Narrative Review Article: Examining Drilling Problems and Practical Solutions Regarding them

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A B S T R A C T

The present study has investigated drilling problems and practical solutions regarding them. It is almost certain that problems will occur when drilling a well, even in the most carefully planned wells. For example, in areas where similar drilling methods are used, pitting problems may be reported where there were no such problems before. Because the formations are heterogeneous. Therefore, two wells near each other may have completely different geological conditions. In well planning, the key to achieving successful objectives is to design drilling programs based on anticipation of possible wellbore problems rather than caution and containment. Drilling problems can be very costly. The most common drilling problems include pipe sticking, loss of circulation, hole deviation, pipe failure, formation damage, hole cleaning, H2S and shallow gas formation, and equipment and personnel problems. Understanding and predicting drilling problems, understanding their causes and planning solutions are essential for overall cost control and successful reaching of the target area. Efroni base fluids have entered the drilling industry since the beginning of 2000, due to their unique properties, they can solve many drilling problems, especially in drained and deviated reservoirs, such as spillage, well wall instability, pressure jam and many other problems. to fix Due to the hundred years of drilling in Iran, most of the old reservoirs have either been emptied or are being emptied. Another characteristic of Iran's fields is the presence of fractured reservoirs with high permeability, which makes drilling in them very difficult and causes loss of capital and irreparable damage to hydrocarbon reservoirs. Unfortunately, despite the many advantages of these fluids, there is still no operational experience of them in the fields of Iran.

Introduction

Drilling a well is a factor to access the oil reservoir and produce oil. Due to the fact that the well usually has different slopes and azimuths and passes through layers with different properties [1], therefore the drilling process is risky. Loss of a well due to instability also leads to huge costs and stoppage in production operations [2]. Therefore, analyzing and predicting well stability is of particular importance. Among the effective parameters in the instability of the well, we can mention the well drilling path, the direction and

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magnitude of the stresses in the ground, rock mechanical properties, pore pressure and mud pressure. Well instability is an important issue in the oil industry and it generally causes significant costs every year due to mechanical, chemical and thermal factors [3]. This issue is the main reason for the rupture of wells and indicates a serious problem in the drilling industry. With the increase of drilling depth, well stability in deep formations with natural fracture has been more attention. The purpose of this research is to investigate the effect of each parameter on oil well stability and identify the most important ones and arrange them based on their importance in oil well stability. Closing oil wells is a new problem. Apparently, all producers, including US shale producers, have no choice but to shut down their oil wells in response to the Great Recession of 2020. The question is how these wells will be restarted after the price recovery. Shutting down oil wells is different from flipping a switch. This should be done with great care given the nature of the well being drilled, its production rate and the characteristics of the oil it produces, but even with careful planning, there is a risk of permanent damage if the well is closed for more than two weeks. Unexpected or unknown rock behavior often causes drilling problems, which will lead to waste of money and time, and sometimes the loss of a part or the whole well. Due to the importance of this issue, well stability analysis is performed at different stages of well design or field development. During drilling, there may be two main problems in the stability of the well wall, namely collapse and induced tensile failure, which can lead to problems during drilling, which can often be solved by determining a safe mud window for drilling the well. resolved it. To predict the safe and stable interval of drilling mud in future wells and to better understand the effective parameters in the instability of the well wall, it is necessary to build an earth mechanical model (MEM). The mechanical earth model contains a logical set of information related to geology, regional stresses, rock mechanical properties and pore pressure, which is used as a tool to quickly update information for use in drilling operations and reservoir management. A failure criterion is needed to detect the occurrence of failure in rock. Various failure criteria are used in well stability analysis, each of which predicts different values for rock strength and minimum mud weight required for well stability. Therefore, choosing the appropriate failure criterion is very important.

A number of drilling problems along with their practical solutions include

1- Pipe sticking: During the drilling operation, if a pipe cannot be released without damaging the pipe and without encroaching on the drilling rig and pull it out of the hole, it is considered stuck. The maximum allowable hook load is discussed in this section on differential pressure pipe adhesion and mechanical pipe adhesion.

Bonding of pipe with differential pressure

Differential pressure pipe sticking occurs when part of the drill string becomes embedded in a mud cake that forms during drilling on the wall of a permeable formation. If the mud pressure pm acting on the outer wall of the pipe is greater than the formation fluid pressure, pff, which is usually the case, then the pipe is said to be differentially stuck (Figure 1).

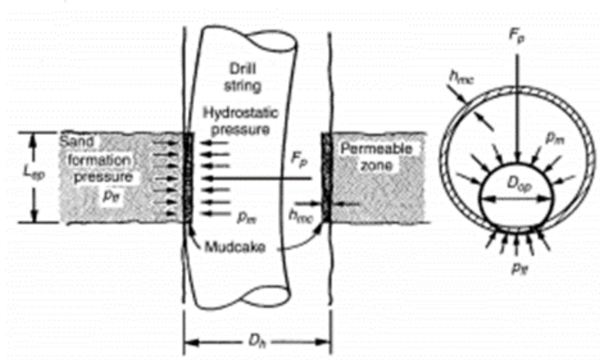

Figure 1. Differential pressure sticking

The differential pressure on the part of the drill pipe embedded in the mud cake can be expressed as:

$$\Delta p = p_m - p_{ff}$$

The pulling force, F_p, required to free the jammed pipe is a function of the differential pressure. Δ_p coefficient of friction, f; Contact area, A_c between tube surface and mudcake.

$$F_p = f \Delta p A_c$$

$$A_c = 2L_{ep}\{(D_h/2 - h_{mc})^2 - [D_h/2 - h_{mc}(D_h - h_{$$

Wherever

$$D_{op} \leq (D_h - h_{mc})$$

The dimensionless coefficient of friction, f, can range from less than 0.04 for an oil-based mud to 0.35 for a weighted water-based mud without added lubricant [2]. Although hole and pipe diameter and hole angle play an important role in pipe sticking force, they are uncontrollable variables when selected to meet well design objectives. However, the shape of drill collars such as square or the use of drill collars with spiral grooves and external tool connections can minimize the clamping force. Some indicators of pipe sticking in differential pressure while drilling permeable zones or known weak pressure zones are increased torque and drag. Inability to go back and forth with the drilling string and in some cases, rotate it and continuously circulate the drilling fluid. Differential pressure pipe sticking can be prevented, or its occurrence reduced, if some or all of the following precautions are taken:

- ✓ Maintain minimum continuous fluid losses while meeting economic objectives of the project [3].
- ✓ Maintain the lowest level of dredged solids in the mud system, or remove all dredged solids if cost effective.
- ✓ Use the lowest differential pressure considering the swab and wave pressures during the cut-off operation.
- ✓ Choose a mud system that produces a smooth mud cake.
- ✓ Always maintain drill string rotation if possible [4].

Pipe adhesion problems may not be completely avoided by differential pressure. If sticking occurs, common field methods for freeing the stuck pipe include reducing the hydrostatic mud pressure in the throat, smearing oil around the stuck section of the drill, and flushing the stuck pipe. Some of the methods used to reduce the hydrostatic pressure in the pharynx include reducing the weight of the mud by dilution, reducing the weight of the mud by gassing with nitrogen, and placing a packer in the hole above the sticking point [5].

Mechanical pipe bonding

The causes of mechanical adhesion of the tube are insufficient removal of perforated cuttings from the pharynx. Borehole instability such as caving, hole collapse or collapse, plastic shale or compacted salt section and key seat. Excessive accumulation of drilled cuttings in the annular space due to improper cleaning of the hole can cause mechanical sticking of the pipe, especially in directional well drilling. A large number of suspended cuttings settling to the bottom when the pump shuts off or a bed of fixed cuttings sliding down the bottom of a directional well can pack the bottom hole assembly (BHA) causing sticking of the tubing. In directional well drilling, a fixed cutting bed may be formed at the bottom of the borehole. If this condition is present during exit, it is likely that the tube will stick. That's why it's a common practice to make several rounds from the bottom up with the drill from the bottom to wash out any cuttings that may be present before the trip [6].

An increase in the torque and tension and sometimes in the pressure of the circulating drill pipe is a sign of a large accumulation of cuttings in the throat and possible problems of sticking the pipe. However, it is important to briefly mention pipe sticking issues related to borehole instability problems. The most difficult issue is shale drilling. Depending on the mud composition and mud weight, the shale can penetrate, or plastically flow inward, causing mechanical adhesion of the pipe. In all formation types, using mud that is too light can result in hole collapse, which can cause mechanical sticking of the pipe. Also, when drilling salt that exhibits plastic behavior under overburden pressure, if the mud weight is not high enough, the salt tends to flow inward, causing mechanical sticking of the pipe. Signs of a potential pipe sticking problem are caused by wellbore instability, increased circulating drill pipe pressure, increased torque, and in some cases, no return of fluid to the surface [7].

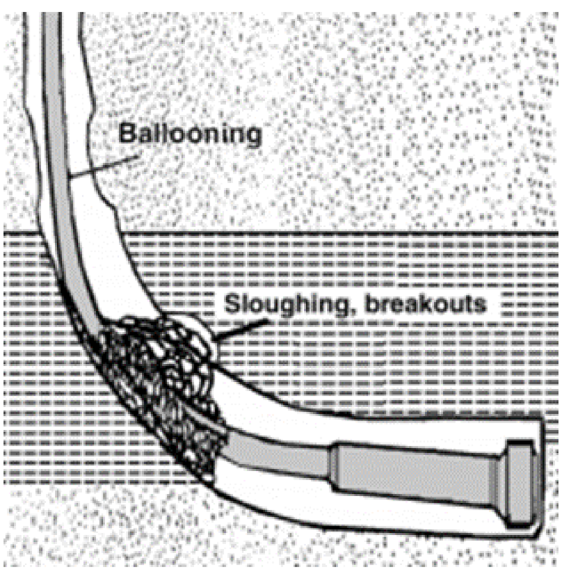

Figure 2. Pipe adhesion caused by well instability.

The key place is one of the main reasons for the mechanical adhesion of the pipe. The key seat mechanism consists of wearing a small hole (slot) next to a full gauge hole. This groove is created by the rotation of the drilling string with a lateral force applied to it [8].

Depending on what caused the pipe to stick, mechanically stuck pipes can be handled in a number of ways. For example, if the suspected cause is cuttings accumulation or perforation, rotating the drill string and increasing the flow rate without exceeding the maximum allowable equivalent circulating density (ECD) is a possible solution to freeing the pipe. If the narrowing of the hole is due to plastic shale, the increased mud weight may free the pipe.

Drilling pipe failure

Drilling pipe failures can be placed in one of the following categories:

- ✓ Torsion due to excessive torque.
- ✓ Separation due to excessive tension.
- ✓ Burst or collapse due to excessive internal pressure or external pressure respectively.
- ✓ Fatigue as a result of mechanical cyclic loads with or without corrosion [9].

Twist off

Pipe failure as a result of twisting occurs when the shear stress caused by high torque exceeds the ultimate shear stress of the pipe material. In vertical well drilling, excessive torques are generally not observed in conventional drilling methods. However, in directional and wide-reach drilling, torques in excess of 80,000 lb/ft are common and can easily cause twisting in improperly selected drill string components.

Parting

Pipe separation failure occurs when the induced tensile stress exceeds the ultimate tensile stress of the pipe material. This condition may occur when pipe sticking occurs and an additional tension is applied in addition to the effective weight of the pipe suspended in the hole above the attachment point [10].

Falling and bursting

Pipe failure as a result of spillage or bursting is rare. However, in extreme conditions of high mud weight and complete loss of blood circulation, tube bursting may occur [11].

Tiredness

Fatigue is a dynamic phenomenon that can be defined as the initiation of microcracks and their propagation in macrocracks as a result of repeated stresses. It is a process of local progressive structural fractures in materials under the effect of dynamic stresses. It is well established that a structural member that may not fail under a single application of static load. If applied repeatedly, it may easily fail under the same load. Failure under cyclic loads is called fatigue failure. Drill string fatigue failure is the most common and costly type of failure in oil, gas and geothermal drilling operations. The combined effect of cyclic stresses and corrosion can reduce the life of a drill pipe by a thousand times. Cyclic stresses are caused by dynamic loads caused by vibrations of the drill string and the reversal of the bending load in the curved parts of the hole and buckles caused by rotation. Despite the vast amount of work devoted to pipe fatigue failure, it is still poorly understood. This lack of understanding is attributed to the wide variety of statistical data in determining the type of service and environment of the drilling field, the number of operating loads and frequency of occurrence, the accuracy of methods in determining stresses, quality control during construction, and the use of material fatigue data [12].

Prevention of pipe failure

Although pipe failure cannot be completely eliminated, there are certain measures that can be taken to minimize it. Fatigue failures can be reduced by minimizing induced cyclic stresses and ensuring a non-corrosive environment during drilling operations. Cyclic stresses can be minimized by controlling the intensity of the buckle and drill string vibrations. Corrosion can be reduced with corrosive blankets and mud pH control in the presence of H_2S. Proper drill string relocation and inspection are typically the best measures to prevent failure [11].

The severe deviation of the well and the creation of keyholes or bending of the well is one of the factors that cause the pipes to get stuck. It cannot be claimed that no deviation occurs during the drilling of a straight well. Various factors such as a sudden change in the weight on the drill bit, a sudden change in the type of formation or the slope of the formation may cause the well to deviate from its direct path. If the amount of deviation is within the permissible limit, no acute problem will occur, but if the amount of deviation exceeds the permissible limit, it will cause a dogleg in the well. The risk of deviation and creating a dogleg in the upper parts of the well is more than in its deeper parts. As the drilling continues and the well gets deeper, the drilling pipes tend to become busy. This problem causes contact of the drilling pipes with the upper part of the well at the Dogleg points. If over time and the rotation of the drilling string, a key is created in these points [13].

Problems of drilling oil wells in shale formations

During or after the drilling of underground excavations such as oil wells, instabilities are observed in the walls of the wells, so that 90% of well instability problems related to drilling occur in shale formations. On the other hand, shale formations are found in 75% of drilled sections in Iran, which cause a number of problems such as complete or partial collapse of the well or even loss of the well before reaching its goal. Due to their low permeability, shale formations in most cases play a role as cover rock in petroleum systems and in some cases have also been observed as reservoir rock. What raises the sensitivity and weakness of shale formations in creating these problems is the issue of shale hydration and swelling, especially in contact with water environments [8].

With the start of shale swelling, the total or partial collapse of the well can happen in a moment or in a period of time and lead to stuck pipes, poor cleaning of the well, closure of the well and lack of efficiency in drilling. Due to the abundance of clay minerals in shales, these rocks often have little resistance. According to the studies conducted by researchers, the governing mechanisms in instability depend on many factors, including the type of shale and its characteristics, well profile, in situ stress, temperature gradient and the characteristics of the drilling mud system. By having this information and optimizing the drilling mud pressure in shale formations, instability can be prevented [14].

Investigating piping and cementing problems during oil or gas well drilling operations

Portland cement is the most important material used in cementing oil and gas wells. This cement in oil wells is different from the type of construction in terms of temperature and high-pressure conditions. Portland cement has a high compressive strength, which is caused by the hydration of cement compounds, and its important characteristics are gradual, uniform and predictable hardening, low permeability and lack of solubility in water [5].

Such properties are necessary for the isolation and stability of the well wall. Portland cement consists of four main compounds: tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3a) and tetra calcium aluminoframate (C_4af). These compounds are formed as a result of the reaction between lime, silica and iron oxide at a temperature of about 1500 degrees Celsius. The cements used in oil and gas wells are similar to construction cement, but by adding various chemicals and performing special operations, they can withstand the harsh conditions inside oil wells [7].

According to API regulations, different properties of cement inside the well can be controlled and adjusted by adding different types of additives. Wall pipe cementing program is usually done during drilling operation. According to the conditions of the well and the properties of the used drilling mud, the required cement is selected and tested in the mud and cement laboratory, and then the cement program is communicated to the drilling operation [9].

The first effective parameter in the hydrostatic pressure of the well in drilling and cementing operations is the volumetric weight of the fluid that the formations around the well will be in contact with and under their pressure. The second factor is fluid flowability during injection. The fluid weight factor can be controlled in the design and execution phases, but the issue of fluid flowability control is more difficult than weight control. There are three main methods used to lighten the cement slurry, the first two methods are common and preferred by most drilling companies.

- ✓ Using water-loving additives or extenders.
- ✓ Using lightweight solid additives in slurry to reduce weight.
- ✓ Using liquid hydrocarbons such as diesel or kerosene with a specific gravity of less than 0.1 and creating an emulsion in water [5].

The main reasons for using light grouts can be summarized as follows

- ✓ Reducing the hydrostatic pressure of the cement column to prevent the breaking of the formation layers and erosion and subsequently the possible eruption of the well.

- ✓ Reducing the weight of the cement stone column behind the wall pipe due to the suspension of wall strings.
- ✓ Preventing channeling and migration of gas in the case where the length of the parietal string is long.
- ✓ Preventing high pressure from pumps and preventing pipes from breaking or bending [6].

The purposes of using grout lightening materials can be summarized as follows

- ✓ Reducing the weight of grout and finally reducing the weight of cement.
- ✓ Increasing the initial strength of cement.
- ✓ Preventing grout spillage.
- ✓ Strengthening the durability of cement stone over time by reducing permeability and heat resistance.
- ✓ Reducing the effect of water separation from the slurry.
- ✓ Increasing the volume of slurry with the lowest costs.
- ✓ Increasing or decreasing the half-time of the slurry as a side effect of the additives.

Pipe laying and cementing can be considered as one of the most important services during oil or gas well drilling operations. The life of the well, the amount of production and the duration of its exploitation depend to a large extent on the degree of success of these services. In the piping operation, the well is covered by a special steel pipe string, and subsequently, in the cementing operation, the annular space between the pipe and the well wall is filled with a cement slurry with certain compositions [3].

The cement slurry that fills the corridor behind the pipes in this way hardens over time and the resulting cement stone covers the casing pipes like a strong sheath and connects them with the formation. This cement sheath performs several functions that can be summed up in two words: protection and prevention. Cement gives stability to the well wall and protects the casing pipes against external pressure caused by the layers of the earth, as well as against electrolysis and corrosion caused by corrosive underground water and sour hydrocarbons or direct contact of the pipes with the strata. It prevents the migration of fluids from one formation to another and the unwanted contamination of valuable hydrocarbons [7].

A cemented well without leakage is capable of effectively directing the fluid from the reservoir to the surface, so the cementing operation determines the life of the well and shows how long the well in question can remain productive. In addition to the issue of safety and cost reduction in dry drilling, the environmental issue related to chemicals is important due to the protection of the water table during and after drilling. If the pressure of the annular space becomes less than the pressure of the formation, the fluid inside the formation enters the well and causes the eruption of the well. If the hydrostatic pressure of the annular space exceeds the pressure of the formation, any leakage of fluid into the formation will cause formation failure and damage to the well. In addition, a significant amount of drilling fluid or cement is wasted due to formation failure [11].

The first and most important parameter affecting the hydrostatic pressure of the well in drilling and cementing operations is the volume weight of the cement slurry, which the formations around the well will be in contact with and under its pressure. Typically, the specific gravity of lightweight cement grouts is between 90 and 111 pounds per cubic foot (pcf). According to the API standard for different classes of cement, the lightest pure slurry can be prepared with class C and with a water-to-cement ratio of 56 to 111 pcf weight, but the problem is that many formations cannot withstand hydrostatic pressure [13].

They do not have such grouts. In order to avoid breaking the layers of the formation and wasting the grout in their weak and fragile sections, it is necessary to use lighter grouts. The specific weight of ultra-light grouts is less than 90 pcf, and they are designed and implemented in oil, gas and geonormal wells, considering the resistance of the ground layers against the pressures from the upper and adjacent layers, in order to prevent the crushing of cement stone. Currently, light cement (between pcf 90 and pcf 111) is made by adding weight-reducing materials to cement slurry, such as bentonite, glauconite, and other oil well cement extenders such as pozzolans, diatomic soil, and perlites, but practical measures for Preparation of super light cement has not been done [6].

In this plan, it is desirable to present the methods of preparing and manufacturing cement slurry with a specific weight of 80 pcf, which have the quality and standards mentioned in this report, so this large company is considering drilling oil and gas wells, in the field Stylization of cement in the walls and lining of oil and gas wells to interact and cooperate with the owners of this technology [1].

Solutions and proposals must meet the following requirements

- ✓ Preparation and production of cement mortars with a specific weight of about 80 pcf.
- ✓ It has a high temperature stability of 200 degrees Fahrenheit.
- ✓ It should be resistant to salt water with a concentration of 250 grams per liter of sodium chloride.
- ✓ To be resistant to high concentration of calcium (about 1% by weight) in water.
- ✓ have a suitable flowability for injection in the well.
- ✓ Do not make a change in the timing of the cement slurry [2].
- ✓ Its corrosion properties should be controllable and not cause severe corrosion of wall pipes and downhole tools.
- ✓ Be compatible with all types of drilling fluids (water base and oil base).
- ✓ It is possible to prepare the desired mixture in operational conditions.
- ✓ Do not change the compressibility limit of cement [4].

Suggested solutions

- ✓ Using lightweight polymer and composite materials that can maintain strength and improve the rheology of cement slurry.
- ✓ Using nano technology in the production process to achieve better quality.
- ✓ Using sponge materials to reduce the weight of cement mortar [7].
- ✓ Using polymer materials to reduce the weight of cement mortar.
- ✓ Using new materials and methods to reduce the weight of cement slurry.
- ✓ Using any other new method that can meet the necessary requirements in protecting the casing pipes and preventing the migration of fluids from one formation to another [9].

Unacceptable solutions

- ✓ Materials that increase the viscosity of cement mortar.
- ✓ Materials that change the flowability of cement mortar.
- ✓ Materials and methods that cost more than the conventional cost in this field.
- ✓ Materials that cannot be pumped or injected into the well, or require extensive and expensive equipment [13].
- ✓ Materials and methods that cause destruction of oil or gas formation.

- ✓ It is not recommended to use materials that do not have high flexibility. Because such materials change the rheology, strength of cement and other properties of cement slurry despite reducing the weight of the slurry [2].

Some of the problems that may arise when oil wells are closed

1- Pressure behavior: There is a type of well shut-off whose purpose is to increase oil or gas production by creating pressure in the rock bed containing hydrocarbons. This type of blackout cannot last more than a few months and is a short-term affair and is suitable for wells that are drilled in rocks with the right pressure, that is, the pressures that have the potential to cause it. This is not applicable to low pressure wells. According to the experts of oil technology magazine in low pressure wells, the closure of this system can negatively affect the permeability of oil rock [9].

2- Cross flow: Cross flow refers to the flow of oil and gas from high pressure areas, from rock areas to low pressure areas. In this case, on the one hand, there is a problem that it is more difficult to recover oil and gas from the low-pressure zone, and on the other hand, the cross flow is problematic. Because it leads to undesirable mixing of hydrocarbons from different regions in the region and it is not possible to separate different hydrocarbons [1].

3- Low and high: Ups and downs are common in horizontal wells. One of the biggest advantages of horizontal wells is the proper connection between the well and the reservoir. The purpose of ups and downs of the wells is to increase the connection between the well and the tank and improve the yield [1].
However, things go awry when the well is closed. Accumulation of water in the well is a problem that experts warn and eventually makes the well unusable. If too much water accumulates in the well, it may not be economical to pump all of it to reach the oil. Some experts point out that water is not the only substance that accumulates in a horizontal well if an oil well is shut in for a long time. Heavier hydrocarbon materials such as paraffin and bitumen can accumulate in the well and negatively affect the future performance of the well [6].

Conclusion

In drilling a well, it is possible to face many problems such as high pressure and low-pressure formations, loose formations, cracked formations, unstable formations, and after drilling any of these problematic formations, we are forced to install a string of wall pipes or finally Let's drive a line of lining pipe. The result of this work requires the acceptance of high costs of wall pipe and lining. Also, we have made a telescope from our well, the final diameter of which is very small, and we cannot make proper use of the well.
The temporary lining pipe is: an expandable piece of pipe that is driven into the well after drilling the problematic part of the well, and then it is easily expanded by a rotating tool and sticks to the wall of the well, and then it is cemented and after that Drilling continues with the same size as the previous drill bit. That is, without reducing the diameter of the well, we have isolated the problem area of the well and continued drilling, and finally we install the wall pipe or lining of our production with a more suitable diameter.
While if we wanted to act in the usual way, after finishing the drilling of the problematic area, we should drive a line of wall pipe or lining and continue drilling with a smaller drill bit. Instability at any stage of a well's life can cause delays in drilling, completion and exploitation, especially in horizontal drilling where access and control are relatively less. Instability creates many costs. The costs that can be reduced by

using comprehensive geomechanically models and investigating the effective parameters in the instability of the well and maximize the stability of the well and the certainty of the stability analysis results. The path of well drilling, the direction and magnitude of stresses on the ground, rock mechanical properties, Young's modulus, Poisson's ratio, adhesion and friction angle are among the parameters that uncertainty analysis and sensitivity analysis are due to the non-constant and non-homogeneous nature of the environment. A stone can lead to a correct understanding of the stability situation. The effect of faulting regimes on the stability of oil and gas wells is of particular importance, and in addition to vertical wells that have different geomechanically behaviors in different faulting regimes, horizontal wells are in a more critical situation than Change in different fault regimes.

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