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РАННИЕ ПРИЗНАКИ ПРИХВАТОВ ТРУБЫ И МЕТОДЫ ПРЕДУПРЕЖДЕНИЯ

EARLY SIGNS OF PIPE STICKING AND WARNING METHODS

Майкоби Алию Абубакар
ассистент кафедры БНГС,
Уфимский государственный нефтяной
технический университет
alimaikobi@mail.ru

Четвертнева Ирина Амировна
доктор технических наук,
профессор кафедры БНГС,
Уфимский государственный нефтяной
технический университет

Тахир Джаафар Ибрахим
старший преподаватель,
кафедра нефти химия и нефтегазовое дело,
Баеро университет г. Кано, Нигерия

Аннотация. Прихват бурильных труб является одной из основных осложнений при любой операции бурения, особенно при бурении горизонтальных или наклонно-направленных скважин через глубокие пласты. Прихват трубы происходит во время бурения, каротажа и спуска обсадной колонны и особенно колонны заканчивания с многоступенчатым гидроразрывом (MSF). Это приводит к длительному непродуктивному времени, ограничивает производительность бурения и увеличивает стоимость скважины. Чем раньше инцидент с прихваткой трубы прогнозируется и устраняется, тем выше шансы на успех в освобождении трубы или предотвращении серьезного застревания изначально. Время имеет решающее значение в таких случаях, поскольку неправильная реакция на инцидент с прихватом может легко усугубить ситуацию. В этой работе представлены различные признаки и методы предупреждения этих инцидентов.

Ключевые слова: механический прихват (механическое прилипание), обвал стенок скважины, геометрия ствола скважины, дифференциальный прихват, зоны осыпей.

Maikobi Aliyu Abubakar
Assistant of the Department of BNGS,
Ufa State Oil
technical university
alimaikobi@mail.ru

Irina Amirovna Chetvertneva
Doctor of Technical Sciences,
Professor of BNGS Department,
Ufa State Oil
technical university

Tahir Jaafar Ibrahim
Senior Lecturer,
Department of Petroleum Chemistry
and Petroleum Engineering,
Bayero University of Kano, Nigeria

Annotation. Stuck pipe is one of the main challenges in any drilling operation especially drilling horizontal or deviated wells through deep reservoirs. Stuck pipe occurs while drilling, logging, running casing and running lower completion especially the Multi-Stage Fracturing (MSF) completion string. This causes long non-productive time, limits the drilling performance and increases the well cost. The earlier a stuck pipe incident is predicted and mitigated, the higher the chance of success in freeing the pipe or avoiding severe sticking in the first place. Time is crucial in such cases as an improper reaction to a stuck pipe incident can easily make it worse. Various signs and mitigation techniques of stuck pipe are presented in this work.

Keywords: mechanical sticking, hole pack-off, wellbore geometry, differential sticking, key seat.

Stuck pipe mechanisms are the downhole means due to which the sticking action occurs. These mechanisms are multi-variate; they require specific conditions to occur and are enhanced by several dynamics. The drillstring is considered stuck when it cannot be retrieved from the wellbore, despite the ability or inability to lower it downhole, rotate it, or to circulate. In other words, as long as the drillstring cannot be pulled out of hole using the maximum allowable tensile strength of the drillstring, it is considered stuck. It is considered as such due the different types of sticking mechanism, for example in case of differential sticking, circulation is usually not interrupted, while in the case of key seating, down hole movement of the drill string remains possible during stuck incidents [1, 2, 3].

The high severity of stuck pipe incidents puts its prevention at the top of the priority list for the field operations. The ongoing production of a reservoir continuously changes the drilling environment and the rock stresses from their original state, hence, the continuous optimizations of operational procedures and well designs are required and should reflect the changes of the risk level including any additional risks. A static strategy to prevent stuck pipe over the life of the field is not efficient and stuck pipe incidents may increase due to inappropriate designs, operational procedures and execution plans at different stages of the field life. Similarly, an over conservative approach increase the operating cost and reduce operation efficiency. In

deep and interbedded reservoirs, the risk of stuck pipe increases significantly as the field is being produced, due to some layers being more depleted than others because of permeability and production variations, leading to significant uncertainties of both the reservoir pressure and the stresses in the wellbore [4].

In many fields, although learning curves should reduce the number of stuck pipe events at the development stages, the stuck pipe events increased or remained at the same level. This is due to the continuous change of drilling environment and the stuck pipe risk level (Figure 1).

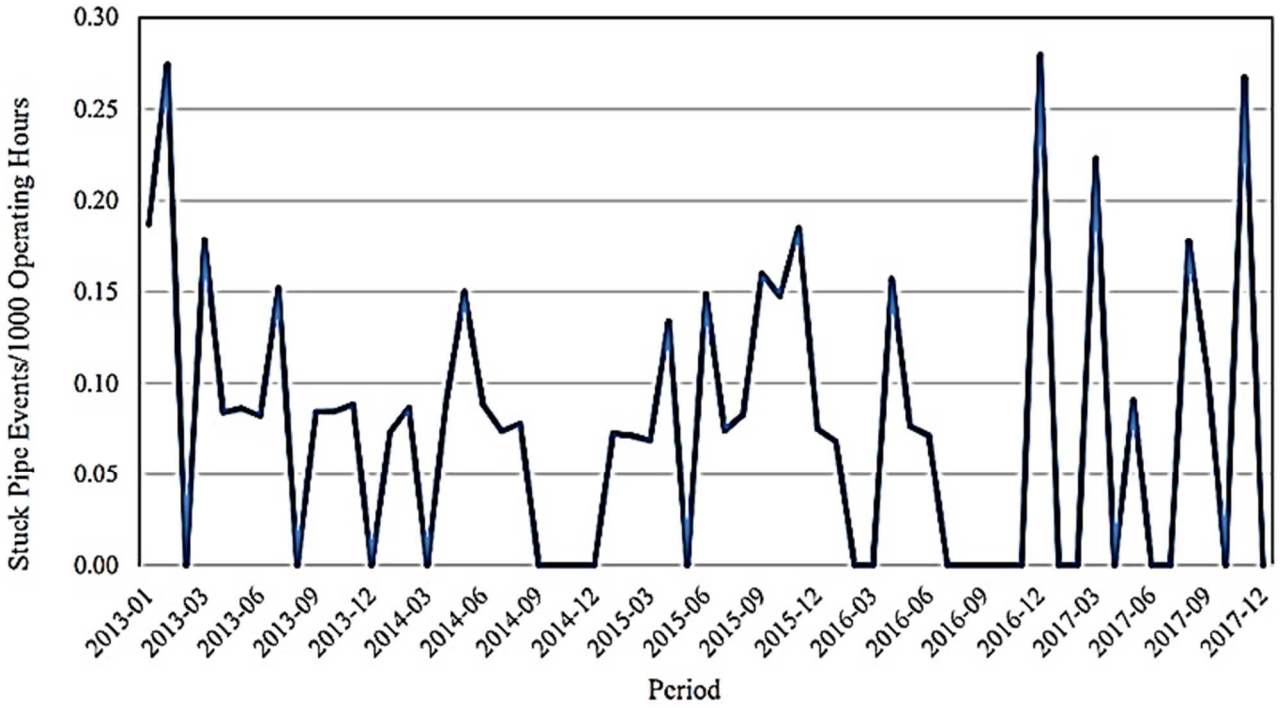

Figure 1 – Field «A» Stuck pipe events over time [4]

When a pipe is stuck, the mechanism and cause of sticking need to be identified in order to execute the corresponding freeing procedures and remediation measures. Freeing the drillstring can take less than an hour in minor cases, and it can last days in severe sticking cases, if freed at all. The sooner the stuck pipe mechanism of the incident is identified, the faster the correct response can be taken, and the higher the chance of freeing the pipe [16]. In fact, 50 % of stuck pipe cases become free within 4 hours, while less than 10 % become free after 4 hours (Figure 2). In a worst-case scenario, when freeing the pipe becomes unsuccessful, the drilling engineer needs to consider an alternative plan of action and proceed with a sidetracking operation, adding additional costs to the drilling plan [5].

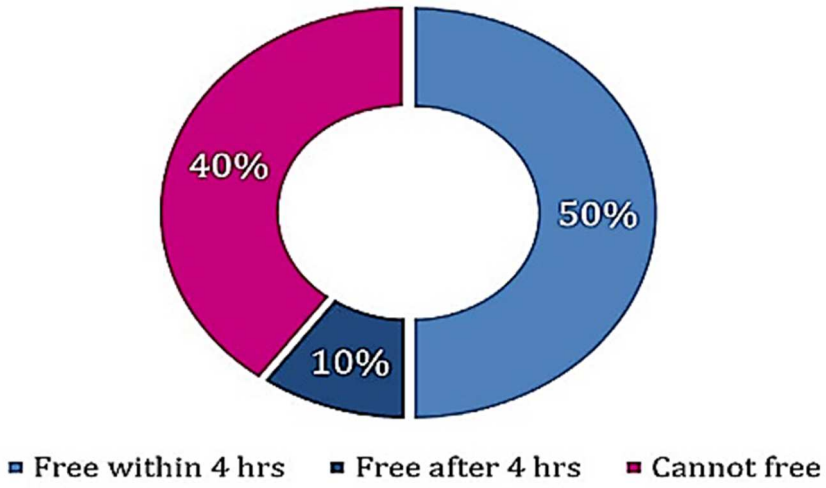

Figure 2 – Significance of time in freeing stuck pipe [2, 3]

It is important to understand these mechanisms and the different factors involved in order to carry out the appropriate actions for optimal prevention. The procedures taken based on initial diagnosis can be the deciding factor between the ability to free the pipe or losing the pipe and opting for a sidetrack, or abandonment. Some stuck pipe incidents occur due to a combination of forces and factors, the incident can start with a specific mechanism of sticking and lead to another mechanism with time. Even if the incident starts with the possibilities of limited movement or rotation, it degrades with time to impossible pipe movement in any direction. This is another reason why time is critical in such incidents; besides the cost of lost time. For example, it is very common to have a stuck pipe after loss circulation during drilling through a lost zone as the drilling fluid fails to transport the cuttings off bottom causing pack-off. It is also common to get stuck after making a connection, right when the drillstring starts to move after some still time. Therefore, it is important to correctly diagnose and report the stuck pipe incident in order to ensure correct remedial actions are put in the right place [1, 6].

The most common drilling activities prior to sticking are presented in Figure 3.

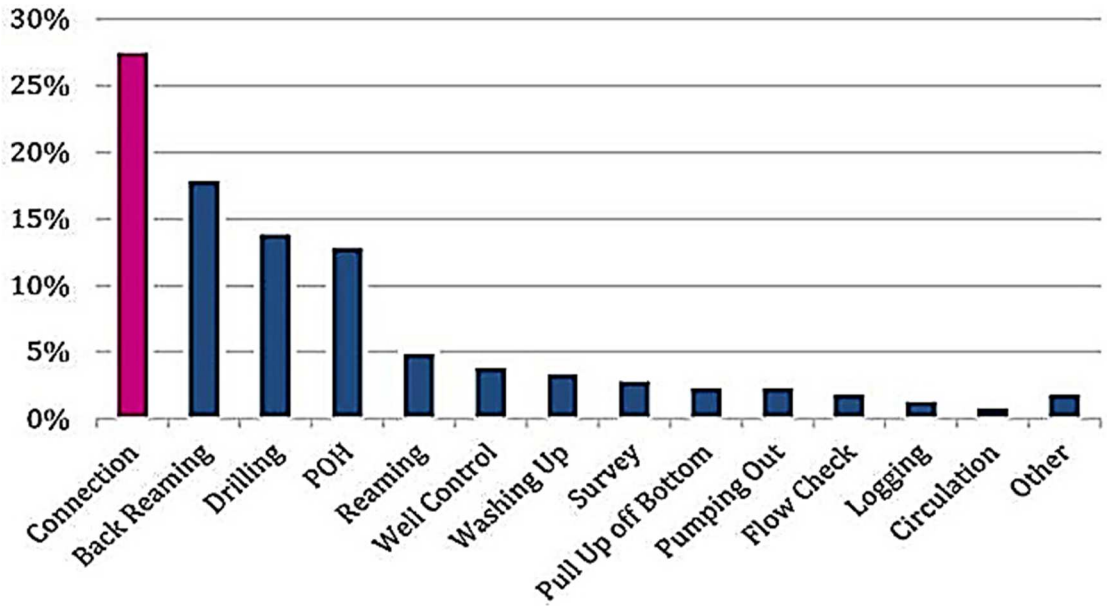

Figure 3 – Most common drilling activities prior to stuck pipe incidents [2, 3]

Stuck pipe incidents are usually classified according to their sticking mechanism, i.e. the force or means that prevent pulling the drillstring out of hole. Drill strings can be stuck either mechanically or differentially. Table 1 presents a summary of the different stuck pipe types and causes [3].

Table1 – Mechanisms and causes of stuck pipe

Mechanisms		Causes	
Mechanical Sticking	Pack-off and Bridging	Poor Hole Cleaning	
		Wellbore instability	Chemically stressed shale Mechanically stressed shale Unconsolidated sands Junk in hole Fractures and faults
	Wellbore Geometry	Dog Leg	Key seats Stiff assembly Micro-dogleg
		Ledges Squeezing formation Under-gauge hole	
Differential Sticking		Differential Pressure	

Mechanical Sticking Mechanisms

Mechanical sticking usually occurs when the drill string is moving and is caused by a physical obstruction or restriction. Mechanical sticking can be classified into two major subgroups: (I) Hole pack-off and

bridges; stuck pipes which are related to wellbore instability or settled cuttings are in this category and (II) Wellbore geometry interferences; this refers to stuck pipes which are related to the condition of wellbore geometry such as key seats or an undergauge hole. Major causes of mechanical stuck pipe are wellbore instability and improper hole cleaning. Most wellbore instability problems are related to shale layers due to swelling and hole enlargements resulting from compressive failure owing to excessively low wellbore pressure. Adequate hole cleaning, on the other hand, is an essential part of the drilling operation. If the cuttings are not removed from the well properly, they settle around the drill string causing the drill collars to become stuck. This problem is encountered often in over gauge sections where annular velocities are low [3, 6].

In general mechanical sticking occurs as a result of one or more of the following conditions: Inadequate hole cleaning (Inadequate removal of drilled cuttings from the annulus), formation (wellbore) instabilities, key seating, running into under-gauge hole, accumulation of cuttings, drilling plastic formations {plastic shale or salt sections squeezing (creeping)}, large boulders falling into the wellbore, running tools with too large a gauge for the hole diameter [1, 2, 3].

Pack-off and Bridging

Hole pack-off and bridging occur when the wellbore around the drillstring is plugged with debris or when a portion of the wellbore wall collapses around the drillstring, preventing the pipe from movement, and restricting or preventing circulation. This mainly occurs as a result of poor hole cleaning (when the cuttings, cement blocks, or junk are not properly transported out of hole, they settle and build on the wellbore causing compaction around the drillstring). Bridging occurs when larger sizes of the same solids wedge themselves across the drillstring and open hole clearance resulting in restricted circulation with little or no string movement. Pack-off is a result of small solids (cuttings, debris, cement particles, junk, etc) settling down and sticking the pipe by plugging the annular clearance between the drillstring and the wellbore and preventing circulation with little or no drillstring movement [1, 2, 3].

Pack-off usually occurs when the mud pumps are off for an extended period of time, such as when pulling out of hole (POOH). It is usually very difficult to free the pipe in cases of pack off or bridging and the chance of success is lower than in differential or wellbore geometry sticking mechanisms.

The other potential cause of pack-off is formation geomechanical rock mobility and instability (wellbore instability), which refers to formation failure causing caving or collapse of the wellbore. Wellbore instability imposes the most severe cases of stuck pipe, where the drilling engineer would opt for fishing or sidetracking. It can be due to chemically or mechanically stressed shale, reactive shales, unconsolidated formations/sands, overburden stress, or fractured and faulted formations. Wellbore stability is also affected by certain factors, including: rock strength, stress anisotropy, mud density, mud filtrate, well path, and wellbore geometry [1, 2, 3].

Sticking mechanism due to pack-off and bridging mostly occur while tripping or making a connection and is characterized by impossible or restricted circulation with relatively high standpipe pressure and restricted rotation and axial movement [2, 3].

Hole pack-off and bridging are operationally identified by different indicators such as: excessive torque and drag (T&D), abrupt increase in circulating pressure, decrease in set-down weight while running in hole (RIH) and reduced cuttings size or excessive and irregular cuttings over the shakers [2].

There are eight categories of stuck pipe caused by Pack-off and Bridging as follows: (1) Cutting settling in vertical and deviated wells; (2) Shale instability; (3) Unconsolidated formations; (4) Fractured formations; (5) Cement block; (6) Soft cement; (7) Junk in hole; (8) Collapse casing

Hole pack off is strongly linked to poor hole cleaning. Therefore mitigating this stuck pipe problem is best achieved through efficient hole cleaning. This is done which is done by observing the following on field procedures: (I) Good mud rheology especially plastic viscosity, yield point and gel strength; (II) Sufficient mud flow rate and hydraulics to maintain the required annular velocity to carry cuttings to the surface; (III) Ensuring reciprocating and rotating the drill pipe while circulating hole clean; (IV) Eccentricity of the pipe making sure that the pipe is placed in the center of the wellbore to ensure having similar annular velocities around the drill string; (V) Control rate of penetration (ROP) to ensure that the drilling process is not creating more cutting and solids than the mud system can carry and dispose; (VI) Plan regular wiper trips as they to clean the hole, wipe swelling clays, and ream problematic sections.

Wellbore Geometry Interferences

Stuck pipe incidents can occur due to abrupt or severe changes in the wellbore direction and configuration, key seats, ledges, micro doglegs, under gauge hole or stiff BHA. Key seats are the major of these problems and basically form in the presence of sufficient dogleg, pipe rotation, side load and time, where the pipe basically cuts a slot across the formation (Figure 4). It normally occurs in shallower open hole depths due to the higher string tension which provides a greater side load and more rotating time to cut across a dogleg. The BHA then gets stuck at that key seat when tripping out of the hole. The presence of ledges due to interbedded hard-soft formations favours the formation of key seats (Figure 5) [2, 3].

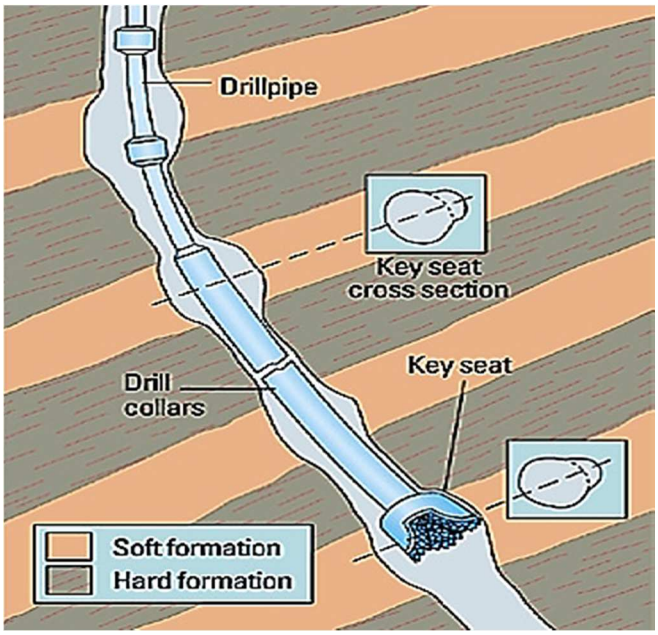

Figure 4 – Stuck Pipe due to Key seat in the Wellbore

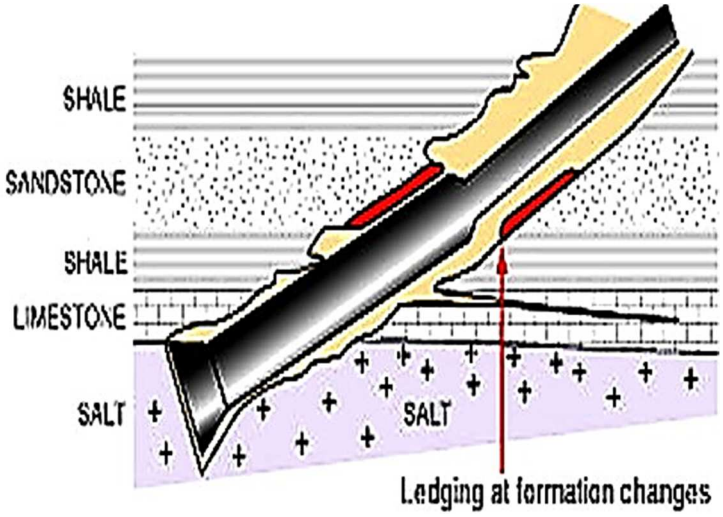

Figure 5 – Ledges at interbedded hard-soft formations favours the formation of Key seats

There are several operational signs that can indicate the presence of an undesired wellbore geometry downhole. For example, a key seat causes constant T&D spikes at the tool joints while tripping out of the hole and vice versa. Sudden drag is also another indicator when the BHA reaches high-dogleg (potential key seat) depth. The presence of such signs at interbedded, hard-soft layers can indicate that a key seat was actually formed since these inter beds favor ledge formation [2].

There are eleven cases in this category: (1) Stiff bottom hole assembly; (2) Key seat; (3) Micro dog-legs; (4) Ledges; (5) Mobile formations; (6) Undergauge hole; (7) Hydro-Pressured Shale; (8) Geo-Pressured Shale; (9) Overburden Stress; (10) Tectonic Stress; (11) Unconsolidated Formation.

Wellbore geometry stuck pipe can be averted by observing the following procedures: (I) Sharp dog-legs should be avoided. If they are suspected while drilling, reaming trip should be considered to eliminate the key seat; (II) Drilling through salt formations should be done with high mud weight, as much as it is allowed by the pressure gradients; (III) The BHA needs to be positioned carefully and stabilizers should be used while tripping across under-gauge sections.

Differential Pressure Sticking

Differential sticking can result when pressure from an overbalanced mud column acts on the surface area of the drill string against a filter cake deposited across a permeable formation. The surface area of the pipe that is embedded into the mud cake has a pressure equal to the pore pressure acting from one direction

while the hydrostatic pressure acts in the other direction. When the hydrostatic pressure in the wellbore is higher than the formation pressure, the pressure differential forces the pipe towards the borehole wall (Figure 6). This usually occurs along the drill collars because they normally have larger diameters, which increase the cross sectional area that is in contact with the wellbore, hence, they have less annular clearance and they are the first portion of the drill string to encounter the permeable section [7].

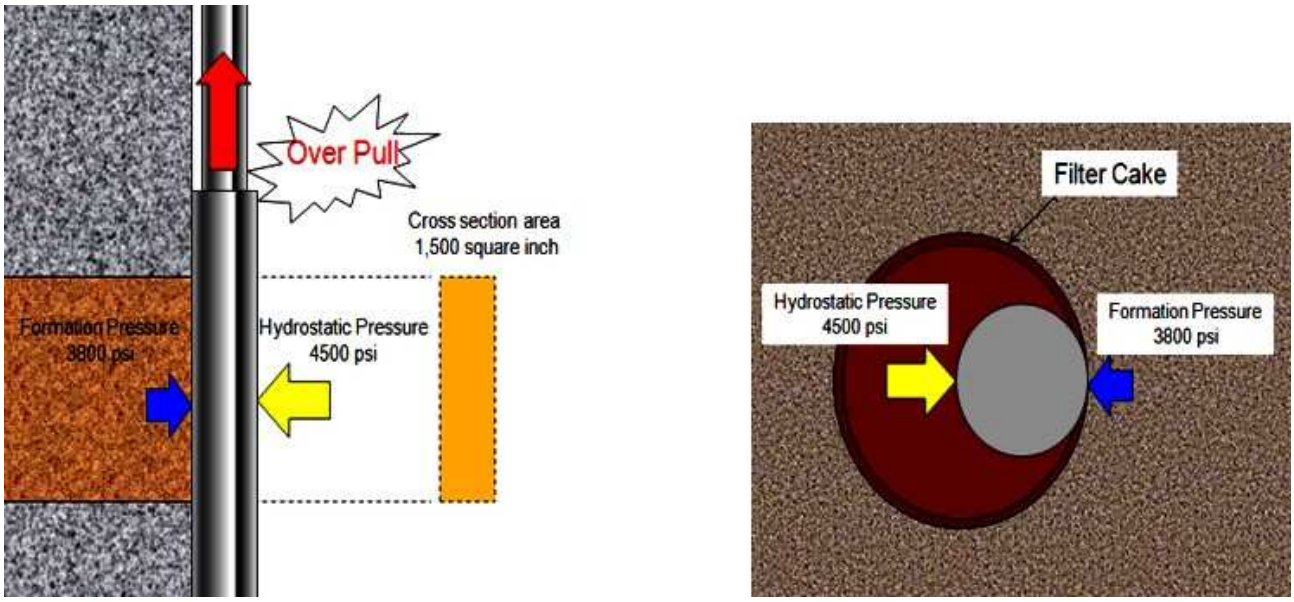

Figure 6 – Stuck Pipe due to Differential Pressure between the Hydrostatic Head and Formation

Differential sticking can usually be avoided by taking certain measures, such as: (I) Minimizing and maintaining the overbalance circulating mud pressure (including ECD). Extra caution should be taken not to go underbalance and risk a kick; (II) The use of spiral drill collars to minimize the contact area between the BHA and the wellbore; (III) Always minimize the time of static pipe during connections and surveys; (IV) Maintaining a low value of fluid loss and avoiding having thick filter cake through permeable zones. Thick filter cake will cause a reduction in the clearance between the wellbore and the BHA and will lead to differential sticking; (V) Keep circulating to remove high solids from the mud to minimize the thickness of the filter cake. To avoid differential sticking, the filter cake is recommended to be thin, hard and impermeable.

Список литературы:

1. Майкоби А.А. Наилучшие методы по снижению прихватов бурильных труб (Best practices to reduce drill string sticking) / А.А. Майкоби, Р.А. Исмаков // Мат. науч.-практ. конф. «Технологические решения строительства скважин на месторождениях со сложными геолого-технологическими условиями их разработки», посвященной памяти Виктора Ефимовича Копылова. Тюменский индустриальный университет. – Тюмень, 2022.

2. Detection of Stuck Pipe Early Signs and the Way Toward Automation / A.A. Alshaikh [et al.] // SPE Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE. November 12–15, 2018. SPE 192975. – URL : https://doi.org/10.2118/192975-MS

3. Mitchell J. Trouble – Free Drilling: Stuck Pipe Prevention. Third Edition. Drillbert Engineering Incorporated. The Woodlands. – Texas, USA, 2014.

4. Atriby K. Integrated Approach to prevent and Mitigate Stuck Pipe in Interbedded Depleted and High Pressure Gas Reservoirs. SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition, Dammam, April 23–26, 2018. SPE 192329. – URL : https://doi.org/10.2118/192329-MS.

5. Jahanbakhshi R. Prediction of Wellbore Stability in Oil and Gas Wells: An Artificial Neural Network Approach / R. Jahanbakhshi, R. Keshavarzi // Presented at the 46th U.S. Rock Mechanics/ Geomechanics Symposium. Chicago, Illinois, USA, 24–27 June, 2012. ARMA-2012-243.

6. Muqeem M.A. Stuck Pipe Best Practices – A Challenging Approach to Reducing Stuck Pipe Costs / M.A. Muqeem, A.E. Weekse, A.A. Al-Hajji // SPE Saudi Arabia Section Technical Symposium and Exhibition. Al-Khobar, Saudi Arabia. April 8–9, 2012. SPE 160845. – URL : https://doi.org/10.2118/160845-MS

7. Методы экспериментальных исследований дифференциальных прихватов / А.А. Майкоби [и др.] // Бурение и нефть. – 2024. – № 6. – С. 32–38.

List of references:

1. Maicobi A.A. Best practices to reduce drill string sticking / A.A. Maicobi, R.A. Ismakov // Proceedings of the scientific and practical conference «Technological solutions for well construction at fields with complex geological and technological conditions of their development», dedicated to the memory of Viktor Efimovich Kopylov. Tyumen Industrial University. – Tyumen, 2022.

2. Detection of Stuck Pipe Early Signs and the Way Toward Automation / A.A. Alshaikh [et al.] // SPE Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE. November 12–15, 2018. SPE 192975. – URL : https://doi.org/10.2118/192975-MS

3. Mitchell J. Trouble – Free Drilling: Stuck Pipe Prevention. Third Edition. Drillbert Engineering Incorporated. The Woodlands. – Texas, USA, 2014.

4. Atriby K. Integrated Approach to prevent and Mitigate Stuck Pipe in Interbedded Depleted and High Pressure Gas Reservoirs. SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition, Dammam, April 23–26, 2018. SPE 192329. – URL : https://doi.org/10.2118/192329-MS.

5. Jahanbakhshi R. Prediction of Wellbore Stability in Oil and Gas Wells: An Artificial Neural Network Approach / R. Jahanbakhshi, R. Keshavarzi // Presented at the 46th U.S. Rock Mechanics/ Geomechanics Symposium. Chicago, Illinois, USA, 24–27 June, 2012. ARMA-2012-243.

6. Muqeem M.A. Stuck Pipe Best Practices – A Challenging Approach to Reducing Stuck Pipe Costs / M.A. Muqeem, A.E. Weekse, A.A. Al-Hajji // SPE Saudi Arabia Section Technical Symposium and Exhibition. Al-Khobar, Saudi Arabia. April 8–9, 2012. SPE 160845. – URL : https://doi.org/10.2118/160845-MS

7. Methods of experimental studies of differential sticking / A.A. Maicobi [et al.] // Drilling and Oil. – 2024. – № 6. – P. 32–38.