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An experimental study to evaluate the use of oil to prevent differential stuck pipe in Nahr Umr oil field

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Abstract

Differential pipe sticking (DSP) is a main challenge when using water-based drilling fluids developed with bentonite clay. This study employed a Fann VG meter, a self-fabricated tester, and a stickance tester to examine the effect of oil on water-based drilling mud (WBM) and to control this issue. The study found that oil is more suitable than WBM for the composition of drilling fluids. Empirical investigations showed that adding oil to the drilling fluid maintained its rheological characteristics, reduced filtration loss from 19 to 8 cc, and decreased the friction coefficient from 0.32 to 0.05. The tendency of the drilling fluid to stick was also significantly diminished, indicating its effectiveness in preventing differential stuck pipe issues associated with water-based drilling mud. Additionally, it was observed that oil should be used in high-permeable zones rather than WBM. The Nahr Umr oil field was selected to study the problem of differential stuck using a simple well site test for monitoring and optimizing drilling fluid properties. The study concluded that using emulsion mud as a drilling fluid can prevent and treat differential stuck pipe without any torque, due to its ability to reduce the friction coefficient to less than 0.05. However, it is essential to ensure that the oil percentage does not exceed 3% to avoid any change in the rheological properties.

Keywords: Bentonite; Friction coefficient; Filtration Loss; Differential stuck pipe.

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1- Introduction

The embedded between the drill string and mud cake, typically through a permeable zone, and are kept in the same place by pressure of mud that is greater than the pressure of the formation. When the drill pipe cannot move up, down, or rotate but free circulation of mud is still available, differential sticking may be present. This condition significantly affects drilling effectiveness and increases the costs of the well [1-4].

Because it is possible for a large drill pipe section to become stuck in the filter cake, differential pipe sticking becomes more severe when the rotation of the drill pipes is stopped. If the drill pipe comes into contact with the filter cake that is stuck to the wall, the hydrostatic pressure of the mud column will force it through the well wall. As a result, a significant portion of the drill pipe eventually gets stuck in the filter cake when the mud pressure exceeds the formation pressure [5, 6].

Using oil to increase the coefficient of lubricity and reduce the water-based drilling fluid tendency to stick by applying lubricants is one way to reduce differential sticking. In the past, refined or crude petroleum oils have been used for this purpose. Alternative options include soaps, detergents, fatty acids, asphalts, and commercial lubricants such as ester blends, vegetable oil/glycol blends, ester/glycol blends, and glycol surfactant blends, which can all be used in place of diesel oil [7].

Kercheville et al. presented a comparative study of diesel oil and soybean oil as oil base drilling mud. The results showed that soybean oil can reduce fluid loss more than the oil diesel also found that the soybean oil mud exhibited Bingham plastic rheological model with applicable (low) yield point and gel strength when compared with the diesel oil mud [6].

Halliday and Clapper showed an unsuccessful attempt to free the stuck pipe by jarring the stuck pipe with the original drilling fluid. So, it has been decided to experiment on the non-oil fluids from that point [7].

Reid et al. conducted laboratory experiments to investigate differential sticking and assess the effectiveness of spotting fluids. Most techniques suggested involving taking measurements directly on muds and mud filtrates. To model the borehole conditions and create the mud cake, they typically utilize one of two geometries: either a cylinder or a flat mud cake. The former is thought to simulate sticking in the borehole conditions more closely and thus produce more accurate findings [8].

Nazaneen and Ayad A. Alhaleem conducted a study to analyze the occurrences of the differential stuck pipe in Khabaz Oil field. To investigate the issue of stuck pipes

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in this oilfield, well Khabaz-34 was chosen. The graphing analysis program Easy View was used to analyze stuck pipe incidents. Eventually, they suggested using the right kind of drilling mud with the right rheology characteristics and optimizing the casing seat design to minimize the likelihood of a stuck pipe [9].

Faleh Al-Mahdawi and Karrar Saad used the LTLP filter press to assess the effectiveness of silicon oxide nanoparticles. They discovered that increasing the concentration of nanoparticles causes the amount of filtrate to decrease [10].

Amal and Ahmed presented the effect of using chemical materials such as banana peels and corn cobs to improve the properties of drilling mud. The results showed there is a direct correlation between the addition ratios, the increasing in rheological properties, and the decrease in filtration. They concluded that the possibility of moving toward banana peels and corn cob apart from being environmentally friendly, the choice of using them considered economically more efficient than other chemical additives [11].

Fadhil, H. and A, A. Al.Haleem presented that Tanuma and Zubair formations' shale cuttings were described using a stereomicroscope, and the shale structure was observed using a scanning electron microscope. Determined that the specified drilling mud for Tanuma shale can be used to drill Zubair shale and that the reverse is incorrect. They also reached the conclusion that the shale rocks are scattered in fresh water and can become stable by utilizing inorganic additives (KCl) [12].

This work aims to find the effect of bentonite clay on drilling mud properties and how can reduce this effect by using oil. Also, shows the overview of spotting fluids and the evaluation of the testing steps of adding oil and its influence on rheological properties, torque, and friction coefficient to select the best mud properties. The result can be used to design drilling fluids to prevent differential pipe sticking.

2- Area of study

Nahr Umr oil field has a stratigraphic column that ranges from the Upper Jurassic to Tertiary Ages (i.e., stretches from the bottom of Ratawi formation to the Dibbdiba formation) as illustrated in Fig. 1. It is mostly made up of thick carbonate layers interspersed with clastic rocks. The Mishrif formation (carbonate), and Zubair formation (clastic) are major reservoirs within the Nahr Umr oil field that contain huge volumes of hydrocarbons derived mostly from the Cretaceous Period [13].

3- Experimental work

3.1. The material used

There were many materials applied in the research are bentonite clay and several chemical additives, including carboxy methyl cellulose (CMC), partially hydrolyzed polyacrylamide (PAC-LV), and oil lubricants.

3.2. Setup and procedure of experimental

The coefficient of friction was measured by using a tester of lubricity as per standard procedures and the rheology proprieties were measured by Fann VG viscometer. A self–fabricated experimental setup used to determine sticking torque Fig. 2.

3.3. Fann VG viscometer

A device used to determine the viscosity and gel strength of drilling mud is also referred to as a direct-indicating viscometer or a V-G meter. The rotating cylinder and bob viscometer measure the direct indication of viscosity. All instruments have two rotational speeds: 300 and 600 rpm.

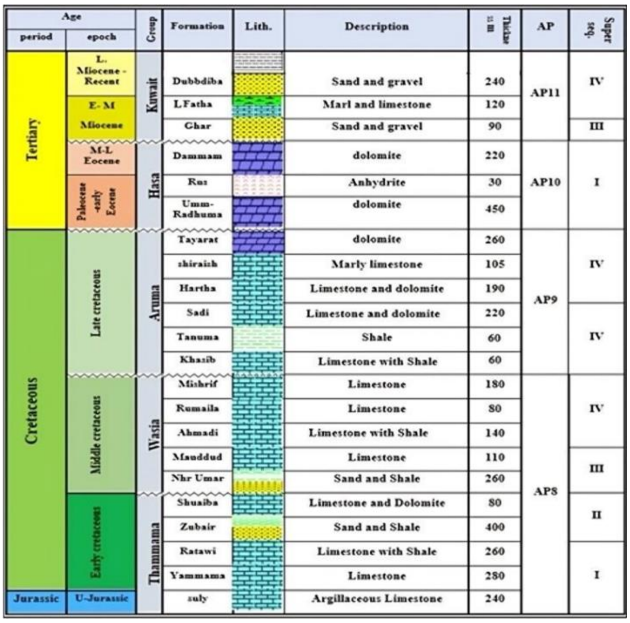

Fig. 1. Nahr Umr oil field stratigraphic column [13]

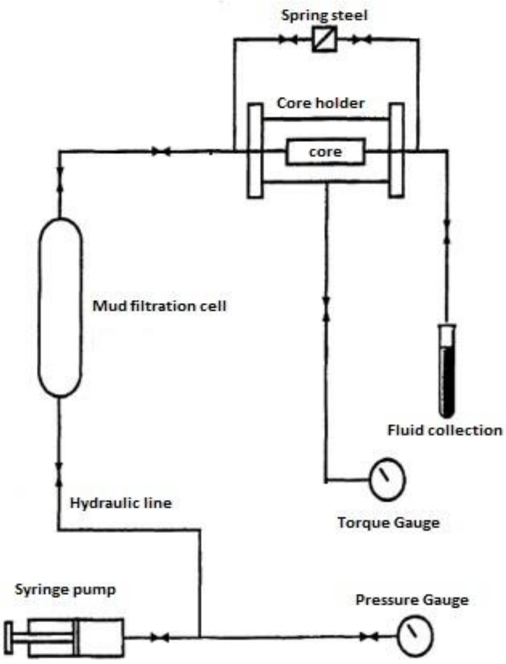

Fig. 2. Schematic of self-fabricated setup

3.4. Self-fabricated equipment description

A schematic of homemade equipment used to measure sticking tendency is shown in Fig. 2. A cell of mud filtration, a wrench of torque, and a syringe pump are the components of it. The mud inside the filtration cell is hydraulically pressurized using the syringe pump. A spring steel wire has now been allowed to a changed O-ring seal that was formerly located in the center of the top end cap. A new entrance valve is made so that the syringe pump hydraulic line can press the cell. The end of the steel wire in the cell is attached to the polished steel ball that sits on the filter media. The polished steel ball that sits on the filter medium is attached to the end of the steel wire in the cell. The wire that extends from the cell has a torque gauge attached to the end of it [14].

To conduct the test, the top end cap is replaced, filter paper is inserted within the cell, and the cell is filled with mud. The gauge system of the ball and torque is then set up. The test holds the mud similarly to a typical fluid-loss measurement, analyzing fluid loss and determining the mud's tendency for sticking. A differential pressure of 400 psi is used during testing. As the filtering process continues, the filter cake encloses the steel ball. As the torque gauge rotates, the amount of required force to remove the ball from the filter cake is measured after 30 minutes. This calculates the torque needed to dissolve the connection by rotating and assesses how strongly the ball adheres to the cake.

3.5. The experimental procedure

First, measurements are made of the friction coefficient and the force needed to release a bentonite water suspension's stuck ball. Next, drilling fluid without the ingredient that controls sticking tendency is created, and the rheology, loss of filtration, friction coefficient, and torque necessary to free-stick the ball are all estimated. Finally, employing a sticking tendency controlling additive, the same properties of the drilling mud were determined. Reduced friction coefficient and sticking torque are properties related to sticking tendency that may help reduce differential pipe sticking issues.

4- Results and discussions

Spotting oil was able to diminish the forces caused by the adhesion of the cake and steel as well as the sticking forces caused by the pressure differential. By showing that the time it takes to free the pipe was significantly reduced with the use of spotting oil with added agent to make it more oil-wetting, as well as by the use of a pipe coated with a material that makes it gain more affection for oil, they have furthered the theory of oil wetting actions. Since then, other experimental procedures and spotting fluid compositions have been created and applied in the industry [8]

A laboratory testing and evaluation for Tanuma formation by using many methods such as linear swelling meter (LSM) and capillary section timer test (CST) to investigate the root causes of its reactivity when it contacts with drilling mud. They concluded that Tanuma formation is moderately active shale and tends to disperse in the fluid, especially with fresh water [15,16].

Firstly, it was determined how much bentonite was present in the suspension of bentonite and water, and the results are displayed in Table 1. With the rise in bentonite concentration and the friction coefficient as the required torque to release the ball sticking increases. It shows that there is a possibility of stuck pipe issues in the oil fields if the solid concentration is increased.

The composition of this drilling mud, which was created using bentonite clay, CMC, and PAC-LV, is presented in Table 2. Table 3 displays its properties of rheological, coefficient of friction, filtration characteristics, and sticking propensity. The results of the experiment indicate that the rheological characteristics are acceptable.

Table 1. Sticking tendency effect caused by bentonite concentration

Bentonite concentration (w/v)	Friction Coefficient)	Torque Required (in-Ib)
1	0.3	6.5
2	0.31	8
3	0.34	9.5
4	0.36	11
5	0.39	14

Fig. 3 shows the bentonite concentration effects on the torque required to release the string with water base mud.

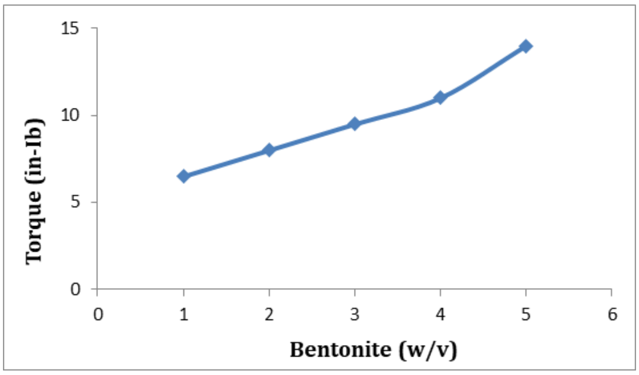

Fig. 3. Bentonite effect on sticking tendency

However, there may be a tendency to stick when it is used for drilling operations since the 14 lbs/inch of torque required to release a stuck ball will impact the drilling rate and drilling duration. Oil is therefore utilized in drilling fluids to reduce friction, torque, and drag.

Measuring the torque necessary to release a steel disc that was in contact with a filter cake using the Differential Sticking Tester at various time intervals and filtration intervals. It permits the formation of a filter cake and the achievement of sticking, and after the extra mud has been removed and a spotting fluid has been given time to soak into the filter cake, it assesses the spotting fluid's performance [6].

Table 2. Drilling mud composition

Fraction	Units	Composition
Bentonite clay	(w/v)	6
PAC-LV	(g/l)	0.18
CMC	(g/l)	0.4
Polyanionic cellulose	(g/l)	0.7

Table 3. Drilling mud properties

Properties	Units	Value
AV	C.P	32
YP	Ib/100 ft^2	35
PV	C.P	17
Gel strength (zero)	Ib/100 ft^2	15
Gel strength (10 min)	Ib/100 ft^2	29
Loss of filtrate	cm^3/30 min	19
Friction coefficient		0.32
Torque to free stuck at 400 psi differential stuck	In-Ib	14

Table 4 and Table 5 illustrate the mud emulsion effects on the rheological properties of the drilling fluids, properties of filtration, coefficient of friction, and ability to stick. Plastic viscosity, apparent viscosity, or yield strength are influenced by this lubricant. The gel loses some of its strength in this process. This indicates its compatibility with drilling fluid.

Loss filtration decreased from 19 to 8 ml. The drilling fluid also protects the formation, which is an extra benefit. This might be because when differential pressure is used, a very thin layer of oil forms.

Both the friction coefficient and the torque needed to release stick the ball both significantly decrease. The stuck ball can be released without the use of torque if there is a friction coefficient of less than 0.05. This work shows that systems using water-based drilling fluids can produce differential pipe sticking, which can be reduced by using oil.

Table 4. 1% (v/v) oil effect on drilling fluid properties

Properties	Units	Value
AV	C.P	31
YP	Ib/100 ft^2	36
PV	C.P	16
Gel strength (zero)	Ib/100 ft^2	15
Gel strength (10 min)	Ib/100 ft^2	28
Loss of filtrate	cm^3/30 min	8
Friction coefficient		0.05
Torque to free stuck at 400 psi differential stuck	In-Ib	Nil

Table 5. 2% (v/v) oil effect on drilling fluid properties

Properties	Units	Value
AV	C.P	30
YP	Ib/100 ft^2	36
PV	C.P	15
Gel strength (zero)	Ib/100 ft^2	15
Gel strength (10 min)	Ib/100 ft^2	28
Loss of filtrate	cm^3/30 min	8
Friction coefficient		0.05
Torque to free stuck at 400 psi differential stuck	In-Ib	Nil

The values from Table 4 and Table 5 are evaluated; it can be shown that oil performs better than water at lower concentrations to prevent the tendency of water-based drilling fluid that causes pipe sticking.

When the values from Table 6 are evaluated, it can be shown that the percentage of oil must be equal or less than 3% in order not to effect on the mud properties.

The most crucial property of drilling fluid is frequently filtration rate, especially when drilling permeable formations where the hydrostatic pressure is higher than the formation pressure. Proper control of filtration can prevent or minimize wall sticking and drag and, in some areas, improve borehole stability. The results depict that the water base mud can increase the loss of filtrate when using bentonite that led to the problem of differential stuck pipe, when adding oil to the mud found that it is possible to reduce the loss of filtrate which may assist to increase the likelihood of releasing the differential stuck as illustrated in Fig. 4.

Table 6. 3% (v/v) oil effect on drilling fluid properties

Properties	Units	Value
AV	C.P	26
YP	Ib/100 ft^2	24
PV	C.P	18
Gel strength (zero)	Ib/100 ft^2	16
Gel strength (10 min)	Ib/100 ft^2	24
Loss of filtrate	cm^3/30 min	8
Friction coefficient		0.05
Torque to free stuck at 400 psi differential stuck	In-Ib	Nil

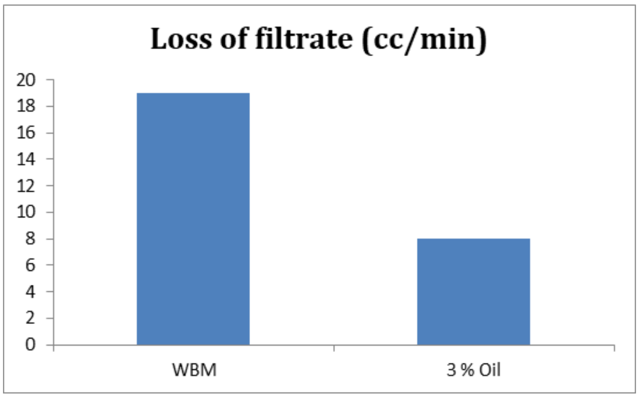

Fig. 4. Comparison of loss of filtrate

The fundamental reason for choosing to study the rheological properties, plastic viscosity, and yield point as well as the filtration properties, fluid loss, and filter cake as the basis for comparison, is the relevance these properties offer to the overall drilling mud performance. The yield point (YP) is a measurement of a mud's ability to remove cuttings from the annulus. A fluid with a high YP is not Newtonian and will carry cuttings more effectively than a fluid with a lower YP but similar density. Also, the frictional pressure loss and YP are directly related. It is crucial to note that when the drilling mud is being circulated, excessively high YP causes high pressure losses. The results showed that when adding oil to the drilling mud, it can control the rheological properties within acceptable range as shown in Fig. 5.

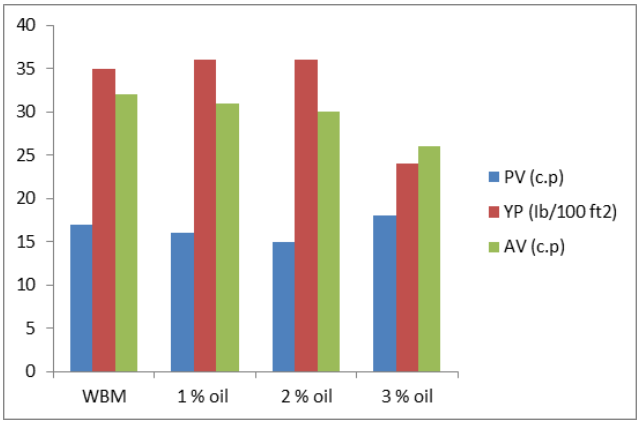

Fig. 5. Comparison of oil effect on rheological properties

5- Conclusion

a. At high concentrations, bentonite clay significantly increases the likelihood of pipes sticking. An increase in bentonite concentration in water-based mud leads to a considerable rise in the friction coefficient, supporting the idea that the likelihood of pipe sticking increases.

b. The suitable percentage of oil in the drilling mud should not exceed 3 % to avoid any changes in rheological properties.

c. Adding oil to the drilling mud reduces the friction coefficient to less than 0.05 and decreases the torque needed to release the ball sticking. This indicates the oil's ability to prevent stuck pipe problems resulting from water-based mud.

d. Finally, the laboratory assessment based on torque measurements is considered one of the main categories for evaluating differential stuck pipe issues.

Abbreviation

AV	Apparent viscosity
C.P	Centipoise
CMC	Carboxy Methyl Cellulose
DSP	Differential Stuck Pipe
PAC-LV	Partially Hydrolyzed Polyacrylamide
PV	Plastic Viscosity
WBM	Water Base Mud
YP	Yield Point

References

[1] F. E. Dupriest, W. C. Elks and S. Ottesen. "Design Methodology and Operational Practices Eliminate Differential Sticking." *SPE Drilling & Completion*. 2011. https://doi.org/10.2118/128129-PA

[2] A. H. Assi and H. Ahmed. "Enhancing the rheological properties of water-base drilling fluid by utilizing of environmentally-friendly materials."*Journal of petroleum research and studies*, vol.32,pp.66-81. 2021. http://doi.org/10.52716/jprs.v11i3.533

[3] S.I Jardine, D.P. McCann and S.S. Barber. "An Advanced System for the Early Detection of Sticking Pipe." *IADC/SPE Drilling Conference*, New Orleans, Louisiana, USA, 1992. https://doi.org/10.2118/23915-MS

[4] W. B. Bradly, D. Jarman, R. S. Plott, R. D. Wood, T. R. Schofield, R. A. Auflick and D. Cocking. "A task force approach to reduce stuck pipe costs." *SPE/IADC Drilling conference*, Amsterdam, Netherlands, 1991. https://doi.org/10.2118/21999-MS

[5] D. Knox and P. Jiang. " Drilling further with water based fluids-selecting the right lubricants", *SPE 92002*, *SPE International Symposium on Oilfield Chemistry*, The Woodlands, Texas, February 2–4. 2005. https://doi.org/10.2118/92002-MS

[6] J. D. Kercheville, A. A. Hinds and W. R. Clements. "Comparison of Environmentally Acceptable Materials with Diesel Oil for Drilling Mud Lubricity and Spotting Fluid Formulations." *SPE/IADC Drilling Conference*, Dallas, Texas, USA, 1986. https://doi.org/10.2118/14797-MS

[7] W.S. Halliday and D.K. Clapper. "Toxicity and Performance Testing of Non-Oil Spotting Fluid for Differentially Stuck Pipe." *SPE/IADC Drilling Conference*, New Orleans, Louisiana, USA, 1989. https://doi.org/10.2118/18684-MS

[8] P.I. Reid., G.H. Meeten., P.W. Way., P. Clark., B.D. Chambers., and A. Gilmour. "Mechanisms of Differential Sticking and a Simple Well Site Test for Monitoring and Optimizing Drilling Mud Properties" *IADC/SPE Drilling Conference*, New Orleans, Louisiana, 12–15 March. 1996. https://doi.org/10.2118/35100-MS

[9] N. S. Amin and A. A. Alrazzaq. "Analysis of stuck pipe incidents in khabaz field," *Iraqi Journal of Chemical and Petroleum Engineering*, vol.19, pp. 47–53. 2018. https://doi.org/10.31699/IJCPE.2018.4.6

[10] F. Al-Mahdawi and K. Saad. "Enhancement of Drilling Fluid Properties Using Nanoparticles." *Iraqi Journal of Chemical and Petroleum Engineering*, vol.19, pp, 6- 21. 2018. https://doi.org/10.31699/IJCPE.2018.2.4

[11] A. H. Assi and A. A. Haiwai. "Enhancing the rheological properties of water-base drilling fluid by utilizing of environmentally-friendly materials." *Journal of petroleum research and studies*, vol.32, pp.66-81, 2021. http://doi.org/10.52716/jprs.v11i3.533

[12] F. Hameed. and A. A. Alrazzaq. "Formulating Inhibited Fluids for Stable Drilling Operations into Tanuma and Zubair Shales, Zubair Oilfield, Southern Iraq" *Iraqi Geological Journal*, 55, 108–119. 2022. https://doi.org/10.46717/igj.55.2D.9ms-2022-10-25

[13] K. T. Alhisnawy and A. A. Alrazzaq . " Using of Unconventional Method Depending on Well Power in Mishrif Formation to Release Differential Stuck Pipe, Nahr Umr Oil Field, Southern Iraq." *Iraq Geological Journal*, vol.56, No.2B, pp. 67-74, 2023. https://doi.org/10.46717/Igj.56.2B.5ms-2023-8-14

[14] D. A. Krol. "Additives cuts differential pressure sticking of drill pipe" *Oil Gas Journal*. 82:55–59. 1984.

[15] K. T. Alhisnawy, A. A. Alrazzaq and W. M. Emtair. "A descriptive study of differential stuck pipe problem in Nahr Umr oil field: principles and treatments *Iraqi Journal of Chemical and Petroleum Engineering*, vol.25, pp. 105-114, 2024. https://doi.org/10.31699/IJCPE.2024.3.12

[16] F. Hameed and A. A. Alrazzaq. "Laboratory Testing and Evaluation of Shale Interaction with Mud for Tanuma Shale Formation in Southern Iraq." *Iraqi Journal of Chemical and Petroleum Engineering*, vol.23, pp. 35–41, 2022. https://doi.org/10.31699/IJCPE.2022.3.5

الفحوصات المختبرية والتقيمية لاستخدام طين الحفر النفطي لمنع حدوث الاستعصاء التفاضلي في حقل نهر عمر

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الخلاصة

يعتبر الاستعصاء التفاضلي من المشاكل الرئيسية عند استخدام البنتونايت في طين الحفر المائي. تم استخدام جهاز fann VG meter و جهاز a self– fabricated وجهاز stickance tester في البحث لفحص تاثير اضافة النفط في طين الحفر المائي والسيطرة على هذه المشكلة. عند المقارنة وجد ان النفط مناسب اكثر للاستخدام في طين الحفر. التجارب اظهر ان طين الحفر يحتفظ بخواصه الريولوجية ويقلل معامل الاحتكاك وايضا يساعد على التقليل من فقدان الراشح من ١٨ الى ٨ سم^{٣} وتقليل معامل الاحتكاك من ٠,٣٢ الى ٠,٠٥ عند اضافة النفط . ان ميل طين الحفر للالتصاق تتضاءل بشكل كبير, مما يشير الى انه سيكون مناسبا تماما لمنع حدوث مشكلة الاستعصاء التفاضلي التي يسببها طين الحفر المائي. بالاضافة لذلك, لوحظ ان النفط يجب ان يستخدم في الطبقات ذات النفاذية العالية بدل الماء. تم اختيار حقل نهر عمر لدراسة مشكلة الاستعصاء التفاضلي باستخدام عينات حقلية ومراقبة خواص طين الحفر المثالية. اخيرا, تم استنتاج ان استخدام الطين المستحلب كطين حفر يمكن ان يمنع ويعالج مشكلة الاستعصاء التفاضلي بدون اي عزم بسبب قدرته على تقليل معامل الاحتكاك اقل من ٠,٠٥ ولكن يجب ان يؤخذ بنظر الاعتبار ان النسبة المئوية للنفط يجب ان لا تزيدعن ٣ % من اجل تجنب اي تغيير في الخواص الريولوجية لطين الحفر.

الكلمات الدالة: البنتونايت، معامل الاحتكاك، فقدان راشح الطين، الاستعصاء التفاضلي.