Journal Homepage: http://ijcpe.uobaghdad.edu.iq
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 25 No. 3 (September 2024) 105 – 114
EISSN: 2618-0707, PISSN: 1997-4884

A descriptive study of differential stuck pipe problem in Nahr Umr oil field: principles and treatments

Karrar Talib Alhisnawy [a, b, *], **Ayad A. Alhaleem A. Alrazzaq** [a], **Waleed M. Emtair** [c]

a Petroleum Engineering Department, College of Engineering, University of Baghdad, Baghdad, Iraq
b Basra Oil Company, Drilling Department, Basra, Iraq
c Arabian Gulf Oil Company, ALBAYDA, LIBYA

Abstract

Differential-pressure pipe sticking is one of the main problems that occurs during drilling operations, leading to an increase in the non-productive time (NPT). To address this problem, the industry uses a range of spotting fluids to enable the recovery of a differentially stuck pipe effectively. Thus, any delay in solving this problem can turn into a difficult rescue operation that can eventually lead to the abandonment of the well in extreme conditions. Therefore, it is crucial to choose the appropriate spotting fluid that is suitable for the specific mud composition, as using an unsuitable spotting fluid may result in dangerous conditions. Additionally, other factors can further complicate the process of freeing a stuck pipe. Therefore, for prevention, remediation, and enhancing the recovery of stuck pipes, it is important to understand the root causes of the pipe sticking issue, the conditions that lead to it, and the operational mechanisms of various spotted fluids and their application areas.

This paper studies the challenges of pipe sticking during drilling operations, particularly emphasizing differential pipe sticking, and the role of spotting fluids in releasing pipe sticking. It discusses the testing and evaluation methods used to choose appropriate spotting fluids while rejecting the inferior options, highlighting the benefits and disadvantages.

This study, which was conducted at Well NR-A in the Nahr Umr field in southeastern Iraq, aims to address the problem of differential stuck pipes. By employing a stuck pipe list check table, the mechanism of this problem was diagnosed, resulting in a thorough analysis of the causes of differential stuck pipe and subsequent steps necessary to release the stuck pipe. Finally, recommendations are presented to improve testing and evaluation methods, overcoming the limitations of conventional methods.

Keywords: Differential Stuck pipe; Mud cake; spotting fluids; non-productive time (NPT); the Nahr Umr field.

Received on 30/11/2022, Received in Revised Form on 21/01/2023, Accepted on 24/01/2023, Published on 30/09/2024

https://doi.org/10.31699/IJCPE.2024.3.12

1- Introduction

One of the primary concerns for drilling engineers is nonproductive time (NPT), especially with the increasing expenses associated with rig time. Pipe sticking was found to be responsible for 25% of the operator's NPT during drilling operations in a 2012 study. Out of this, differential pipe sticking was responsible for 30.5% of the NPT. While mechanical sticking was the cause of the remaining incident. Similarly, differential sticking was to cause for 32% of cases involving stuck pipes that occurred in 2017. Most of these occurrences happened during or following pipe connection operations [1].

Fig. 1 illustrates the likelihood and probability of mechanical pipe sticking, differential pipe sticking, and stuck pipe incidents related to pack-off and hole shape. The results indicate that mechanical pipe sticking happens more than differential pipe sticking, both in terms of probability and likelihood. However, since differential pipe sticking is one of the significant occurrences that significantly raises the NPT and the total drilling cost, this paper provides a thorough study of the factors associated with the differential pipe sticking problem, the rescue techniques, the different spotting fluids used to recover a differentially stuck pipe, as well as the various testing and evaluation methods to select the best spotting fluid for rapid recovery of a stuck pipe [2].

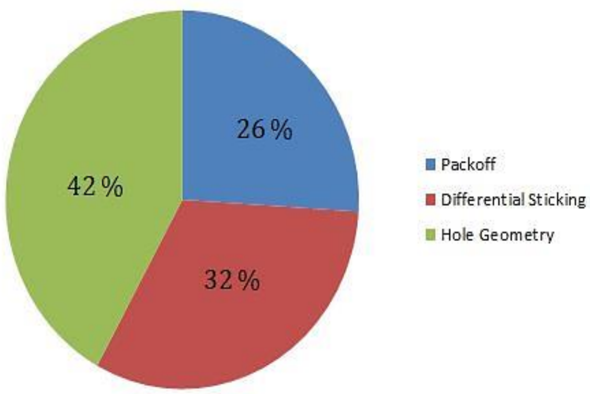

Fig. 1. Stuck Pip Incidents by the Sticking Mechanism [3]

*Corresponding Author: Email: karrar.taleb2108m@coeng.uobaghdad.edu.iq

Stuck pipe occurs in association with many factors or operational activities. The probability of a pipe sticking problem during the making of a connection is more than washout and well-control incidents. This is due to the fact that the static condition of the drill string during making a connection allows it to embed into the mud cake matrix easily in the presence of high permeable or depleted formations. Back reaming operations have the second-highest probability and propensity of causing it, followed by drilling activities as the third highest and pull out of hole (POOH) coming in forth during which stuck pipe incidents are likely to occur. So, to reduce the severity of pipe sticking issues, these procedures require extra caution, proper operating expertise, and the application of technical knowledge [3].

In terms of cost, the differential stuck pipe can translate to as much as 40% of the well cost [4]. This led the industry, in its early history, to focus on minimizing differential stuck pipe incidents. It was later discovered that some level of sticking happens almost always during drilling operations and that it is impractical to have its elimination as an operational or design objective. This is because, in spite of all safety precautions and advised procedures, there are certain actions that cannot be avoided during drilling operations that end up stopping the pipe's movement. This means that the possibility of pressure-differential pipe sticking increases frequently. Therefore, the industry should attempt to control the factors that keep a drill string free to move [5, 6].

In this work, the mechanism of differential pressure sticking will be discussed in order to achieve a better understanding of its underlying causes, this discussion will then move on to the factors that have the greatest impact on the severity of the sticking, Afterwards, a study of the diagnosis process, the recommended practices to avoid differential sticking, and the different remediation techniques used conventionally. The overview of spotting fluids, a comparison of their various types and compositions, as well as an explanation of how they function, is covered in the second section. The last part provides a review of the evolution of the testing and assessment steps, and lastly the limitations and areas of possible future advances in this field.

2- Area of study

The Nahr Umr oil field is about 25 km north-northwest of Basra city in southern Iraq, between latitudes (30 35' - 30 50') and longitudes (47 45' 47 45'). It is situated between Majnoon field and eastern Zubair field, which it is saddled between, and is divided into two parts by the Shat Alarab river. Although it is believed that the structure is a part of the Majnoon oil field, geological research has proved that they are really separated by a saddle, as seen in Fig. 2. From bottom to top, the following formations contain oil: Zubair formations (Lower Cretaceous). Nahr Umr and Mishrif formations (Upper Cretaceous). The best reservoirs are Zubair and Mishrif formations [7]

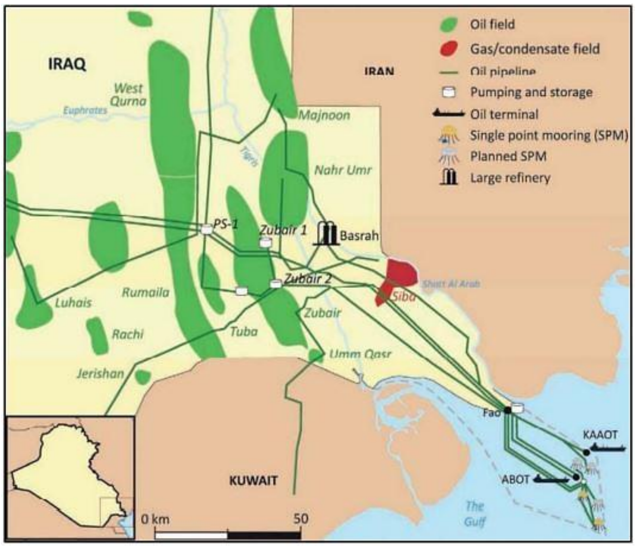

Fig. 2. Nahr Umr Oil Field Location [7]

3- Mechanism of differential-pressure pipe sticking

The stuck pipe can lead to NPT during drilling processes. It happens when pulling the drill string from the borehole requires a strength exceeding the maximum allowable tensile strength of the drill string. This means the drill string or a portion of it cannot be rotated and/or moved within the wellbore [6, 8]. Pipe sticking is classified into two types mechanical or differential. There are also sticking due to other reasons such as equipment failure, or due to a combination of the above-mentioned types. These cases are not going to be discussed in this paper**.**

Differential-pressure pipe sticking as a type of pipe sticking has usually occurred in permeable formations and, most of the time, following stopping the pipe movement. In this type of sticking, the pressure differential across the permeable zone, or the difference between the hydrostatic and formation-fluid pressure, is primarily responsible for holding the pipe against the borehole wall; see Fig. 3 for a showing. The pressure differential represents a seal to push the drill string into the filter cake and prevent it from moving. Permeable zones resort to forming thick impermeable filter cake, and as the drill string becomes stable, it is likely that it gets embedded in the filter cake. As a result, the filtrate is forced to escape from the filter cake and into the permeable formation until the pressure within the cake drops to as close as the formation pressure [2, 5, 9, 10].

As sticking is confirmed, the pressure differential across the pipe is transmitted to the fine solids in the filter cake, so they develop an effective stress. When the permeability of the formation is high, the higher the pressure drop within the filter cake, the higher the pressure differential across the pipe, and consequently, the higher the effective stress. Reid et al., [9] concluded from their laboratory experiments that the force resisting pipe pullout can be divided into two kinds; pressure differential across the filter cake, which is the prevailing force, and adhesion of the filter cake to the drill string. They found that adhesion force can form up to 45% of the total resistance and it can differ with time depending on the filter-cake thickness and composition.

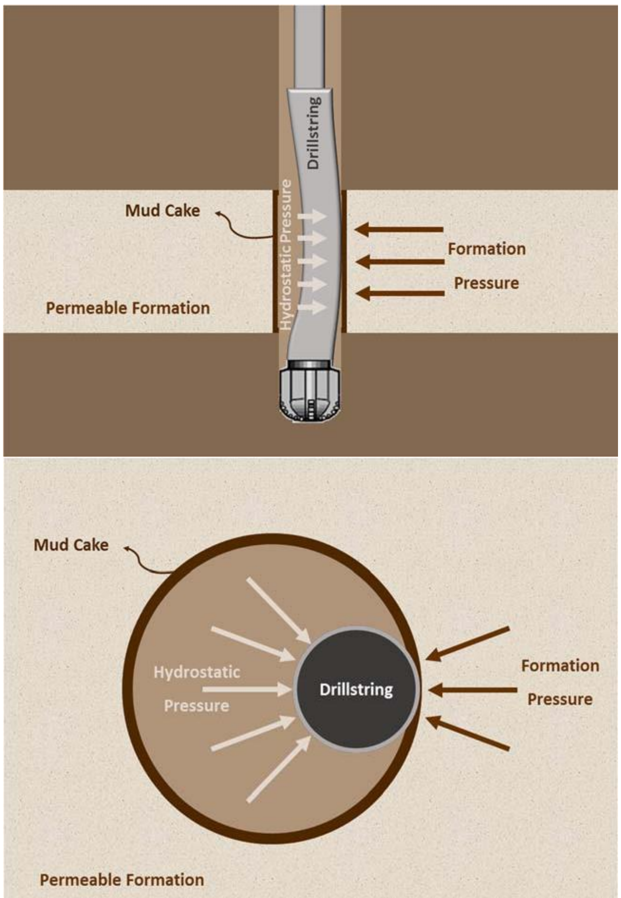

Fig. 3. Differential Pressure across the Drill String and Embedment of the Drill String in Mud Cake [9]

Because of the process of solid pressure increase and hydraulic pressure decrease within the mud cake, the pressure between the drill collar and the mud cake gradually changes to solid pressure. At the same time, the water leaves the mud cake into the formation and the cake shrinks. This shrinkage causes an increase in the contact between the drill collars and the mud cake. These two processes cause an increase in the friction forces between the drill string and the mud cake, making more sticking force due to the adhesion between the two, increasing the overall force required to pull out the drill string [11].

In terms of bonds, Clark and Almquist, [10] classify the bonds depending on pressure variation along the contact area in terms of the degree of embedment. This can be stated through three cases: (a) the strongest attachment is indicated by maximum pipe embedment in the filter cake, which means that the adhesion forces at the cake/pipe interface, are greater than that at the formation/cake interface. (b) A small change in initial pressure and a weak force at the cake/pipe interface relative to the other interfacial forces are both indicated by little pipe embedment. In this case, either a dynamic filtration is still carried out or the cake maintains its permeability. By reducing the effective stress, the sticking can then be resolved, allowing the pipe to move against the cake. (c) The third scenario happens when the interfacial forces at the formation/cake interface and at the cake/pipe interface are similar in value, and the cake strength is the weakest bond. This case requires shearing the cake to free the pipe.

4- Analysis of differential sticking factors

The friction factor between the drill string and the mud cake, along with the contact area and the differential pressure, all contribute to the creation of the differential sticking force [12]. This force needed to release the pipe increases as the isolated portion of the pipe expands, which depends on the ratio of the pipe to hole diameter and the rate of cake thickening. The initial area of the pipe isolated from the hydrostatic pressure is impacted by the pipe-to-hole diameter ratio. The properties of the mud and the permeability of the formation determine how quickly cakes develop. These two variables control the clay mud cake's compressibility and the rate of filtrate loss. As time goes on, filtration through the mud cake continues and the isolated area expands [9].

Controlling the weight of the mud, which essentially affects the hydrostatic pressure in the borehole, provides additional means of influencing the severity of the differential stuck pipe. Mud weight during conventional overbalance drilling must follow a number of requirements in order to help with good control, borehole cleaning, and wellbore stability. In addition to achieving these requirements, the mud weight should not be excessive to prevent loss of circulation or, worse yet, formation fracture, both of which can have damaging effects. Choosing the proper mud weight is especially important in areas where the formation pressure is low and/or the permeability is high because a high mud weight can result in an excessive differential pressure, which may cause differential sticking [11].

The amount of friction between the drill collars' steel and the mud cake is the third factor in determining the pull-out force. The friction force preventing the pull out of the drill string is mostly caused by the friction between the clay and the steel, as previously discussed because there is very little friction between the water and the steel. As the filtrate is forced out of the cake and into the formation while the clay is still allowed to come into contact with the steel, this becomes even more important. As a result, when creating the drilling mud, it is important to take the mud cake's solid content into account. The more severe the sticking, the larger the percentage of solids, and the higher the friction factor [11]. In a net shell, Reid et al., [9] have observed that it is impossible to predict the sticking potential from only one mud property, hence testing techniques are necessary to determine the sticking properties of various mud compositions. They have found from their tests that gel water base mud (WBM) has the highest sticking propensity value and oil base mud (OBM) has the lowest. An intermediate sticking tendency value was displayed by polymer (WBM).

The sticking time must be taken into account because the majority of the other factors impacting the severity of sticking and the effectiveness of unsticking the pipe are time-dependent [14]. As a result, generally speaking, increasing the sticking time prior to spotting increases the releasing period [15]. The creation and use of remediation procedures aimed to mitigate these factors and handle differential stuck pipe (DSP) occurrences must take this into consideration.

Nazaneen and Ayad Abdul Alhaleem, [11] conducted a study to analyze the occurrences of the stuck pipe in Khabaz Oilfield. To investigate the issue of stuck pipes 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.

5- Spotting fluids composition

For many years, the basis fluid for early spotting fluids was petroleum oil (either crude or refined), diesel oil, or kerosene. However, certain of these usages have been restricted, particularly for diesel, due to environmental concerns and new environmental laws. Over time, several additives were employed in place of diesel, but many of them were later found to be ineffective. Mineral oils were then employed as an oil-based drilling mud after being changed and processed to remove the poisonous and aromatic components. No apparent changes in pipe release times were found between low-toxicity mineral oils and diesel oil, making them equally effective [16, 17]. Later, synthetic oil is paraffinic oil, specifically a group of compounds known as poly-alpha-olefin, which contain no aromatic compounds. This inverted emulsion fluid was developed to show that it has the necessary fluid qualities and a low level of toxicity to serve as the basis for spotting fluids [18].

The seven major kinds of spotting fluids now in use are brine, surfactants, lubricants, filter-cake degrading agents, glycol, acid, and solvents. The filter cake is mostly dehydrated and osmotic degraded using brine. It can be used as a soak tablet to help the filter cake dehydrate, or it can be quickly pumped around a stuck pipe to wash or thin the cake [19, 20].

Surfactant pills are used in spotting in water-based mud where lubricants or glycol pills are required to lubricate the area around the sticking zone and reduce friction between the drill pipe and the formation and the filter-cake solids. To acquire more effective lubrication, they must make sure the surface area of the stuck pipe zone is wet with water. Surfactants are used to provide the base mud low-water loss, low mud filtrate surface tension, thin filter cake, and stable emulsion qualities, according to Jardine et. al, [21].

More recently, some additives were introduced for use in spotting fluids to perform exothermic reactions to generate heat at the site of downhole application. This fluid utilizes D-limonene as a base material for the spotting fluid, and a thermal activator [2]. This concept of utilizing heating to help free stuck pipes was observed by Clark and Almquist, [10] when they noticed that the pipe release time decreased as the temperature increased.

The use of spotting oil to conduct wetting action, wash the water to lower the hydrostatic head, relieve the differential pressure, and release the pipe is one of the earliest remedial approaches. It was expected that the oil may pass through the space between the drill collars and the mud cake, lubricate or dehydrate the mud cake to break its contact with the pipe, and then operate to balance the pressure on each side of the pipe. The use of a specialized spotting fluid requires quick and efficient application in order to achieve freeing.

In reality, Reid, [9] has proven in their laboratory work that 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.

6- Testing and performance evaluation

Reid et al., [9] conducted laboratory experiments to investigate differential sticking and assess the effectiveness of spotting fluids. The suggested techniques involve measuring mud and mud filtrates directly. To replicate 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. While Balsie et.al, [22] believed it to have a significant disadvantage by preventing the filter area from growing over time, as it would in the real scenario and which is a key component of the phenomena. The other important factor in testing methods is the direction of the freeing forces applied to simulate the forces applied on the drill string in the field during stuck pipe incidents. These forces are mainly either axial by working the pipe along the vertical axis (sliding), or rotational by applying torque or applying radial pull. Temperature, pressure, and dynamic circulation parameters can all be taken into account in the testing in addition to the standard static conditions for cake formation [22, 23].

As lubricity is a crucial component of the spotting fluid used in stuck pipe incidents, it is one of the primary tests done on spotting fluids. Two phases of the drilling mud lubricity were the subject of testing protocols provided by Tarhan and Faulk, [12]. The first is the lubricity qualities test, which measures the film strength and lubricity coefficient. The lubricity coefficient is the coefficient of friction between a steel ring rotating under fluid pressure and a metal surface. The film strength test, however, uses the same mechanism as the previous test to determine the same measurements at extremely high pressures, with the exception that the torque is much higher. The second testing method Tarhan a Faulk, [12] described involved 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.

The software-driven methodology has been used to create a novel test setup that allows for the performance prediction of various spotting fluids [12]. This test device also simulates the pipe/mud cake contact area using a spherical shape and permits interaction between the mud cake and the spotting fluid for soaking. The steel ball is released by the device using an axial pulling force, and the test results are then graphically presented on the screen. When the axial pulling force reaches its maximum, the test may be stopped.

Al-Mahdawi and Saad, [20] 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.

Measuring drilling parameters like overpull, downhole torque, and surface torque involves a new set of differential sticking assessment techniques. Several published approaches suggest an integrated sticking pipe monitor that, as the drill string moves, automatically determines the friction forces and factors based on depth. It makes use of the downhole weight on bit, surface and downhole torque readings, and hook load. Additionally, hole size and geometry are taken into account. And BHA to calculate the values of the sliding and rotating friction coefficients, which were tracked throughout all drilling phases. Unless sticking is established, it is assumed in these approaches that the friction factors are constant for a particular drilling operation at a particular depth. Based on this supposition, the approach can produce an alarm for the drilling crew to help them identify stuck pipes earlier [21, 22].

Hameed and Al. Haleem, [23] conducted laboratory testing and evaluation for Tanuma formation by using many methods 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.

7- Diagnosis of stuck pipe mechanism

The identification of a stuck pipe problem involves referencing Table 1**,** which is based on the pipe movements and visual observations made by crew members to determine whether the pipe has moved up or down. The factors listed in Table 1 can be alternatively referred to as symptoms of the stuck problem. Based on these symptoms the type of stick can be identified [24, 25].

Table 1. Types of Stuck Pipe

Pipe Motion Prior to Sticking	Pack-off	Differential Sticking	Mechanical Sticking
Move up	2	0	2
Rotating up	0	0	2
Move down	1	0	2
Rotating down	0	0	2
Static	2	2	0
Pipe motion after sticking			
Down free	0	0	2
Down restricted	1	0	2
Down impossible	0	0	0
Pipe rotation after sticking			
Rotate free	0	0	2
Rotate restricted	2	0	2
Rotate impossible	0	0	0
Circulating pressure after sticking			
Circulating not restricted	0	2	2
Circulating restricted	2	0	0
Circulating impossible	0	0	0

By analyzing all surface indications, we can accurately diagnose the type of stuck and implement appropriate recovery techniques for each type of stuck [26, 27].

8- Mathematical computations

8.1. Stuck pipe depth

The stuck pipe depth can be calculated by following equation [28]:

$$SPL = \frac{Pdps * Kfpt}{F} \quad (1)$$

Where: SPL - Stuck pipe location (ft). Pdps - Stretch of Drill Pipe (inch). Kfpt - Free-point constant. F - Force applied to stretch the pipe (KIb). The free point constant (Kfpt) is given by:

$$Kpft = As * 2500 \quad (2)$$

Where: As is the pipe wall cross-sectional area (sq. inch).

$$As = (ID^2 - OD^2) * 0.7854 \quad (3)$$

Where: ID is the inner diameter of the drill pipe in inches. OD is the outer diameter of the drill pipe in inches.

8.2. Margin of overpull

By using the following equation, the margin of overpull can be estimated [29]:

$$\text{Margin of overpull} = Ta - Th \quad (4)$$

Where: Ta – Maximum tensile strength (lb) multiplied by 0.9. Th – Weight of string * buoyancy factor (Ib).

8.3. Buoyancy factor

The following equation is used to calculate the buoyancy factor [30, 31]:

$$\text{Buoyancy factor} = 1 - \frac{\rho\ \text{mud}}{\rho\ \text{steel}} \quad (5)$$

Where: ρ steel $= 7.85$ gm/cc.

9- Result and discussion

9.1. The problem

While drilling the 12 1/4" hole in well NR-A at a depth of 2306 m in the Mishrif formation, the rate of penetration (ROP) averaged 1.8 m/hr. As shown in Fig. 4., the torque began to increase, and ROP gradually decrease. This decrease in ROP is due to broken teeth of the bit, as shown in Fig. 5, which is unable to drill the formation rock. This led to an increase in torque, necessitating the replacement of the bit with a new one. Then, the operator increased the RPM and checked the mud properties. However, when the torque remained at a high value, the decision was made to pull out in order to replace the bit. During the pull-out process to a depth of 1874 m and while making a connection slowly, the string became stuck after spending about 20 minutes' time period.

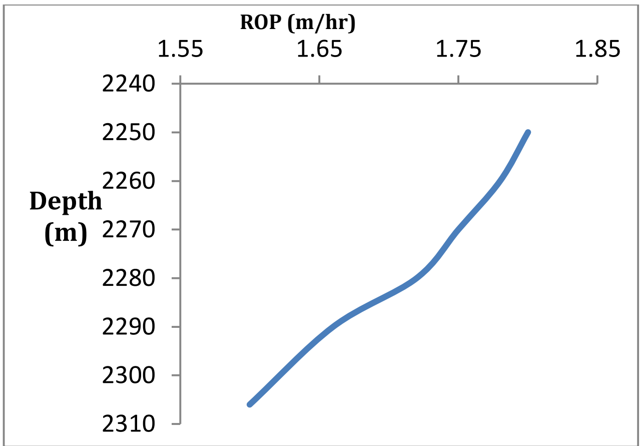

Fig. 4. The rate of Penetration (ROP) as a function of Depth for well NR-A in the Nahr Umr Oil Field

After analyzing Table 2 and Table 3, it is evident that the high mud weight is resulting in the formation of mud cake in the permeable zone which causes an increase in filtrate. This problem must be treated by using materials such as carboxy methyl cellulose (CMC) and polyanionic cellulose (PAC) to prevent it from becoming difficult to treat and potentially causing a differential stuck pipe. The stuck pipe depth is 2271 m by using Eq. 1 as shown in Table 4.

Fig. 5. Photo of 12 ¼" Drill Bit Taken at the Surface

9.2. The treatment of the problem

The procedure to free the differential stuck pipe is:

a. Apply the maximum flow rate possible while taking the efficiency of the pumps into account.
b. Work string up with over-pull gradually from 10 to 25 tons.
c. If the previous try failed to free the stuck, jar down used to release the stuck pipe with (over pull 55 ton/slack off 35 ton). This operation was repeated many times.
d. If the previous step failed to free the stuck, spotting 6 m3 of a friction-reducing fluid (stuck breaker + diesel) and displaced by 3 m^3 water then 18 m^3 mud within the stuck zone to decrease the contact area between the stuck pipe and formation, and waiting for 6 hours to activate spotted fluid and then pull the string with (over pull 60 ton/slack off 30) as shown in Table 5, the string got released successfully.

Table 2. Actual Mud Properties

Hole Size (in)	Casing Size (in)	Depth (m)	Formation	Mud Weight (gm/cc)	M.F.V (sec)	Mud Cake (mm)
26	20	352	L-Fars	1.05	50	1
17 ½	13 3/8	805	Dammam	1.28	50	¾
12 ¼	9 5/8	2634	Mauddud	1.3	55	¾
8 ½	7	3393	Ratawi	1.32	52	¾

Table 3. Pressure Values in Mishrif Formation

Depth	Mud Weight (gm/cc)	Formation Pressure (psi)	Fracture Pressure (psi)	Hydrostatic Pressure (psi)
2306	1.3	4114	5340	4259

Table 4. Stuck Pipe Depth Estimations

Kfpt	Pdps (in)	Pull Force (K-Ib)	SPL (ft)	SPL (m)
13187.5	20	44.6	5913	1803

Table 5. Showing Margin Overpull Calculations

Dry String Weight (ton)	Steel Density (gm/cc)	Mud Density (gm/cc)	Buoyancy Factor	String Weight in Mud (ton)	Ta (ton)	Th (ton)	Margin Overpull (ton)
66	7.85	1.3	0.83	55.07	110.63	55.07	55.56

Fig. 6 shows the effect of differential stuck pipe on the total time of the well and how it leads to high cost and time.

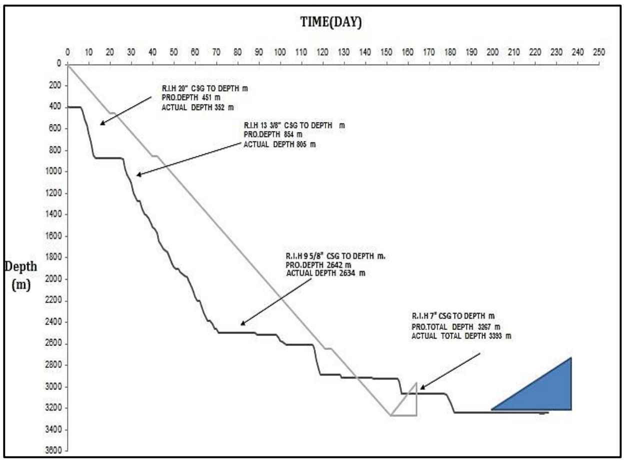

Fig. 6. Drilling Time Curve

9.3. Mud cake thickness measurement

The filtration rate is typically the most crucial property of a drilling fluid, especially when drilling permeable formations where the hydrostatic pressure is higher than the formation pressure. Filtration can increase borehole stability in some cases and prevent or mitigate wall sticking and drag. The results depict that the water base mud can form a thick mud cake when using bentonite leading to the problem of differential stuck pipe, when adding oil to the mud found that it is possible to reduce the mud cake which may assist in increasing the likelihood of releasing the differential stuck as shown in Fig. 7. Using filter press device at room temperature of 100 psi differential pressure to conduct mud cake test.

10- Gaps and future developments

The current stuck pipe assessment and forecast approaches are still not accurate enough to be completely beneficial in reducing drilling's nonproductive time. Such systems' limitations include the requirement for well-established, industry-specific trends as well as the fact that their output is only as good as the input data, which is frequently inaccurate on its own. In addition, the measurement methods used to obtain measuring while drilling (MWD) data are a substantial source of mistakes. The relative error in the stuck pipe trends used to identify sticking, and consequently the less-than-ideal accurate stuck pipe incidents prediction percentage, can be attributed to the fact that these tools are not always consistent in a given field.

The fundamental limitation of the second set of procedures for sticking assessment and spotting fluids evaluation, which is based primarily in laboratories, is the time factor. When a stuck pipe incident occurs, it is impossible to send fluid samples to the lab in time for a test to be completed. Testing a mud's propensity for sticking and the performance of a spotting fluid in advance won't always produce results that are beneficial for the sticking situation when it actually occurs since the actual drilling conditions may change significantly from the intended conditions.

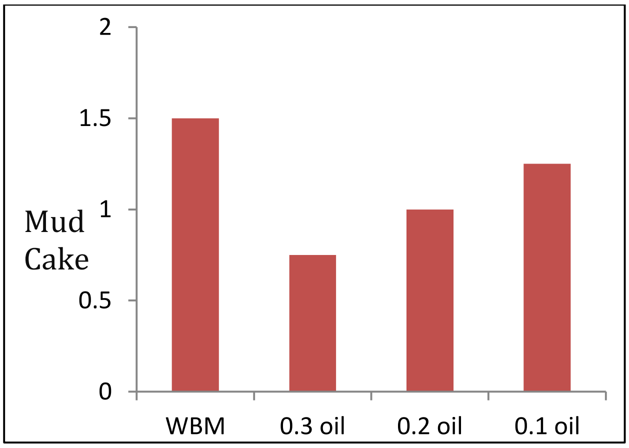

Fig. 7. Mud Cake Measurement with additional oil

The limitations in simulating the borehole geometry, temperature, and pressure conditions are another limitation of the current lab procedures. Additionally, they are restricted to a subset of the force directions that are applied to the drill string on the field. Simulating mud flow conditions, whether static or dynamic, has limitations as well. These elements influence the severity of sticking and the success of spotting to unstick the pipe. Therefore, these laboratory techniques restrict our understanding of the relationships between the various elements influencing the occurrence of sticking and the efficiency of spotting fluids.

11- Conclusions

Differential sticking is a common problem that occurs during drilling operations that can cause damaging accidents, lost time, and expenses. This problem happens when the drilling string becomes stuck in the wellbore due to two main factors: the adhesion forces between the string and the mud cake, and differential pressure across the mud cake preventing the drill string. There are two basic classifications of differential sticking assessment: the laboratory assessment based on torque measurements and the real-time assessment based on MWD data. Unrestricted circulation can be used to identify differential sticking during drilling when the pipe becomes stuck but the string cannot be rotated or moved. Finally, the principal method for treating differential sticking is spotting fluids, particularly when jarring and torquing up are insufficient to release the pipe.

Abbreviation

BHA: Bottom hole assembly
DSP: Differential stuck pipe
HWDP: Heavy-weight drill pipe
MWD: Measuring while drilling
NPT: Non-productive time
OBM: Oil base mud
WBM: Water base mud
WOB: Weight on bit

References

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

[2] M.G. Hilfiger, C.J. Thaemlitz and E. Moellendick, "Advanced Spotting Fluids for Remediation of Differentially Stuck Pipe," *SPE Middle East Oil & Gas Show and Conference*, Manama, Bahrain, 2017. https://doi.org/10.2118/183959-MS

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

[4] H. Santos. "Differentially Stuck Pipe: Early Diagnostic and Solution". *IADC/SPE Drilling Conference*, New Orleans, Louisiana, 2000. https://doi.org/10.2118/59127-MS

[5] M. Lazim and M. Al-kubaisi "Structural study of Nahr Umr Oil Field in Southern Iraq," *Journal of Petroleum Research and Studies*," Vol. 6, PP.23-41. 2016. https://doi.org/10.52716/jprs.v6i2.147

[6] W. Helmick and A. Longley. "Pressure-differential Sticking of Drill Pipe and how it can be avoided or relieved," *Drilling and Production Practice*, New York, USA,1957.

[7] J.M. Courteille and C. Zurdo. "A New Approach to Differential Sticking," *SPE Annual Technical Conference and Exhibition*, Las Vegas, USA, 1985. https://doi.org/10.2118/14244-MS

[8] 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

[9] P. I. Reid, G. H. Meeten, P. Clark 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, USA, 1996. https://doi.org/10.2118/35100-MS

[10] R. K. Clark and S. G. Almquist, "Evaluation of Spotting Fluids in a Full-Scale Differential Pressure Sticking Apparatus," *paper* SPE 22550,1992. https://doi.org/10.2118/22550-PA

[11] 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

[12] D.O. Trahan and M.B. Faulk. "Use of polyalphaolefin in downhole drilling." U.S Patent 5045219, 1991.

[13] R.G. Bland and D.K. Clapper. "Hydrocarbon invert emulsions for use in well drilling operations." U.S Patent 5141920, 1992.

[14] C.O. Walker. "Additive composition for release of stuck drill pipe." U.S Patent 4230587A, 1980.

[15] 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

[16] D.C. Albers and D.R. Wieland. "The Evaluation of Surface-Active Agents for Use in the Prevention of Differential-Pressure Sticking of Drill Pipe." *SPE Production Research Symposium*, Tulsa, Oklahoma, USA, 1962. https://doi.org/10.2118/298-MS

[17] Y.M. Bushnell-Watson and S.S. Panesar. "Differential Sticking Laboratory Tests Can Improve Mud Design." *SPE Annual Technical Conference and Exhibition*, Dallas, Texas,USA, 1991. https://doi.org/10.2118/22549-MS

[18] B.A. Oriji and I.S. Aire. "A Model Approach to Analytically Identify Stuck Pipe and Its Mechanism in Wellbore," *European Journal of Engineering and Technology Research*, vol. 5, pp. 387–394, 2020. https://doi.org/10.24018/ejeng.2020.5.3.1845

[19] M. Amanullah and M. Al-Arfaj. "Novel Method and Apparatus for Sticking Fluid Performance Evaluation." *SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition*, Dammam, Saudi Arabia, 2017. https://doi.org/10.2118/187982-MS

[20] 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

[21] 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

[22] J.P. Belasie, D.P. McCann and J.F. Leshikar. “A Practical Method To Minimize Stuck Pipe Integrating Surface and MWD Measurements.” *IADC/SPE Drilling Conference*, Dallas, Texas, USA. 1994. https://doi.org/10.2118/27494-MS

[23] 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

[24] 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

[25] M. A. Issa, A. A. Alrazzaq and Y. Mukhtar. “Review of the Mechanisms for Preventing, Diagnosing, and Treatment of Pipe sticking in Drilling Operations.” *Iraqi Journal of Chemical and Petroleum Engineering*, vol.24, pp. 133-140, 2023. https://doi.org/10.31699/IJCPE.2023.3.13

[26] 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

[27] M. A. Muqeem, A. E. Weekse, and A. A. Al-Hajji, “Stuck Pipe Best Practices - A Challenging Approach to Reducing Stuck Pipe Costs.” *SPE Saudi Arabia Section Technical Symposium and Exhibition*, Al-Khobar, Saudi Arabia, 2012. https://doi.org/10.2118/160845-MS

[28] J. P. Deville. “Spotting Fluid Compositions and Associated Methods.” U.S Patent No. 8 048 829. 2011.

[29] H. D. Outmans. “Mechanics of Differential Pressure Sticking of Drill Collars.” *SPE Petroleum Transactions of AIME*, Vol. 213, pp.265-274,1958. https://doi.org/10.2118/963-G

[30] M. R. and P. A. Monaghan. “Differential Pressure Sticking-Laboratory Studies of Friction between Steel and Mud Filter Cake.” *Journal of Petroleum Technology*. 1962. https://doi.org/10.2118/151-PA

[31] 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

دراسة لمشاكل استعصاء الانابيب التفاضلي في حقل نهر عمر: المبادئ والمعالجة

كرار طالب الحسناوي [١، ٢، *]، اياد عبدالحليم عبدالرزاق [١]، وليد مفتاح امطير [٣]

١ قسم هندسة النفط، كلية الهندسة، جامعة بغداد، بغداد، العراق
٢ شركة نفط البصرة، قسم الحفر، البصرة، العراق
٣ شركة الخليج العربي للنفط، البيضاء، ليبيا

الخلاصة

تعد مشكلة التصاق الأنابيب بسبب الضغط التفاضلي واحدة من المشاكل الرئيسية التي تحدث أثناء عمليات الحفر، مما يؤدي إلى زيادة الوقت غير المنتج (NPT). لمعالجة هذه المشكلة، تقوم الصناعة النفطية باستخدام مجموعة من سوائل التكسير لتمكين استعادة الأنابيب العالقة بشكل فعال. وبالتالي، فإن أي تأخير في حل هذه المشكلة يمكن أن يتحول إلى عملية إنقاذ صعبة يمكن أن تؤدي في النهاية إلى التخلي عن البئر في ظروف قاسية. لذلك، من الأهمية بمكان اختيار سائل الاستكشاف المناسب الذي يتناسب مع تكوين الطين المحدد، حيث أن استخدام سائل غير مناسب قد يؤدي إلى ظروف خطيرة. بالإضافة إلى ذلك، يمكن لعوامل أخرى أن تزيد من تعقيد عملية تحرير الأنابيب العالقة. لذلك، للوقاية والعلاج وتعزيز استعادة الأنابيب العالقة، من المهم فهم الأسباب الجذرية لمشكلة التصاق الأنابيب، والظروف التي تؤدي إليها، والآليات التشغيلية للسوائل المختلفة ومجالات تطبيقها.

تقوم هذه الورقة البحثية بدراسة تحديات التصاق الأنابيب أثناء عمليات الحفر، مع التركيز بشكل خاص على التصاق الأنابيب التفاضلي، ودور سوائل التكسير في تحرير التصاق الأنابيب. تتناول هذه الدراسة طرق الاختبار والتقييم المستخدمة لاختيار سوائل التنقيط المناسبة مع رفض الخيارات الرديئة، مع تسليط الضوء على الفوائد والعيوب. تهدف هذه الدراسة، التي أجريت في بئر NR–A في حقل نهر عمر جنوب شرق العراق، إلى معالجة مشكلة الأنابيب العالقة التفاضلية. من خلال استخدام جدول فحص قائمة الأنابيب العالقة، تم تشخيص آلية هذه المشكلة، مما أدى إلى تحليل شامل لأسباب الأنابيب العالقة التفاضلية والخطوات اللاحقة اللازمة لتحرير الأنبوب العالق. أخيرًا، يتم تقديم توصيات لتحسين طرق الاختبار والتقييم، والتغلب على قيود الطرق التقليدية.

الكلمات الدالة: استعصاء الانابيب التفاضلي، كعكة الطين، وقت عدم الانتاجية، ضخ السوائل، حقل نهر عمر.