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Optimization of Drilling Well Design: A Review

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Abstract

Drilling well design optimization reduces total Authorization for Expenditures (AFE) by decreasing well constructing time and expense. Well design is not a constant pattern during the life cycle of the field. It should be optimized by continuous improvements for all aspects of redesigning the well depending on the actual field conditions and problems. The core objective of this study is to deliver a general review of the well design optimization processes and the available studies and applications to employ the well design optimization to solve problems encountered with well design so that cost effectiveness and perfect drilling well performance are achievable. Well design optimization processes include unconventional design(slimhole) compared with fat design, in addition to optimizing casing setting depth selection and casing string loads. Finally, we demonstrate well trajectory design considerations and optimization. The optimization process that mentioned above is significantly reduce drilling cost and time since, slimhole design with smaller casing and hole size reduce mud volume cost, steel cost and pump fuel cost. Optimum casing seat selection can ovoid serious problem such as kick and losses that increase nonproductive time (NPT) if kick tolerance and downhole pressure profile is not considered. Anticipating optimum stress loads in casing design is most effective way to reduce casing strings cost avoiding additional cost for designing with useless worst conditions. Wellbore trajectory optimization with geomechnic consideration is major concern to reduce the problem encountered with high torque, drag, formation collapse that result stuck pipe and non-productive time (NPT).

Keywords: optimization of well design, casing seat, casing design, wellbore trajectory.

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1- Introduction

As firms continue to expand their drilling operations in existing oil and gas areas across the globe, the time has come to optimize profits by improving drilling design to reduce associated costs [1]. The focal point of the optimization process is to reduce drilling time and associated cost per each well. Horizontal drilling is a preferred technique for exploiting non-commercial reserves. Unlike normal directional drilling, horizontal wells require extensive engineering work [2].

When drilling oil and gas wells, it is not possible to reach the well target in a single section due to formation pressure uncertainty. This presents difficulties and risks when drilling. Consequently, the engineering team gets the opportunity to undertake a comprehensive field analysis. As a result of studying offset well data, geological and geomechanical investigations, a new well design is presented that is optimized for best drilling performance and decreased costs [3].

2- Optimization of Well Design

The focal point of the optimization process is to reduce drilling time and associated cost per each well [4]. Engineers apply drilling optimization in order to drill wells more successfully and efficiently. Directional drilling's specific objectives include good hole quality, robust directional control, high angle-build capacity, maximum durability, optimal penetration rate (ROP), and minimal non-productive time. This may be achieved through optimum design. Including hole and casing size optimization, casing seat selection, casing loads design, horizontal well trajectory and applications of new and high techniques [5].

Alternative solutions to meet well plan goals and objectives are needed to optimize casing design. These options include the quantity of casing strings, casing seats, and cement top that can be used within the constraints of available resources [6].

Casing setting depths are determined in accordance with the well's pore pressure and fracture pressure, which are frequently acquired through an offset well. Other design considerations, such kick tolerance and differential sticking constraints, are also considered [7].

Planned wellbore trajectory is required for directional and horizontal drilling. It's especially critical for multi-well platforms, where a number of considerations must be taken into account prior to determining the ultimate well path. To improve well trajectory, essential mathematical formulations must be created to reflect changes in directional well planning and profile [8].

Drilling expenses will be minimized by collaborating with the team from the beginning of the well design stage to ensure that the well reaches its intended destination in a regulated and safe way [9].

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Lummuas defined the philosophy of optimized drilling That is, use the first well's record as a basis for computations and apply optimal design and methods to the second and third wells, negotiating a $6.00/ft. field price much sooner. By using optimal design and methods, an operator can drill more wells each year or develop wells that might otherwise be uneconomical [10].

2.1. Typical (Fat) and unconventional (slimhole) well design

A well that was drilled using standard casing and bit sizes is known as a "fat design". In general, the most of wells drilled in the majority of fields across the world follow a three-section hole size structure. The surface hole is 17 1/2" in diameter (13 3/8" casing), the intermediate hole is 12 14" in diameter (9 5/8" casing), and the production hole is 8 12" in diameter (7" casing). As indicated in the Fig. **1** [11].

"slimhole design" Unconventional design reduces hole sections and casing strings to the smallest functional size. Risk-based design may be employed to match the well's purpose. Initial cost savings were anticipated by comparing hole size, steel/casing, disposal, and fluid needs [12].

Slimhole industry was a 1950s cost-effective option. Oil corporations didn't focus slimhole drilling throughout the 1960s and 1970s. In the 1980s, Sweden developed a slimhole technique that reduced shallow reservoir drilling expenses by 75%. Late 1980s thinking changed because flat oil prices and the necessity to expand exploration results in a cost-effective manner. Since then, slimhole drilling has become an alternative to traditional oil and gas drilling. In the early 1990s, slimhole uses developed, allowing advancements in well completion to permit widespread slimhole use [13].

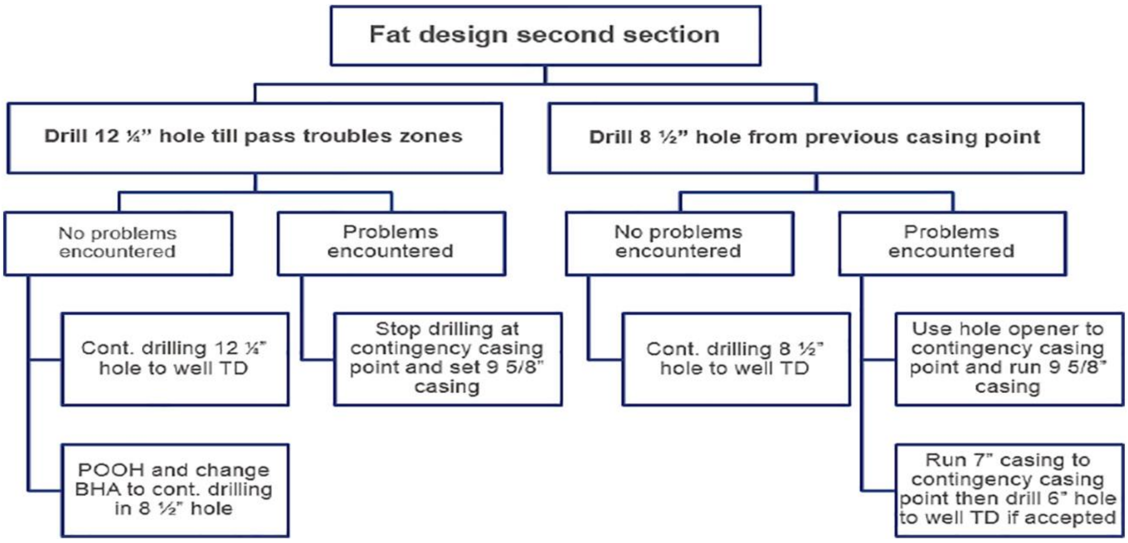

Fig. 1. Design Decision Tree [11]

2.2. Casing seat selection

The key design phase for constructing the well plan is identifying the depths to which the casing will be driven and sealed. The designer must evaluate geological variables such as formation and fracture gradients, as well as hole difficulties, internal business standards, and, in many situations, a variety of regulatory requirements [14].

2.2.1. Casing Setting Depth (CSD) selection method

The Top-Down Technique begins with the selection of the conductor depth and then uses pore and fracture gradient data to compute the subsequent casing point, whereas the Bottom-Up technique relies on pore and fracture pressure data to establish the casing setting depth. For drilling wells, the casing point is established at total depth by determining a needed casing diameter at full depth for drilling wells. When it comes to drilling for exploration, the top-down approach is preferred over bottom-up, as seen in Fig. **2**. However, the top-down approach can be utilized in difficult subsurface geological circumstances; therefore, not all drilling wells use the bottom-up approach [15].

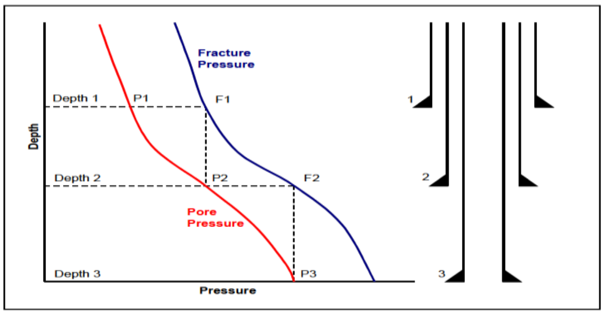

Fig. 2. Idealized Casing Seat Selection [16]

2.2.2. Landmark® CasingSeat software

One of the main applications of this software is specifying the best shoe placements based on downhole pressure variation, and the engineer design parameters such Kick tolerance and differential pipe sticking. In addition, other important applications can be provided by this software are The creation and maintenance of mud schedules and the determination of casing and hole diameters [17].

2.3. Casing Loads design

Casing design consists of identifying characteristics that impact casing fail and selecting the safest and most cost-effective casing types and weight for a particular application. There are three basic forces acting on the casing: rupture, stress, and collapse. These are the forces that exist inside the wellbore. They must be predetermined and kept below the criterion for casing strength [18].

2.3.1. Collapse Load (Pc)

Casing collapses if outer radial stress exceeds internal. Empty casing maximizes collapse load. Estimating casing collapse load can be calculated by using the formula below [18].

$$Pc = Pe - Pi \tag{1}$$

2.3.2. Burst Load (Pb)

The event that the internal radial load is higher than the exterior radial load, the casing will be subjected to a burst load, also known as a net burst load. Utilizing the formula, determine the burst load, denoted by Pb, at any location along the casing can be calculated by formula mentioned below [18].

$$Pb = Pi - Pe \tag{2}$$

Where: Pi is internal pressure (psi), Pe is exterior pressure (psi).

It is important to take into consideration the pressure capacity of the wellhead and BOP for burst design. The loads depicted in Fig. **3** that are utilized to calculate the burst and collapse loads on the casing are determined from an operating scenario study [18].

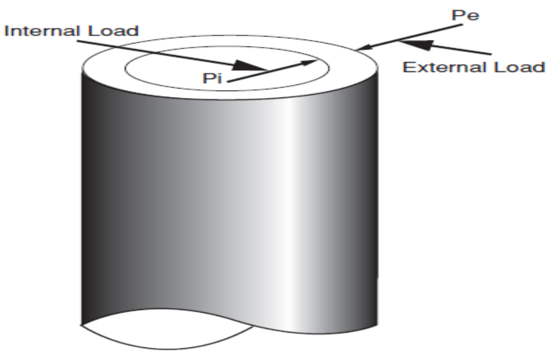

Fig. 3. Radial Load of Casing [18]

2.3.3. Axial Load

The loads on the casing may be tension or compression, as shown in Fig. **4**. Casing axial stress varies with length. During installation, drilling, and production, the casing is stressed axially. The axial loads from each operation must be evaluated and added to yield the overall casing load [18].

2.3.4. Triaxial Loading

They are a total of three loads, and they are categorized as radial, axial, and tangential are depicted in Fig. **5** [18].

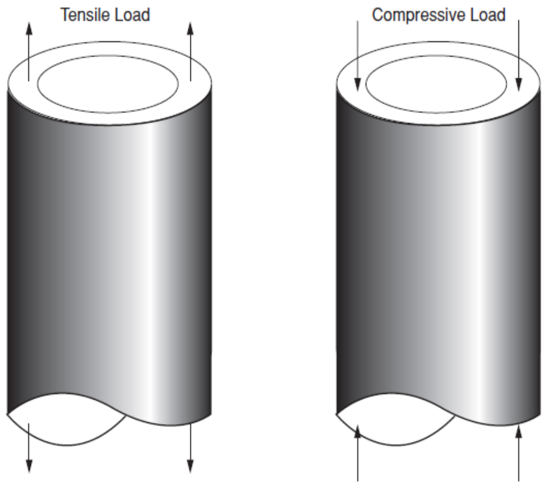

Fig. 4. Axial Load of Casing [18]

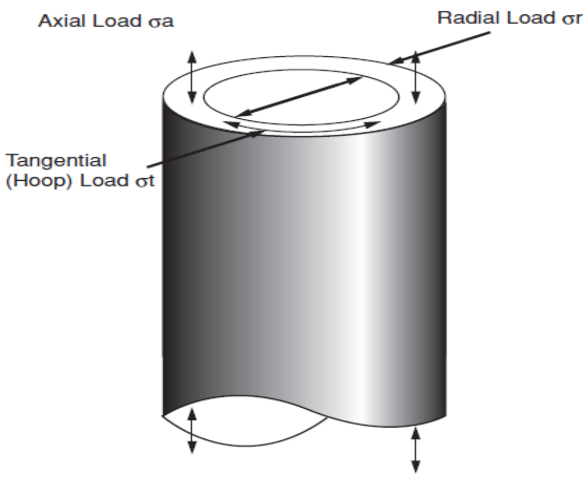

Fig. 5. Tri-axial Loads on Casing [18]

2.3.5. Design Factors

In order to achieve the design loads, the actual loading data are multiplied by a design factor. Design elements are mostly decided by experience and are impacted by casing failure implications [18].

2.3.6. Landmark® StressCheckTM software

Casing strings are created and analysed by this tool. StressCheck can construct casing strings at desired specifications. StressCheck reduces total casing costs by automating the specification of real burst, collapse, and axial loads, by optimizing the quantity and casing length sections, not cruellest load capacity profiles. Compared to typical enclosure designs, 40% can be saved. Fig. **6** demonstrates casing design procedures, elements, and conditions [19].

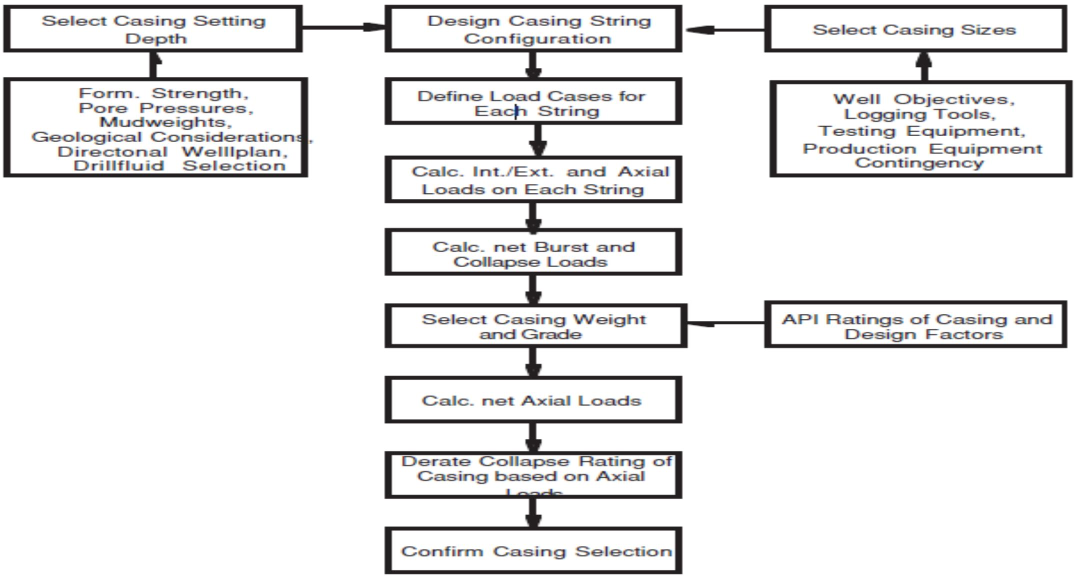

Fig. 6. Casing Design Process [18]

2.4. Horizontal well profile design

Horizontal wells are drilled at an angle of up to ninety degrees via curved sections and then horizontally into the reservoir. horizontally into the rock, then. In practical situations, the inclination angle of horizontal wells ranges from 80 to 100 degrees. In a horizontal well with perfect slope, the angle is 90 degrees. There are three types of horizontal well patterns: short (30 to 200 feet radius of curvature), medium (200 to 1,000 feet), and long (1,000 to 3,000 feet) turn radius [8].

2.4.1. Well profile design considerations

a. single curve design

Hole angle design rises from 0 to 90 degrees as shown in Fig. **7**. If this design is used, formation and drilling BHA build-up tendencies must be known to avoid losing the target resulting from high or insufficient build rate. If the build rate is lower, the well route falls underneath the target. If it is too great, it goes over. Both cases need excellent repair [20].

b. Double curve design

If build up is too rapid, the well path would be above the target, necessitating re-drilling. The well path will be below the reservoir if the build rate is reduced, prohibiting drilling. Fig. **8** shows how a tangent portion below the initial build-up curve might solve the above problems. Some reservoirs tilt internally [20].

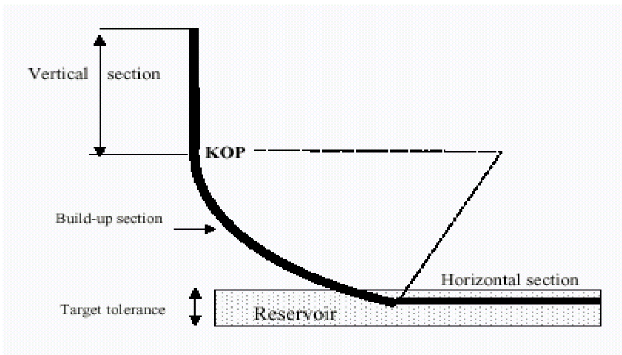

Fig. 7. Single Curve Design [20]

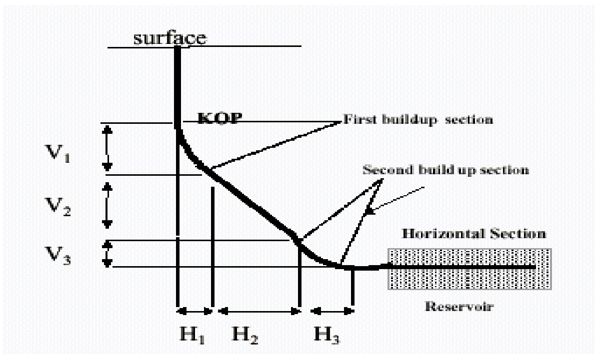

Fig. 8. Double Curve Design [20]

2.4.2. The Landmark® COMPASSTM Software

The well trajectory is created utilizing, a tool COMPASSTM Software that enables speedy and exact design of wells and early identification of possible problems. On the list of capabilities are survey and planning techniques, torque-drag optimization, anti-collision plotting with moving cylinder, and ellipse of uncertainty. It aims to enhance the effectiveness and cost-effectiveness of directed well planning and wellbore monitoring [21].

2.4.3. Well bore trajectory optimization

Wellbore design involves optimizing trajectory. Optimizing wellbore trajectory reduces geostress loads and extends wellbore service life. Fixing a reservoir's surface increases the need for trajectory optimization. Several methods are used to compare wellbore trajectory options. As a wellbore stability indicator, mechanical in-situ stresses are significant. Optimal well orientation for wellbore stability lowers normal stress difference. In-situ tensions dictate well direction. Rock mechanics help determine wellbore trajectory. The amount and position of the max. horizontal loads can be determined from wellbore failures such as breakouts, washes, and drilling-induced fractures [8].

3- Literature Review

Many researchers studied different aspects of well design optimization related with fat and slimhole well design casing setting depth selection, casing loads design and wellbore trajectory optimization.

3.1. slimhole well design compared with conventional (fat) design studies

Using the slim hole optimization design is an application that got the attention of several researchers who studied and applied possible casing and hole size reduction in different aspects and applications of drilling wells.

Kroell and Spoerker. in this study, the impacts of drilling on well productivity were reviewed, and contemporary completion techniques were emphasized. Comparison of conventional drilling and slimhole formation-damaging potential. Throughout the well's life cycle, the economic arguments for adopting slimhole technology during drilling are assessed against predicted low productivity. Numerous studies and simulations of the influence of slimhole well configuration on inflow performance revealed that a wellbore diameter reduction has a little direct impact on inflow performance. By definition, high-productivity wells are unsuitable for slimhole completions. Slimhole completion is possible for low to medium production reservoirs. Economic benefits must be carefully weighed against any downsides, and a design strategy must be based on life-cycle well economics [22].

Worrall et al. they showed that since 1987, 46 wells have utilized Slim Hole Drilling. Since daily progress no significantly reduces with reduced hole diameters, the design of the well may be streamlined. Reduced expenses by one-fourth Activity reduction reduces environmental effect. Using complementary assessment and completing techniques, oil companies may reduce the size of their wells, hence decreasing field development expenses. They also illustrated the possibilities of Slim Hole Drilling for the oil industry. Wells account for an average of sixty percent of the entire cost of a project. This Drilling technique seems to have the ability to drastically reduce these expenditures, and consequently the costs associated with field development [23].

David and Vogelsberg. demonstrated that by decreasing the horizontal hole diameter from 8.75" to 6.7", well construction expenses are reduced by 25%. They analysed the expense of decreasing the lateral hole size from 8.5"/5.5" to 6.75"/4.2". Downhole equipment, drill strings, rig capabilities, and drilling fluid formulation have all been enhanced to increase ROP. To maintain stimulation efficacy and well value, completions with smaller holes were constructed. In many geological plays, well building costs decreased by approximately 25 percent, making unconventional assets a more appealing investment [12].

3.2. casing seat selection studies

Several researchers worked on casing setting depth optimization based on well conditions and kick tolerance.

Azi. designing Casing setting depth for development well Furak was obtained with 442 feet of seawater depth. The depth of each casing is determined via downhole pressure variation studies as well as bottom-up estimations of casing setting depth. The rotary table must produce zero. Conductor casing is 1010 feet deep with an equal mud of 8.5 PPG, casing surface depth is 2495 feet with 9.4 ppg, intermediate casing is 6470 feet with 10 ppg, and production casing is 9810ft. with 11.3 ppg [7].

Santos. A method for planning the set depths of surface and intermediate casing was presented using the concept of kick tolerance. The method was implemented in microcomputer software written in FORTRAN. Using the kick tolerance concept, the proposed method adopts an innovative way to discover the casing set depth that is the shallow [24].

Assi. Determined the casing seat depth. The setting elements that should be considered are fracture gradient, pore pressure, and remaining rock lithologies. The casing seat is better defined when the drilling fluid is specified. Each well's casing is evaluated based on fracture and pore pressure and bottom-up technique. The case study shows that Well A has a conductor casing that is 47 meters long, a casing surface that is 533 meters long, and an intermediate casing setting that is 1882 meters long. The depth of the production casing is 3441 m. Both the bottom-up approach as well as the collapse pressure method produced comparable results [25].

Othman. Examined the relationship between casing depth and kick tolerance and well stability by doing sensitivity analyses on selected theoretical well data. The depth of the well casing shoe was calculated and deemed acceptable by the well integrity criteria [26].

Holasek. determined Using seismic, leak-proof capacity analysis, shallow pore and fracture pressure prediction deepens 20" casings. 20 " casing Accurate analysis will enable the casing string to be placed deeper after the conductor is established in the flexible clay [15].

3.3. casing design studies

Several researchers made casing to meet the goals of casing for different well conditions. They did this by taking into account the following optimization understandings through casing grading properties and cost.

Samuel and Gonzale. The design of multistring casing was optimized for complicated loads, annulus gas growth, and well head expansion. Casings for drilling stages are selected to save design expenses. Casing strength, drift diameter, casing section length, quantity of sections, wellhead growth, and casing inventory are accounted for during optimization. The branch-and-bound heuristic provides casing design with structure information. This decreases the optimization effect of annular gas expansion and wellhead rise. It is cost-effective to optimize annuli fluid expansion-wellhead development. Effectiveness will be determined by the annulus gas expansion-wellhead growing issue [6].

Panagiotis. Deviated, deep well casing (type slanted at target depth of 13000 ft), After constructing the pore and fracture pressure profile, the number of casing threads is decided. Then, each section's outer diameters (OD) and equivalent mud density (EMD) must be supplied. A well survey must convert TVD to measured depth (MD). The enclosure was designed for maximum force. Burst, collapse, and stress must be calculated to determine casing thickness and grade [27].

Maitham. Studied drilling Risk evaluation and management of deformation in a 9 5/8-inch casing at Abu-Ghirab and Halfaya oilfields by designing a new casing using Landmark software. The new casing design enhances the bulk and quality of the casing. In Halfaya oilfield, the best 9 5/8-inch casing characteristics are (Grade L80, Weight 53.5 lb/ft and Grade T95, Weight 53.5 lb/ft) while in Abu-Ghirab oilfield, they are (Grade L80, Weight 47 lb/ft and Grade T95, Weight 58.4 lb/ft). Change the kind of casing thread and increase the casing design's collapse and burst load safety factors in order to counteract the influence of external deformation caused by salt creeping and other extra pressure [28].

3.4. wellbore trajectory optimization studies

Researchers have done a lot of work on well bore stability for wellbore trajectory optimization.

Manshid et al, Mohiudin et al, and Yi et al. provided horizontal and deviated wellbore stability models [29-31]. Chabook et al. presented Rock strength requirements affect wellbore stability and trajectory [32].

There are many other studies available on applying trajectory optimization to meet the optimum horizontal well design mentioned below.

Azar and Samuel, Mitchell, Bourgoyn, and Rabia. presented Changes in the vertical and horizontal planes, Directional well planning and well profile [33,34,35,20].

Nie Zhen. The wellbore trajectory and drilling schedule for the JeribeeKirkuk reservoir in the Halfaya Oilfield were optimised. The trajectory optimization technique involves relocating the kick-off of the lower fars Jeribee Kirkuk directional well to Upper Fars. To lessen drill pipe sticking, the angle of inclination and deviated section length in Lower Fars are shortened. In addition, Geomechanic properties of the anhydrite salty layer in Lower Fars were examined. Using a mathematical model and criterion rules for wellbore deformation and stability in Lower Fars formation with various stratigraphy, the wellbore deformation during well drilling was simulated. So far, it has been used in 22 wells, proving that the intricacy of drilling a 311.2 mm hole has been handled [36].

AL-Jawad et al. They demonstrated horizontal well design features in Ajeel field to increase productivity. Elements of design include bit select and casing diameter, determination of setting depths and mud density, hydraulic systems, well geometry, and drill string simulation development. Lastly, the recommended short-radius horizontal well with a build rate of 90 degrees per 100 feet can be done without exceeding the drill string's strength limits [37].

Carden and Grace. Calculated torque and drag for various profiles. The influence of construction pace and ultimate inclination on predicted drag was evaluated in 16 situations. 1°, 2°, and 4° /100 ft were used in the computations. At each construction rate, four computations yielded 35°, 40°, 50°, and 60° inclinations. In each case, a 0.25 friction coefficient was assumed throughout the well. All variables were held constant except build rate, launch point, and ultimate incline. Lowering the build rate to 1°/100 feet and building to 60° reduces trip out drag by 29.90%. To achieve the same goal, the hole must be 1,348 feet longer and drill pipe delivered logging may be needed. The 29.90% drag reduction may not be worth the additional drilling and logging expenditures. The start line would move from 3,970 to 7,111 feet. Building to 60° at 1°/100' instead of 40° at 2°/100' would cut directional drilling expenditures. Building at slower rates and steeper angles reduces drag. Higher speeds and lower inclinations provide more drag. Extended reach wells require greater torque and drag to reach ultimate depth and be cased [38].

4- Future Research

In this study, we investigated that no one has tried to just look at how advanced drilling technologies effect on optimization of the drilling well design Therefore, it is proposed to review down hole enlargement technology such as bi-centre bit and hydraulic reamer for optimizing drilling well design. Moreover, managed pressure drill technique capability for eliminating casing string. Not only that, special well design structure such as multilateral well with directional coiled tubing drilling (CTD) and lean well profile design with technological solution of straight hole drilling device (SSD) should be reviewed extensively.

5- Conclusion

After reviewing a lot of studies and papers regarding the optimal method for designing a well, we can conclude that well design should be optimized in different stages of well planning to achieve drilling performance and reduce drilling cost without drop in well productivity. Slim hole design is one of the optimization process which is cost effective and less risky than conventional (Fat) design. Slim Hole Drilling offers new oil industry options and field development costs can be lowered significantly. In addition, casing seat selection process should be optimized in such a way so that safe well control requirements and well integrity can be achieved. Good practical directional profile and planning helps overcoming the associated challenges. Casing design base that takes into consideration all of the expected loads confirm that mechanical integrity of the well is maintained.

Nomenclature

CSD	casing setting depth
ft.	foot
in.	inch
NPT	Non-productive time
Pc	collapse pressure
Pb	burst pressure
Pe	external pressure
Pi	internal pressure
PPG	pound per gallon
ROP	rate of penetration

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امثلية تصميم بئر الحفر

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الخلاصة

تحسين تصميم حفر الآبار يقلل من إجمالي النفقات الكلية من خلال تقليل وقت إنشاء البئر ونفقاته. تصميم البئر ليس نمطًا ثابتًا خلال وجود الحقل. لذلك يجب تحسينه من خلال التحسينات المستمرة لجميع جوانب إعادة تصميم البئر اعتمادًا على الظروف الحقلية الفعلية والمشكلات المرافقة لها. الهدف الأساسي من هذه الدراسة هو تقديم مراجعة عامة لعمليات تحسين تصميم البئر والدراسات والتطبيقات المتاحة لتوظيف تحسين تصميم البئر لحل المشكلات التي تواجه تصميم البئر بحيث يمكن تحقيق اكثر فعالية من خلال تقليل التكلفة وتحسين ادائية بئر الحفر بصورة مثالية. تشمل عمليات تحسين تصميم الآبار تصميمًا غير تقليدي (بئر نحيف) مقارنةً بالتصميم التقليدي، بالإضافة إلى تحسين اختيار عمق تثبيت وأحمال البطانة. أخيرًا، عرض اعتبارات تحسين تصميم مسار البئر من أجل تقليل استعصاء الأنابيب والوقت غير الإنتاجي.

الكلمات الدالة: امثلية تصميم بئر الحفر، تحديد مواضع البطانة، تصميم البطانة، مسار الحفرة.