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A REVIEW ON: OPTIMIZATION OF DRILLING PARAMETERS PERFORMANCE DURING DRILLING IN GAS WELLS

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Abstract

The effectiveness and efficacy of drilling operations are greatly influenced by the drilling parameters, particularly in gas wells where complicated geological formations and high-pressure settings are common. This research presents some methods of optimization of drilling parameters performance in drilling gas wells. The results of similar cases were also discussed in the research. Data was obtained from reliable data base and the resulting findings were presented. A key observation was the improvement of accuracy and efficiency in drilling of gas wells with the advancement in technologies and computerized computations. The introduction of machine learning and artificial intelligence in this industry present a greater hope for further improvement of accuracy in predicting optimum parameters for optimization of drilling performance during drilling of gas wells.

Keywords: Drilling, Drilling parameters, Optimization

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1. Introduction

Cost reduction coupled with efficiency has been among the major hurdles of drilling gas wells in recent years. Optimization of drilling parameters have direct impacts on cost of drilling, time saved and safe operation of drilling. Researchers have been trying to improve on existing techniques using a computerized mathematical model (optimization) aimed to find and optimize the right combination or proportion of the considered parameters which will yield a lower reduction in the cost of drilling and maximize profit in a safer environment and operations as technology advances and aid in the most optimal decision making as far as gas well drilling is concerned. Drilling is a basic machining process that is used extensively in the mining, construction, and oil and gas sectors to create holes in a variety of materials. According to the Collins dictionary, “drilling is using a tool to make a deep hole in order to find oil, gas, or water using a rotating cutting tool” (Anon., 2010). On the other hand, Drilling parameters, which vary depending on the kind of drilling, material, and project objectives, are essential factors that must be carefully regulated and optimized to guarantee effective drilling operations (Karlsson et al.,1985; Reinhold and Close,1997). Drilling parameter selection and optimization have a major impact on the efficacy and efficiency of drilling procedures. These factors include, but are not limited to, feed rate, tool shape, coolant application, drill bit material, and cutting speed (Kumar and Deivanathan, 2021). The proper selection of bits, rotation speed, feed rate, coolant or lubrication, depth or diameter, pressure, and other drilling parameters are essential for accurate and safe removal of material. Innovations in drilling technology enhance drilling efficiency, sustainability, and precision in mining, oil and gas exploration, and construction. For the best results and the development of global infrastructure, drilling parameters must be mastered. Gaining an understanding of these factors' effects is essential for increasing output, attaining the appropriate level of surface polish, extending the life of the tool, and cutting production costs. Gas well drilling operations are inherently complicated, necessitating precise control over a variety of drilling parameters to guarantee effective and secure operations. This analysis highlights the difficulties, innovations, and best practices in the gas well drilling sector by concentrating on the important drilling parameters and how well they function. Because of the properties of the reservoir, such as pressure, temperature, and fluid composition, gas wells pose particular difficulties. Precise control over drilling parameters is necessary while drilling these wells in order to maximize the rate of

penetration (ROP), regulate downhole conditions, and guarantee wellbore stability (Kuznetcov, 2016). Research on drilling and drilling parameters includes a wide range of theoretical and experimental studies with the goals of maximizing manufacturing cost savings, enhancing product quality, and maximizing machining efficiency. Researchers have attempted to advance drilling technology and its applications in various industrial settings by reviewing pertinent literature. They have also improved drilling and drilling parameters to ensure safe and efficient operations through both theoretical and experimental practices. Drilling operations are becoming more efficient and safer because to technological advancements like autonomous rigs and real-time monitoring systems. Artificial intelligence and robotics are combining to optimize drilling settings dynamically in response to shifting conditions. Comprehending and managing drilling parameters is important for effectively producing holes and satisfying the dynamic demands of worldwide industries. Drilling promises to become more sustainable, safe, and precise in the future. However, as technology advances, more research will need to be done to close the gap between previous studies and improve best decision making, lower manufacturer costs, and increase manufacturer effectiveness, efficiency, safety and also enhance advances in drilling technologies to continue to refine these parameters, offering enhanced precision, productivity, and sustainability across various industries.

Existing research works done on this area such as Melentiev et al. (2016), “Effects of tool geometry and process parameters on delamination in CFRP drilling: An overview” which focuses on the effects on the geometry of the drilling tools and its corresponding parameters. In addition, Ma et al. (2016), “Overview on vertical and directional drilling technologies for the exploration and exploitation of deep petroleum resources” also studied the angle at which drilling tool are placed for exploration and exploitation of deep petroleum resources to boost efficiency, profit and safety operations in drilling. Moreover, Eren and Ozbayoglu, (2010), “Real time optimization of drilling parameters during drilling operations” used real time to improve drilling parameters for safe operations whiles Bani Mustafa et al. (2021), “Improving drilling performance through optimizing controllable drilling parameters” optimizes the performance of drilling using controlled drilling parameters for efficiency, safe operation and to reduce cost of operation.

This review paper sought to provide the most optimized method for improving drilling parameters, compare the advantages and the disadvantages between existing research works and also provide optimum solutions to the limitations in existing works to bridge up the gap between previous to improving sustainable and safe drilling operations

2. Drilling Parameters

2.1. Background of Drilling

Drilling is a cutting process which uses a drill bit to cut or enlarge a hole of a circular cross-section in a solid (Patel and Verma, 2015) or simply it is a machining process used to make a hole on component faces (kumar et al., 2020). Drilling is classified into groups based on factors such as location, source, technology and application (Vincent and Taylor, 2021). The process and its techniques have been research on and improved over the years to ensure efficiency, high profit and a safe environment from primary memorial till date. It is in that light that optimization in drilling was pioneered in 1967 and improved upon for decades to increase productivity and reduce well bore problems. Despite these efforts, optimization in drilling has not reach its maximum potential. To reach this potential in depth knowledge in the mechanism of drilling tool and mechanical features of rocks is vital (Mohammad et al.,2023).

The literature on drilling and drilling parameters covers a wide range of topics, emphasizing both experimental and theoretical approaches. Experimental studies investigate the effects of different drilling parameters on outcomes such as hole quality, surface roughness, burr formation, and tool wear. Researchers have explored various materials and coatings for drill bits, assessing their performance under different cutting conditions. Moreover, studies often compare traditional drilling methods with advanced techniques like high-speed drilling, cryogenic cooling, and laser-assisted drilling to evaluate their advantages and limitations. Theoretical research includes analytical models and numerical simulations aimed at understanding the fundamental mechanisms of drilling processes. Models based on mechanics of cutting, heat generation, and material removal rates provide insights into optimizing drilling parameters for specific materials and applications. Additionally, optimization algorithms and statistical methods are utilized to identify optimal parameter combinations that maximize machining efficiency and minimize production costs.

2.2. *Key Drilling Parameters*

Successful drilling operations require careful consideration and adjustment of several critical parameters: Some key parameters may have direct or indirect impacts on the performance of drilling during drilling of a gas well and these impacts can contribute to machining efficiency, safe operations and production costs. Below are some of the key parameters listed and explain as follows;

- Weight on Bit (WOB): WOB is crucial in gas well drilling to achieve adequate ROP while maintaining bit stability and preventing downhole tool failures. The optimal WOB depends on formation characteristics, mud weight, and drilling fluid properties. Advances in downhole sensor technology have enabled real-time monitoring of WOB, enhancing drilling efficiency and reducing non-productive time (NPT) (Karimi et al., 2019).
- Rotary Speed (RPM): RPM affects ROP, bit wear, and downhole tool longevity. In gas wells, RPM must be carefully controlled to prevent vibrations and maintain hole quality. Automation and data analytics have revolutionized RPM management, allowing operators to adjust speeds dynamically based on formation changes detected by sensors.
- Drilling Fluid Properties: Gas wells often require specific drilling fluid properties to control formation pressures, prevent blowouts, and manage gas influx. Parameters such as viscosity, density, and filtration control are critical. Innovations in fluid chemistry and additives have improved well control and reduced environmental impact (Bourgoyne et al.,2020).
- Hydraulic Parameters: Hydraulic parameters, including pump rate and pressure, play a vital role in transporting cuttings to the surface, preventing formation damage, and maintaining wellbore stability. Real-time monitoring of hydraulics enables operators to adjust parameters to optimize hole cleaning and minimize NPT.
- Torque and Drag: Torque and drag issues are common in gas wells due to high-angle and extended-reach drilling. Proper management of these parameters reduces mechanical stress on drill string components, lowers maintenance costs, and improves wellbore trajectory control. Advanced modeling techniques help predict torque and drag, optimizing well planning.
- Bit Selection and Design: Choosing the right bit design is critical in gas well drilling to maximize ROP and maintain drilling efficiency. PDC (polycrystalline diamond compact) bits are commonly used due to their durability and performance in various formations. Continuous improvements in bit design enhance drilling performance and reduce drilling costs (Al-Mahasneh, 2017).

2.3. *Types of Drilling*

Drilling operations can vary widely depending on the material being drilled and the purpose of the hole. Common types of drilling include:

- Rotary Drilling: Make use of rotational motion combined with downward force to create holes. This method is prevalent in oil and gas exploration, mining, and construction.
- Percussion Drilling: Involves a hammering action to break through hard materials like rock. It is often used in mining and geological exploration (Samuel, 1996).
- Directional Drilling: Used when a hole needs to be drilled at an angle or horizontally, which is common in oil and gas extraction to reach reservoirs beneath the surface.
- Core Drilling: Extracts cylindrical cores of material for geological analysis or testing structural integrity.

2.4. *Impact of Drilling Parameter and Performance in Gas Well*

Below are some of the impacts of drilling parameters performance in drilling of gas well:

- Gas well operations are greatly impacted by drilling characteristics such as bit selection, downhole conditions, rate of penetration (ROP), and drilling fluid qualities. Factors such as bit type, weight on bit (WOB), and rotary speed (RPM) must be balanced in order to optimize ROP. By maximizing the drill bit's cutting action and reducing bit wear and tool failure, proper modifications can improve drilling performance (Karimi et al., 2019).

- Drilling fluids, often known as muds, are essential for cooling the bit, preserving the stability of the wellbore, and raising cuttings to the surface. For drilling operations to be effective, fluid qualities including density, viscosity, and rheological characteristics must be properly managed. Cuttings are transported efficiently and the possibility of clogged pipes is reduced by maintaining the proper mud weight and maximizing fluid viscosity (Caenn et al., 2017). Drilling performance is greatly impacted by the drill bit selection, with Polycrystalline Diamond Compact (PDC) bits being particularly successful in soft to medium formations. Ample flow is ensured by proper bit hydraulics to cool the cutting structure and clean the bit face (Bourgoyne et al.,2020).
- For the purpose of avoiding issues and optimizing drilling settings, downhole conditions must be monitored in real time. Measurement while drilling (MWD) and logging while drilling (LWD) are two examples of technologies that offer vital information on variables including torque, drag, and vibration (Halliburton, 2018). By using this data, choices regarding changing drilling parameters may be made with more knowledge and efficiency. Stabilizing drilling fluid characteristics and avoiding well control problems also depend on maintaining suitable bottom hole pressure and temperature management.
- Improved performance of gas wells may be achieved by applying cutting-edge methods and best practices, such directed drilling and managed pressure drilling (MPD). To maintain optimal drilling performance, it is imperative to engage in continuous review and adaptation to emerging technology and formation features (Aadnoy and Loeset, 2017; Rehm et al., 2018).

2.4.1. Challenges in Gas Well Drilling

Drilling operations can be complex and challenging due to factors such as the hardness and variability of the material being drilled, environmental conditions, and safety considerations. For instance, drilling in deep-sea environments requires specialized equipment and procedures to withstand high pressures and corrosive conditions (Motta et al., 2020). Gas well drilling faces several challenges, including:

- Formation Pressure Variability: Managing fluctuating formation pressures requires adaptive drilling strategies.
- Complex Geology: Dealing with varying rock types and formation characteristics demands robust drilling parameter management.
- Environmental Considerations: providing solutions to environmental impacts, such as gas emissions and fluid disposal, has been very crucial.

2.4.2. Control Measures Practices in Gas Well Drilling

Effective gas well drilling relies on implementing best practices:

- Pre-Well Planning: Comprehensive well planning considers reservoir data, drilling challenges, and environmental factors.
- Continuous Monitoring: Real-time monitoring of drilling parameters ensures proactive adjustments and enhances safety.
- Training and Competency: Well-trained personnel ensure proper parameter management and operational efficiency (Abdulmalek, 2015).
- Collaboration and Communication: Effective communication and collaboration among drilling teams, engineers, and service providers are essential for success.

2.5. Engineering Paradigm of Drilling

Recent advancements and innovations in drilling technology have significantly improved performance in drilled gas wells:

- Automation and Robotics: Automated drilling systems increase efficiency and safety while reducing human error.
- Data Analytics: Real-time data analysis optimizes drilling parameters, enhances decision-making, and reduces NPT (Olajiga et al., 2024).

- Managed Pressure Drilling (MPD): MPD techniques control formation pressures more precisely, improving well control and safety.
- Digital Twin Technology: Digital twins simulate downhole conditions, optimizing parameter adjustments and predicting performance.

3. Discussions

Research methodologies in drilling parameter studies vary widely depending on the objectives and resources available. Experimental approaches involve setting up controlled drilling tests using standardized equipment and measuring devices to quantify outcomes. Factors such as drill bit geometry, cutting conditions, and material properties are carefully controlled to ensure reproducibility and accuracy of results. Advanced experimental techniques may include real-time monitoring of cutting forces, temperature distribution, and acoustic emission to capture dynamic changes during drilling as in the case of Al-Mahasneh (2017).

Numerical simulations play a crucial role in complementing experimental findings by predicting drilling performance under different scenarios. Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), and Discrete Element Method (DEM) are commonly used simulation techniques. These simulations model the interaction between the drill bit and workpiece, considering factors such as heat generation, chip formation, and material deformation. Parametric studies using simulations help in understanding the complex interactions between drilling parameters and optimizing them for specific manufacturing requirements as studied in Bahari (2009) and (Elkatatny, 2021; Nguyen and Vu,2022; Khamis et al.,2023).Optimization is the core to problem solving in multidisciplinary fields of applied mathematics and engineering including computer science due to the ability to express it several forms (Yang, 2018). Optimization is the process of minimizing the usage of resources like energy, tools, cost and production while maximizing the process output such as quality and productivity which has impact on the environment, sustainability process and profit (Abbas et al., 2023). The factors affecting the mud weight and type are termed the environmental or uncontrollable variables. Weight on bit, rotary speed and flow rate on the other hand are the controllable parameters. Some controllable parameters improvement can change some uncontrollable parameters (Lummus,1970).

In the early days of optimization in drilling, mathematical models linking the vital controllable and uncontrollable parameters, and this was used in the process of optimization. Notable among these models is the Bourgoyne and Young (1974). From the early 1990s to date computer algorithms or models are developed to serve the same purpose. The latter models eliminate the issue of low accuracy, stress computational, much more cost-effective solutions in the mathematical models. The optimization of one of the most research area in the drilling industry. Out of the numerous, this paper talks about a few of them.

In an attempt to solve the well bore instability on the Nam Rong Doi oil field, an ANN algorithm was developed to predict the optimum values of the essential controllable parameters. The research was successful, and its implementation will solve the said problem (Nguyen and Vu, 2022). A combination of an analytical optimization model and learning based vibration model provided a result of 14.1% improvement on the average across all formations when compared to the data as a mitigation of excessive vibration ignored by other models at the time (Hedge et al., 2019).

using a trained ANN model and 3000 data points collected and optimized using a self- adaptive differential algorithm evolution algorithm. It also made use of linear regression. The results from this research outperformed all previous correlation of rate of penetration estimation using linear regression (Al-Abdul Jabbar, 2023). This reinforces the statement made by Lummus and others in their research that optimization in drilling has not reach its climax. The existing models are perfected and improved on as technology advances.

The rate of penetration is the most vital drilling parameter considered in optimization in drilling industry and research. AL-Mahasneh, in this study uses data 3 gas wells in RISHA area locations in RISHA gas area. The data was analyzed and the optimum drilling parameters. In addition, the process yielded a productive time of 60.5% of the total time spent for the drilling activity. Further research can be done to improve the productive time and improve the method (Al-Mahasneh, 2017) Similar study in Majnoon field which was well developed. 5 wells from different zones on the field. Data of the lithological specifications, daily drilling reports, mud logging data, bits records and final report were collected and analyzed. In that study, the optimum penetration rate was not obtained due to the complications of flow rate and clean bit in clay intervals (Majeed et al., 2019). Comparing the two studies, though the both use the method of optimization, AL-Mahasneh used the same bit size for all the wells, but Majnoon field study made use of different bit size for each well. Further research can be conducted to

check if the variation in bit sizes caused the failure. Though the study could not achieve its aim, but it proved the impact of flow rate and clean bit in clay intervals. Another research was performed in the Iranian khagiran gas field were comparative drilling optimization method. MATLAB programming was used to model the ROP of the wells. The simulated results were compared with actual values to measure the accuracy of the method. About 80% of the result from the simulation was equal or near to the actual optimum values (Bahari, 2009). A combination of response surface methodology and optimization of rate of penetration in an attempt to improve drilling performance showed that there is a linear relationship between the rate of penetration and the Hankins with accuracy above 80% when compared with the actual value. The accuracy of one the wells considered was 99% which implied that method is very effective though there were discrepancies due to the number of reference cells used for the simulation (Hankins et al., 2015). Recent trend is the use artificial intelligence techniques in optimization of rate of penetration to improve drilling performance. Among the various artificial neural network (ANN) has proven to be every effective (Elkatatny, 2021; Nguyen and Vu,2022; Khamis et al.,2023).

In the nutshell, discussions in drilling research often revolve around optimizing drilling parameters to achieve conflicting objectives such as maximizing productivity while maintaining surface integrity and prolonging tool life. Researchers debate the trade-offs involved in selecting cutting speeds and feed rates to balance material removal rates and tool wear. The effectiveness of different cooling methods, including conventional flood cooling versus advanced techniques like minimum quantity lubrication (MQL) or cryogenic cooling, is a topic of ongoing research. Moreover, discussions extend to the environmental impact of drilling operations and the feasibility of implementing sustainable machining practices.

4. Conclusions and Recommendations

4.1. Conclusions

Drilling parameter research is essential to improving production processes and machining technologies. The study discovered that:

- Bit weight might vary throughout drilling operations, figuring out the ideal bit weight is essential.
- For effective machining results, it is crucial to comprehend how drilling parameters, material qualities, and tool features interact.
- For the purpose of choosing and optimizing drilling parameters in light of operational demands and environmental factors, tailored techniques are crucial.
- In order to improve decision-making in drilling operations, future research may concentrate on creating prediction models that incorporate machine learning and artificial intelligence.
- For gas well output, wellbore integrity, and operational efficiency, drilling parameters must be optimized.
- Innovation in the sector is driven by challenges like as environmental considerations and reservoir complexity.

4.2. Recommendations

Drilling parameters for gas wells must be optimized in order to maximize productivity, reduce expenses, and guarantee safety. It was recommended that:

- Further studies should be conducted to help eliminate wasted time on drilled well and increase production of drilled well to aid in time saving, efficiency and maximize profit.
- Rate of penetration (ROP), bit selection, drilling fluid characteristics, and downhole conditions are important factors. Use bits tailored for the particular formations you meet, such PDC (Polycrystalline Diamond Compact) bits, to get the best ROP possible. To strike a compromise between preventing bit damage and raising ROP, adjust the bit's weight.
- Properties of the drilling fluid are essential for cutting removal, bit cooling, and wellbore stability. Suggestions include preserving the proper rheology, viscosity, and weight of the mud. In addition, bit performance and selection are crucial, with factors including bit type, hydraulics, and wear monitoring must be taken into account.
- Enhancing drilling efficiency and preventing issues can be achieved by constant monitoring and adaptation to downhole conditions. Instantaneous Informed judgements about drilling parameter adjustments need

temperature control, pressure management, and real-time data processing. Gas well performance may be increased by putting best drilling methods and procedures into effect, such as directional drilling, controlled pressure drilling, and drill string design.

- Operators may increase productivity, save expenses, and improve safety in gas well drilling operations by incorporating these suggestions into the drilling process. Maintaining optimal drilling performance requires constant assessment and adjustment to changing technology and formation features.

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