

Technique and technology of drilling inclined wells with large deviation

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Abstract. The relevance this article looks at how to make deep well drilling more stable and efficient. The main aim the article looks at how the rate of descent of the drilling rig affects the stability of the wellbore. This article talks about the characteristics of igneous, metamorphic, and sedimentary rocks and how they affect drilling. Choosing the right drilling technologies is important because sedimentary rocks are the main places where hydrocarbons are stored. When you build mechanical models for drilling, you can figure out how much energy, vibration, and friction are lost. Modern technologies, real-time monitoring systems, and fluid flow control play an important role in reducing risks. Results. The study demonstrates that optimal outcomes are attained through a multi-stage approach, integrating both conventional methods and contemporary technologies.

Key words: Inclined wells, drilling technologies, modern technologies, modern tools, mechanical models.

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1. Introduction. The modern oil and gas industry requires an integrated strategy for controlling drilling activities, making sure that the wellbore stays stable, and improving fluid dynamics. This is because deep well drilling is a complicated and varied process. Effective drilling boosts production and keeps people safe, especially when the geology and operations are hard (Bulatov, 1981; Basarygin et al., 2001; Guliyev and Shirinov, 2009; Akhundov and Hasanov, 2015). There are many important factors that make drilling deep wells hard, such as the physical and mechanical properties of the drill string, the geology of the area, and the properties of the drilling mud and fluid. The main problems are keeping the wellbore stable, reducing the risks that come with hydraulic fracturing, and changing the way drilling is done to fit the situation. This article looks at the basic ideas and methods used to make drilling operations safer and more efficient. This research will investigate the relationship between the descent velocity of the drilling apparatus and the stability of the wellbore, along with the influence of advanced technology in mitigating challenges associated with deep drilling. We will look closely at how geological conditions affect the choice of equipment and technology, as well as drilling management methods that are meant to reduce risk and improve the process. Because drilling in unstable environments has its own set of problems, special attention will be paid to controlling the flow rate, mud pressure, fluid viscosity, and the use of additives. Real-time monitoring systems are very important because they help optimize drilling parameters and adjust to the changing conditions inside the well. We will look at an analytical approach to drilling, which will include figuring out pressure balancing equations and kinematic principles to give us a full understanding of how drilling tools move in turbulent situations. The objective of this study is to ascertain the most effective and secure drilling methodologies to ensure stable wellbores and prevent issues such as hydraulic fracturing or wellbore wall failure. A common thread runs through all of this research: drilling deep wells requires a complete, multi-tiered plan that uses both traditional methods and the latest technology. Every part of the drilling process has its own set of problems and choices that need careful study and planning. The speed at which tripping activities happen during well drilling depends on a number of factors, including the technical specifications of the equipment and other things. A summary of some of these criteria is given above.

2. Methodological part. The scientific novelty of this study lies in the study of the relationship between the speed of descent of the drilling rig and the stability of the wellbore. It is proposed to achieve a more stable drilling method by using real-time monitoring and mechanical models together, taking into account the properties of the rock and the combination of drilling technologies.

Igneous rocks, sometimes referred to as igneous rocks, are generated during volcanic eruptions. Magma that ascends to the Earth's surface after a volcanic eruption experiences fast cooling. Nonetheless, inside the subterranean magma, this process continues gradually and under pressure. Consequently, igneous rocks are categorized as effusive and intrusive types. Common effusive rocks on Earth's surface include diabase, basalt, porphyry, volcaniclastics, pumice, obsidian, and trachyte. Intrusive igneous rocks, including granite, syenite, diorite, gabbro, and peridotite, are characterized by their density and limited permeability, solidifying gradually inside the Earth's subsurface [2]. Igneous rocks often have superior hardness compared to other rock types. Excavations are now conducted in rock formations for geological assessments and tunnel development. Metamorphic rocks are generated by metamorphism, which transpires when igneous rocks are subjected to extreme heat and pressure in proximity. Examples include crystalline schist, marble, quartzite, and analogous materials. denotes rocks with diverse qualities such as. Sedimentary rocks are created by the weathering and erosion of pre-existing igneous and metamorphic rocks that have experienced physical, chemical, and mechanical processes. These compounds have been disseminated throughout the Earth's surface by the actions of the sun, wind, glaciers, rivers, and floods, leading to the formation of substantial sedimentary strata over millions and billions of years. The production of sedimentary rocks is an ongoing and dynamic natural process. Their negligible micro-growth rate of around 0.3-3 mm per century renders this developmental process imperceptible to human observation of nature throughout time. Long-exposed sediments to geological activity have hydrocarbons derived from faunal and floral remnants. The exploration and extraction of oil and gas deposits mostly occur in areas characterized by sedimentary rock formations, and this is not a coincidental occurrence. Sedimentary rocks are categorized into three kinds based on their creation mechanisms:

1. Mechanical sediments.
2. Chemical sedimentation.
3. Organic sediments [1].

Mechanical sediments include both naturally cemented and uncemented particles, often referred to as grains. The hardness of mechanical sediments is influenced by particle interaction, particle size, porosity, cementation degree, and cementing material concentration. The density of these sediments typically ranges from 2.1 to 2.8 g/cm³ in most instances. Chemical sediments are generated when mineral particles in both normal and colloidal solutions undergo precipitation. Cemented rocks demonstrate superior hardness compared to uncemented rocks. The hardness of cemented rocks fluctuates based on variations in particle size and the characteristics of the cementing agent. Examples of naturally occurring sedimentary rocks include limestones, calcareous tuffs, dolomites, marls, and siderites. Organic sediments denote organic sedimentary rocks mostly generated by the biological activities of organisms. The composition comprises naturally occurring particles of herringbone limestone, chalk, diatomite, trefoil, and opal. Organogenic rocks are mostly created in the bottom of seas and lakes. During the drilling of oil and gas wells, heterogeneous rock formations are often encountered. This amalgamation induces changes in both the porosity (the volume of voids inside the rock) and the hardness of the rocks. The rock's density rises with depth owing to the pressure from the above layers. The disparity in rock density at varying depths is attributable to this issue. Rocks exhibiting uniform physical qualities, including thermal insulation, electrical conductivity, elasticity, and hardness, are termed isotropic rocks [4]. Anisotropic rocks exhibit uniform constants in parallel orientations while differing in other directions.

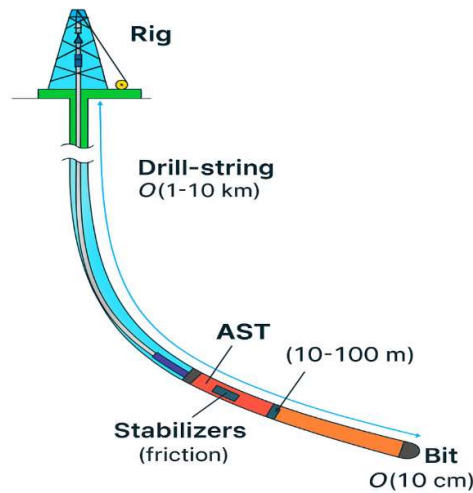


Figure 1. Schematic overview of a drilling system in an inclined well

The first image depicts the structure used in the process of drilling oil and gas wells. The drilling rig is located in the upper part. This device is the main center from which all equipment is controlled. A drill string (a set of drilling pipes), the length of which can vary between 1–10 km, is inserted into the well. Through these pipes, both the drilling fluid circulates and the rotational movement is transmitted to the bottom. At the bottom of the well is a part called BHA (Bottom Hole Assembly), the length of which is between 10–100 meters. The BHA provides the direction and stability of the well. Various devices and measuring equipment are installed there. The bit is located at the bottom and has a diameter of about 10 cm. It drills the well by breaking the rocks. Stabilizers are located on the pipes, which reduce friction and help the well to be drilled in a straighter direction. The image also shows the AST (actuator or special technical part). This part plays an important role in controlling rotation, direction and mechanical forces. Ultimately, this structure ensures a stable and controlled drilling process at depth [8].

Increasing hydrocarbon production by developing, for example, offshore fields, as well as further developing previously drilled areas, involves the implementation of complexly constructed design well profiles, the trajectories of which may contain curved sections with a limited (minimum possible) radius or inclined rectilinear sections of great length (more than 3000 m). The presence of such trajectories is due to the inaccessibility of oil and gas facilities located, for example, under populated areas, water bodies and nature conservation areas, as well as the remoteness of the shelf coastline [6]. The results of the analysis of practical data on drilling wells with a complex profile showed that the actual deepening trajectory in many cases differs significantly from the trajectory of the design profile. As a result, the wellbore is formed with the formation of large caverns and benches that hinder the advancement of the bottom hole assembly (BHA), and the intensity of the curvature and the radius of the sections of the build-up and decline of the zenith angle do not correspond to the permissible strength characteristics of the drill pipes. It is practically impossible to drill such sections using only a downhole motor (DDM) as a bit drive. This is primarily due to the high friction between the drill string (DS) and the rock. As a technological method for increasing the efficiency of drilling with a DDM, they use simultaneous periodic or constant rotation of the drill string by a rotor or top drive. Manufacturers call this method rotary-turbine or combined. Its implementation allows drilling wells of various depths with a wide range of changes in the type and properties of drilling fluids, drilling mode parameters, as well as using different designs and sizes of rock-cutting tools. However, with the current technology of combined drilling, there are problems associated with the instability of the DDM, their stops, as well as accidents

(turning off, destruction of DDM elements) of the DS assembly. The main disadvantage of using simultaneous rotation of the DDM and the BC is the impossibility of adjusting the well profile trajectory during the drilling of inclined straight (tangential) sections. In the case of drilling subsequent intervals located after the tangential section, for example, sections of the zenith angle increase or decrease, it is practically impossible to use the DDM without rotating the BC with simultaneous trajectory adjustment. This is due to the action of additional friction forces between the drilling tool and the rock.

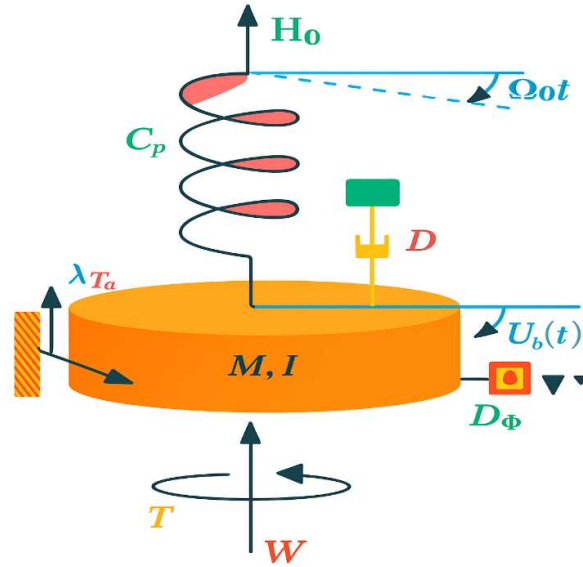


Figure 2. Schematic representation of the benchmark model

This figure depicts a mechanical model of the drilling process. Here, a disk marked M, I is taken as the main element. This disk symbolizes the rotating part of the drill string. The forces and moments acting on the disk are shown. The force denoted by H_0 and an elastic torsion spring called C_p are depicted from above. This spring models the elasticity of the drill pipes. The rotation of the disk is affected by the torque T , and the force W is the force arising from the weight directed downwards. Two important factors are also marked on the disk: λT_a and λT_r . These indicate the clamping and friction. On the side are the symbols $\Phi_b(t)$ and $U_b(t)$, which indicate the angular deformation and displacement occurring in the disk. The figure also shows the elements D and $D\Phi$, which model the shock absorber and friction forces. In short, this mathematical-mechanical model explains the rotational and elastic behavior of a part of the drill string. Its purpose is to calculate vibrations, friction, and energy losses that occur during drilling [8].

Contemporary drilling technology may be classified into two types according to their effect on rock. 1. Techniques using physical drilling. 2. Mechanical drilling techniques. Physical drilling techniques, referred to as shaftless drilling, contrast with mechanical drilling methods. Thermal drilling is a technology that use flame and plasma to fragment rock by the application of extreme heat and temperature. Explosive drilling entails the obliteration of subterranean rocks at the base of a well by detonation. Hydraulic drilling utilizes a high-pressure hydraulic pump to fracture rocks. Electrical impulse drilling entails the fragmentation of rock by the use of an electrical discharge. Chemical drilling use chemical substances to interact with rock, resulting in its degradation. Vibrating drilling employs a vibrodigger to execute drilling while the instrument functions under

the surface. These drilling methods have not yet transcended the confines of laboratory study. Conversely, mechanical drilling is often used due to its adaptability. At now, oil and gas wells are mostly drilled using mechanical techniques. Since the late 19th century, oil and gas wells have been mechanically dug, with depths progressively reaching 8,000 to 12,000 meters. Mechanical drilling methods are categorized into two types: percussive drilling and rotary drilling. Execute the percussive technique. Percussion drilling entails aggressively striking the well's bottom with an axe to fracture the rock. The resultant crushed rock pieces are then mixed with water and extracted from the well's bottom as a slurry or solid-liquid amalgamation. In this situation, the drilling apparatus is turned at a certain angle using keys at the wellhead to form a cylindrical wellbore. Percussion drilling entails the insertion of a substantial drilling implement into the rock, accompanied by periodic elevation and descent of the axe [3]. The drilling apparatus is elevated and descended by a crank-rod mechanism situated at the wellhead via a drilling rig. A crank mechanism transforms rotational momentum into reciprocating motion. A substantial rod connected to the axle aids in fracturing the underlying rock during descent. The process of rock destruction during hammer drilling consists of two independent processes executed sequentially. The first operation entails crushing the rock, followed by the removal of the excavated rock particles from the hole with a rod after elevating the rods. These methods are executed consecutively to enhance the drilling of the well. In this method, given that the well is devoid of contents, casing pipes are introduced into the wellbore to mitigate rock instability in the well wall, and the backside is then cemented. The rod drive method is used in drilling seismic research wells with depths of 10-15 meters, as well as in subterranean constructions, air exchange tunnels, and wells up to 100 meters deep, often utilized in water wells. The extraction of rocks from the well occurred concurrently with the drilling process. To accomplish this objective, all solid rods were substituted with rods (pipes) including internal channels, and the axes used for crushing rocks were replaced with axes containing holes for washing. Furthermore, a piston pump, a receiving tank, and troughs were erected at the wellhead. The presence of polluted drilling mud in the well caused a 3-4-fold decrease in the reinforcing of the hole with protective pipes. Consequently, drilling wells to higher depths became feasible. A concept was then presented to generate a hydraulic effect on the shaft to use the force of the circulating drilling mud solution during the drilling process. The intense impact of the fluid wave will generate significant vibrations at the well's bottom, therefore promoting rock fragmentation [7]. This figure shows a more expanded mechanical model than the previous one. There are now two disks: M_a, I_a and M_b, I_b . These disks represent different parts of the drill string. The upper part again depicts the spring C_p and the force H_o . This spring represents the elasticity of the drill pipe, that is, the bending that occurs during rotation. The spring constant K_b and the shock absorber D_b are placed between the two disks. They indicate the energy transfer between the two parts and the vibration reduction. There are λT marks on both disks - these model the friction and limiting forces. The lower disk is affected by the torque T and the force W . The angular deformations - $\Phi(t)$, $\Phi_b(t)$ and their changes - $U(t)$, $U_b(t)$ are recorded on both the upper and lower disks. This model shows the dynamics of the drill string in more realistic conditions. Because not only one point at the depth of the well, but several segments are simultaneously affected. Through such models, vibrations, torsional waves, and mechanical loads generated in the well are analyzed and optimal parameters for more stable drilling are determined [8].

3. Results and discussions

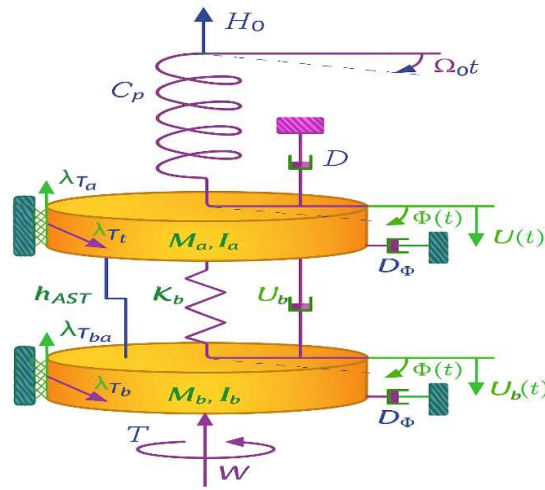


Figure 3. Schematic representation of the drill-string model including AST

The first attempt to create a specific fluid flow model for inclined wells was made (M. Mirkes et al., 2017). For this purpose, the turbulent Navier-Stokes equation was modeled in the inclined coordinate using a correction term $\tan(\beta) - 0.96 = \tan(\gamma)$ since the shear stress increases near the pipe wall during the anisotropic flow regime. The result was that the new model could more accurately estimate the friction coefficient and gas-liquid sliding velocity in inclined wells. However, the applicability of this fluid flow model through an inclined well for petroleum engineering purposes remained uncertain. Therefore, this work attempted to investigate the prediction of reservoir performance in inclined wells. Drilling processes are applied in the petroleum industry to penetrate soil layers and extract minerals (Elkatatny, 2020). During the development of a certain field, the well is directed in a curved line from the vertical direction towards the target node. This type of well is called a diversion well for an oil reservoir and is called a directional well because the wellbore is guided in a specific directional pattern to avoid hydrodynamic obstacles and limit the percentage of water cut. The purpose of drilling and logging is to reduce the cost of finding and extracting hydrocarbons from a geological reservoir. (Richard Chikabvumbwa et al., 2021). Approximately 70-80% of exploration costs are required only during the drilling of the well, so in many offshore oil reservoirs, it is very important to extract initial well parameters such as wellbore inclination and azimuth to determine whether to use logging. data depending on the financial potential of the reservoir [5].

4. Conclusion. The research identified that the primary challenges in deep well drilling pertain to wellbore stability, rock diversity, and the durability of drilling equipment under mechanical stress. The drilling speed and well quality are directly affected by the different mechanical properties of igneous, metamorphic, and sedimentary rocks. Sedimentary rocks are the main target areas because they have a lot of hydrocarbon deposits. At the same time, the drilling equipment's vibrations and friction cause energy to be lost. So, when using mechanical models, you should think about torque, elasticity, and friction forces. New technologies, like real-time monitoring, precise control of the well profile, and optimization of drilling fluid parameters, make drilling safer. The results indicate that drilling deep wells stably and safely is challenging when relying solely on traditional methods. Using a complicated strategy that includes managing technical equipment, rock properties, and drilling fluids is a good way to do things. This method both boosts production capacity and lowers the chance of accidents.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research.

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