

(1) While preparing oil-in-water, emulsifier should be dissolved in water first, and the stable emulsion may form as the volume fraction is 5%.

(2) If the same stirring time is kept, the stirring rate will influence the stability of emulsion to some extent, and the system will be the most stable at $12 \times 103r/min$.

(3) The system will be more stable while reducing filtrate loss for the stabilizer. The system has strong stability at addition of 3%.

(4) With larger addition of weighing agent, the resistivity and standing layering volume are larger, and the system will exceed the stable range as the addition gradually reaches 60%.

(5) Addition of clay enhances the grid structure of the system and improves its stability, and the system is still stable while added to 10%.

Acknowledgments

Project 51774088 supported by National Natural Science Foundation of China. The Corresponding Author is XU Jianjun.

References

- [1] Shen Zhong,Zhao Zhenguo,Wang Guoting. Colloid and Surface chemistry [M]. Beijing: Chemical Industry Press,2004:478-488.
- [2] Xu Jianjun, Xu Yan-chao, Yan, Li-me,et.al. Research on the method of optimal PMU placement. International Journal of Online Engineering,v9, S7, p24-29, 2013
- [3] Xu Jian-Jun, Y. Y. Zi., Numerical Modeling for Enhancement of Oil Recovery via Direct Current. International Journal of Applied Mathematics and Statistics, 2013, 43(13): 318-326
- [4] Longchao, Zhu Jianjun, Xu; Limei, Yan. Research on congestion elimination method of circuit overload and transmission congestion in the internet of things. Multimedia Tools and Applications, p 1-20, June 27, 2016
- [5] Yan Limei, Zhu Yusong, Xu Jianjun,et.al. Transmission Lines Modeling Method Based on Fractional Order Calculus Theory. TRANSACTIONS OF CHINA ELECTROTECHNICAL SOCIETY, 2014 , Vol.29, No. 9:260-268 (In Chinese)
- [6] YAN Li-mei, CUI Jia, XU Jian-jun,et.al. Power system state estimation of quadrature Kalman filter based on PMU/SCADA measurements. Electric Machines and Control. 2014, Vol.18 No.6,: 78-84. (In Chinese)
- [7] YAN Limei,XIE Yibing, XU Jianjun, et.al. Improved Forward and Backward Substitution in Calculation of Power Distribution Network with Distributed Generation. JOURNAL OF XI'AN JIAOTONG UNIVERSITY, 2013, Vol.47, No.6, p117-123. (In Chinese)
- [8] Xu J.J., Gai D., Yan L.M. A NEW FAULT IDENTIFICATION AND DIAGNOSIS ON PUMP VALVES OF MEDICAL RECIPROCATING PUMPS. Basic & Clinical Pharmacology & Toxicology, 2016,118 (Suppl. 1), 38-38
- [9] Xu Jianjun, Wang Bao'e, Yan Limei, Li Zhanping. The Strategy of the Smart Home Energy Optimization Control of the Hybrid Energy Coordinated Control. Transactions of China Electrotechnical Society, 2017, 32(12) 214-223.