Journal Homepage: http://ijcpe.uobaghdad.edu.iq
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 25 No. 2 (June 2024) 49 – 59
EISSN: 2618-0707, PISSN: 1997-4884

Torque and Drag Analysis for Horizontal Extended Reach Coiled Tubing Drilling

Mustafa M. Alezzi [a, *], Ali Khader [b], Aiham S. Kader [a]

a Drilling Department, Field Devision North Oil Company, Ministry of Oil, Kirkuk, Iraq
b Materials and corrosion, Aeronautical/ Mechanical Engineering Department School of computing, Science and Engineering, University of Salford Manchester, UK

Abstract

One of the major elements faced in downhole drilling operations of oil and gas wells is the limited reach of coiled tubing (CT) in horizontal wellbores. To address this issue, this work creates an extended reach limit simulation of CT with starting bending curvature in a horizontal wellbore for an Iraqi well in the Ahdeb oil field. Using Drillbench software, a calculation approach is provided based on contact force and buckling models to determine the extended reach limit of CT. The findings of this study have significant implications for improving downhole drilling engineering design parameters and predicting the extended reach limit of CT. By considering factors such as friction resistance and contact force between the wellbore, a more accurate assessment of the CT's abilities can be suggested based on well trajectory curvature and well devotion. To achieve this, a slim open hole with a diameter of 6 inches was drilled to a measured depth ranging from 3755 to 3986.5 m. The results showed that a consistent trend in azimuth and inclination in the completed section, with the hook load increasing by about 25 tons during pickup and decreasing by 11.4 tons during slack-off along the curved section due to friction effect. Additionally, elongation and relative stress showed slight increase during pickup in curved areas due to friction and temperature effect, while values decreased during slack-off due to drag action. Pressure loss in the curved section was found to be lower compared to the vertical section, primarily due to the bit nozzle discharge effect. Eventually, the friction coefficient values remained within acceptable industry limits. Ultimately, the study determined limited extended lengths for CT in this horizontal well.

Keywords: *Coiled Tubing Drilling; Torque, Drag; Horizontal wells; Extended each.*

Received on 18/09/2023, Received in Revised Form on 06/04/2024, Accepted on 06/04/2024, Published on 30/06/2024

https://doi.org/10.31699/IJCPE.2024.2.5

1- Introduction

The coiled tubing industry grew quickly in the 1980s, and it has continued to develop ever since [1]. It has been effectively used to re-drill existing wells, deepening, side tracking and horizontal well [2]. Because it can save expenses overall, this technology has gained more appeal among operators [3]. Modern CT provides a number of benefits including rapid mobilization, cheaper cost, accelerated operations without the need to pause and connect tubing joints, and relatively high load capabilities for deeper vertical and high-angle reach [4]. The CT length in horizontal wells is still constrained and cannot match its design length [5]. The CT buckling behaviour and the axial force transmission in wellbore circumstances need to be modelled with considerably more precision due to the drastically expanding uses of CTD [6]. Kjell-Inge Sola [7] presents a simple, yet reliable and efficient tool for extending the reach of CT. using a tool called CT Friction Drag reducer (FDR). Calculations based on a simple physics-based model predict that the reach can be extended by over 3000 meters in a horizontal well with a measured depth to true vertical depth ratio (MD/TVD). Jiang wu [8] examined the load transfer and CT buckling that occur during drilling and maximum length of horizontal wells. He concluded that CT buckles in vertical and horizontal sections while build section witnessed rarely buckling. In order to improve axial force transfer, decrease buckling, and extend the limited reach of coiled tubing (CT), J. Abdo [9] assessed the effectiveness of three lubricants. He found that while lowering the friction coefficient (COF) does not change the shape or mode of CT buckling, it does change the initiation and transition between buckling modes and lengthens the lock-up length. In the curved borehole, Yue Qianbei [10] investigated the critical loads of helical and sinusoidal buckling for the CT under bottom weight-on-bit for 23/8 inches CT. The extended length limits for CT under various weight-on-bit and friction coefficients are obtained. In order to explain the behaviors of complete buckling and axial force transmission for (CT) with residual bending in a horizontal well, Zheng Liang [11] constructed an explicit FEA (finite element) model. The findings indicate a CT with residual bending is more prone to buckle than a CT that is straight. In a horizontal wellbore, Jiantao Zhang [12] develops an extended reach

*Corresponding Author: Email: petrolman1982@gmail.com

limit calculation technique of CT with initial bending curvature. The outcomes show that the extended reach limit of CT may efficiently increase by decreasing the initial bending curvature or friction factor. Sinusoidal buckling would be the first buckling shape of coiled tubing whenever compressive loads exceed the critical buckling. Further increase in compressive loads will result in helical buckling of coiled tubing [9]. A schematic of coiled tubing buckling in a horizontal wellbore is shown in Fig. 1.

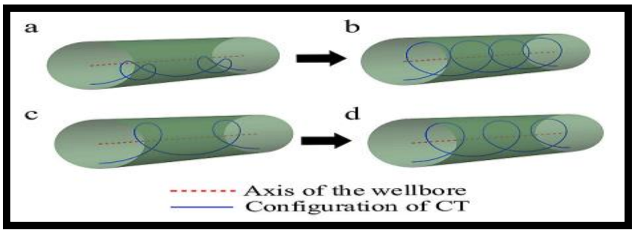

Fig. 1. Configurations of CT in a Horizontal Wellbore: (a) Initial Sinusoidal Buckling, (b) Helical Buckling from Initial Sinusoidal Buckling, (c) Initial Helical Buckling, (d) Helical Buckling from Initial Helical Buckling [12]

Friction reduces the stability of the CT to reach operating depth as the lateral length increases [13]. The inability to achieve the desired depth may cause the CT to buckle and potentially self-lock [14]. In coiled tubing drilling, the effects of torque on helical buckling are problematic [15]. Once the CT is forced into a helix, the force required to push it further into the well increases noticeably [16]. The usage of downhole motors rather than standard rotary drilling has expanded as a result of the use of CT to drill horizontal holes [17]. Although these technologies bring significant savings, but also have problems related to buckling lockup, and fatigue. This research analyses the coiled tubing buckling in horizontal wells consisting of vertical, curved, and horizontal sections using a simulation model to predict the maximum horizontal length that can be drilled and CT lockup possibilities.

2- Buckling of Coiled Tubing

In drilling applications, The CT is subject to local friction resistance and bottom weight-on-bit, with the exception of its own dead weight. Effective weight-on-bit activity and entry of the CT into the wellbore are limited by poor stiffness, which also causes the CT prone to bend instability and significant random contact with the wellbore, both of which increase friction resistance. In horizontal or directional wells, this will have a significant impact on CT's passing and operating capacity. Consequently, studying post-buckling behavior is essential for CT use [10]. Although CT can buckle in every wellbore, the axial compressive load required to cause buckling varies depending on the wellbore. Fig. 2 shows CT tripping into a wellbore with an initial bending curvature.

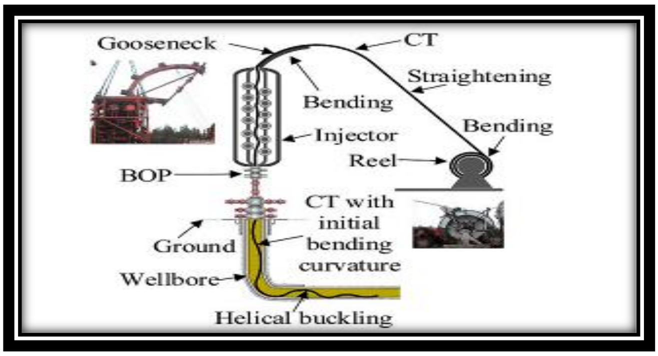

Fig. 2. Schematic of CT Tripping into a Wellbore with an Initial Bending Curvature [12]

2.1. In Inclined Wellbores

The CT in an inclined wellbore is compressed as a result of frictional force and bit weight. The CT will buckle sinusoidally when the axial compressive force reaches the critical (sinusoidal) buckling load [18] as shown in Eq. 1:

$$F_{cr} = 2\left(\frac{EIW_e}{r}\right)^{0.5} \quad (1)$$

Eq. 2 illustrates that helical buckling will happen when the axial compressive load reaches the following helical buckling load F_{hel}.

$$F_{hel.} = 2(2 \times 2^{0.5} - 1)(EIW_e/r)^{0.5} \quad (2)$$

Where r: An annular space or radial clearance between the CT and the wellbore, W is the buoyant weight per unit length, and EI: is the bending stiffness of the segment.

2.2. In Vertical Wellbores

When "slacking off" the weight at the surface to apply bit weight or to force the coiled tubing into the horizontal portion of a vertical wellbore, the bottom of the coiled tubing will be in compression. The coiled tubing will buckle if the compressive load is greater than the critical (sinusoidal) buckling load. For drill strings in vertical wellbores, Lubinski defines a critical buckling load as shown in Eq. 3 below. [18].

$$F_{cr,b} = 1.94(EIW_e^{\,2})^{\frac{1}{3}} \quad (3)$$

3- Methodology and Case Study

3.1. Application of Friction-master

Checking the amount of torque and force that can applied to the bit, the horizontal section that can reached, and the actual string length in a particular situation are all crucial. If these concerns not addressed, it may lead to wells that do not fulfil the standards, with the eventual outcome being a low return on a big financial investment. Before the coiled tubing locks up or undergoes plastic deformation, the critical buckling force may be substantially surpassed. Thus, for coiled tubing, the operating criterion should be lock up and pipe failure. A helpful package of software called Friction-master (Drillbench) is essential for drilling engineers working on horizontal or deviated wells. It can forecast lockup and the maximum run-in depth by computing mechanical characteristics like as force, stress, torque, circulation pressure losses, and along-hole depth adjustments [19].

Important issues to study are:

- Can the wells be drilled with the current equipment?
- Can be maintained with the current equipment?
- Find the lock-up or maximum run-in depth.
- Calculating force, stress, torque, and circulation pressure losses during work-over and drilling operations.
- Cutting transportation and along-hole-depth corrections during work-over and drilling operations.

3.2. Introduction to the example well

The well selected for this case study is a horizontal well drilled recently in Ahdeb oil field in Iraq by using a conventional drill string. The well is designed to have one single build section after the kick-off point followed by a horizontal section. The kick-off point for this particular well is set at (2066.04m) and the build section from this depth to (2906.46m). From this depth onwards the planned target at (3755m) has been drilled horizontally as a target. Furthermore, an extension was made to the horizontal section from depth (3755) to (3986.48) to see the capability of using CT drill rigs and strings for deepening horizontally by designing and modeling it in terms of Torque and Drag. In addition, we have designed a drill string for the CT purpose. However, because of the tiny size of the holes, the weight of the bit and high-speed motors provide penetration rates that are equivalent to those of rotary drilling. In this simulation, we experimented with a variety of strings along with their components and drilling parameters, such as bit weight and rotation speed until we found a string design that was appropriate for the observed depth. Oil-based mud has been chosen rather than water-based once owing to many aspects such as high drilling rates, lowered drill pipe torque and drag, less bit balling, and reduction in differential sticking.

3.3. Well Trajectory

Total Measured Depth = 3986.48 m. True Vertical Depth = 2644.434 m. Horizontal Displacement = 1524.41m. Drill String Total Length = 4020.161m. 7 in Casing Shoe Depth = 2957.48 m. Casing Inner Diameter = 6.457 inch. Fig. 3 shows the trajectory of the proposed well and its survey parameters are shown in Fig. 4.

Table 1 demonstrates the hole profile for the entire well section. The above parameters have been modeled and designed to attain a completely sustainable and efficient wellbore trajectory, thereby meeting the set target direction for the entire well section. It basically shows the starting and setting depth for each section leading to the final destination of the well. Fig. 5 reveals the wellbore geometry for the proposed well.

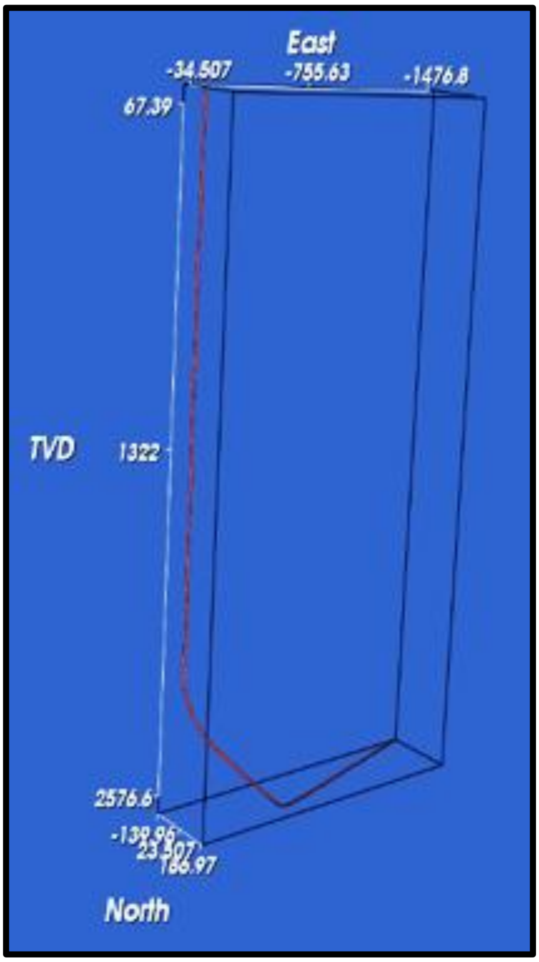

Fig. 3. Trajectory of the Well Section

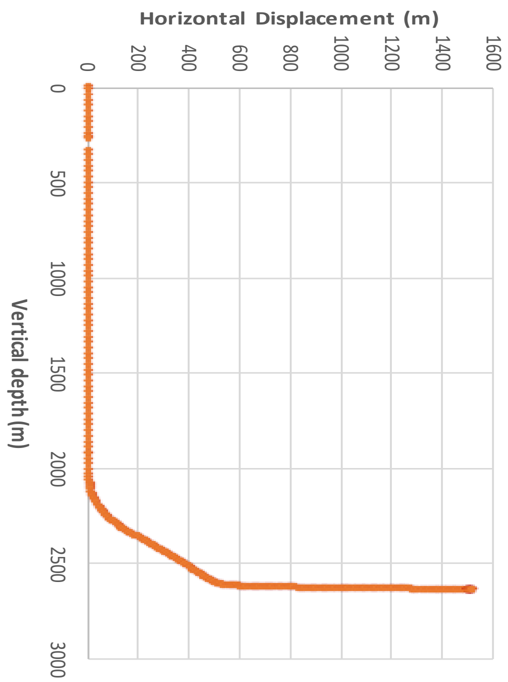

Fig. 4. Survey Parameters

Table 1. Hole Profile

Section	*Diameter (in)*	*Start MD (m)*	*End MD (m)*	*Length (m)*
20" Section	20.000	0	261.5	261.5
13 3/8" Section	13.374	0	1676.9	1676.9
9 5/8" Section	9.620	0	2857.6	2857.6
7" Section	7.000	2803.8	2957.5	153.7
6" Section	6.000	2957.5	3986.48	1028.98

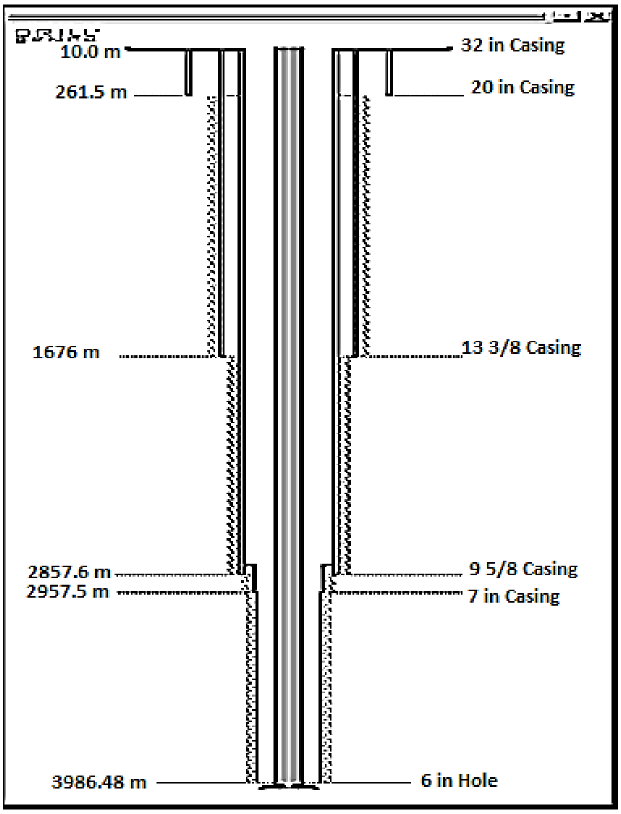

Fig. 5. Well Bore Geometry

3.4. Bottom Hole Assembly/Work String

In the CT drill string, as shown in Table 2, the weight on the bit is limited due to the fact that the string itself required most of the string weights to keep itself in tension and avoid the possibility of lock-up occurring(stop drill string) when the axial force passes the helical force of the string.

3.5. Drill Bit

Fig. 6 reveals the drill bit input parameters. Most horizontal wells CT drilling is dominated by (PDC) bits due to its successful development of a micro-hole CT turbo-drill and high-speed.

3.6. Drilling Mud

Drilling fluid for this horizontal well is oil-based mud (OBM). Water based mud was not chosen for drilling the open hole of 6-inch section, this is because OBM plays an important role in hole cleaning and efficient drilling in horizontal wells. Thinner drilling fluid with low plastic viscosity is often preferred in horizontal wells for good flow rate and to reduce equivalent circulation density. Therefore, the oil/water ratio is set to be at (80/20) as shown in Fig. 7.

4- Results and Analysis of Data

This section will demonstrate the output obtained from running the simulation and analysis of the results achieved. Fig. 8 shows the variation in inclination and azimuth for the entire well section. The build and end of the curvature section can relate to the change in inclination starting from 1.57 degrees at depth 2039.14 m to 82.1 degrees at 2906.46 m. In terms of Azimuth, it is obvious from the graph that the Azimuth within the vertical section has a fluctuation trend compared to the horizontal section, which witnessed a steady trend because keeping the well path towards the planned target is considered one of the most important issues during drilling operations.

Table 2. Work String Input

Component	**Type**	**Section length(m)**	**Inner Diameter(in)**	**Outer Diameter(in)**	**Weight/Length (kg/m)**	**Distance from Bottom(m)**
	Components are specified from bottom to top					
4 3/4Mix BHI	**Motor**	3.2	1.799	4.748	56.55	3.5
MWD	**Mwd**	1.0	1.500	5.000	90.38	4.5
MWD	**Mwd**	6.2	3.080	5.000	86.31	10.7
MWD	**Mwd**	1.0	1.500	5.063	92.88	11.7
DUALFLAPER VALVE	**Custom**	0.4	1.020	2.750	56.55	12.1
MWD	**Mwd**	0.9	1.563	5.063	92.88	13.0
Thruster Single 6.5"	**Custom**	1.4	2.000	4.750	94.43	14.4
NM SUB	**Custom**	0.9	1.375	5.000	79.20	15.3
TOOLSTRING CENTERLIZER	**Custom**	0.5	1.375	2.875	81.85	15.8
CIRCULATION SUB	**Custom**	1.1	2.000	3.748	85.92	16.9
HYDRAULIC DISCONNECT	**Custom**	0.6	0.875	2.875	37.20	17.5
NON-ROTATING JOINT	**Custom**	1.3	1.000	1.812	74.41	18.8
CHECK VALVES	**Custom**	1.1	1.750	2.875	96.73	19.8
CT CONNECTOR	**Custom**	0.3	1.000	2.750	34.87	20.2
COILED TUBING	**Drill pipe**	4000.0	2.563	2.875	8.13	4020.2

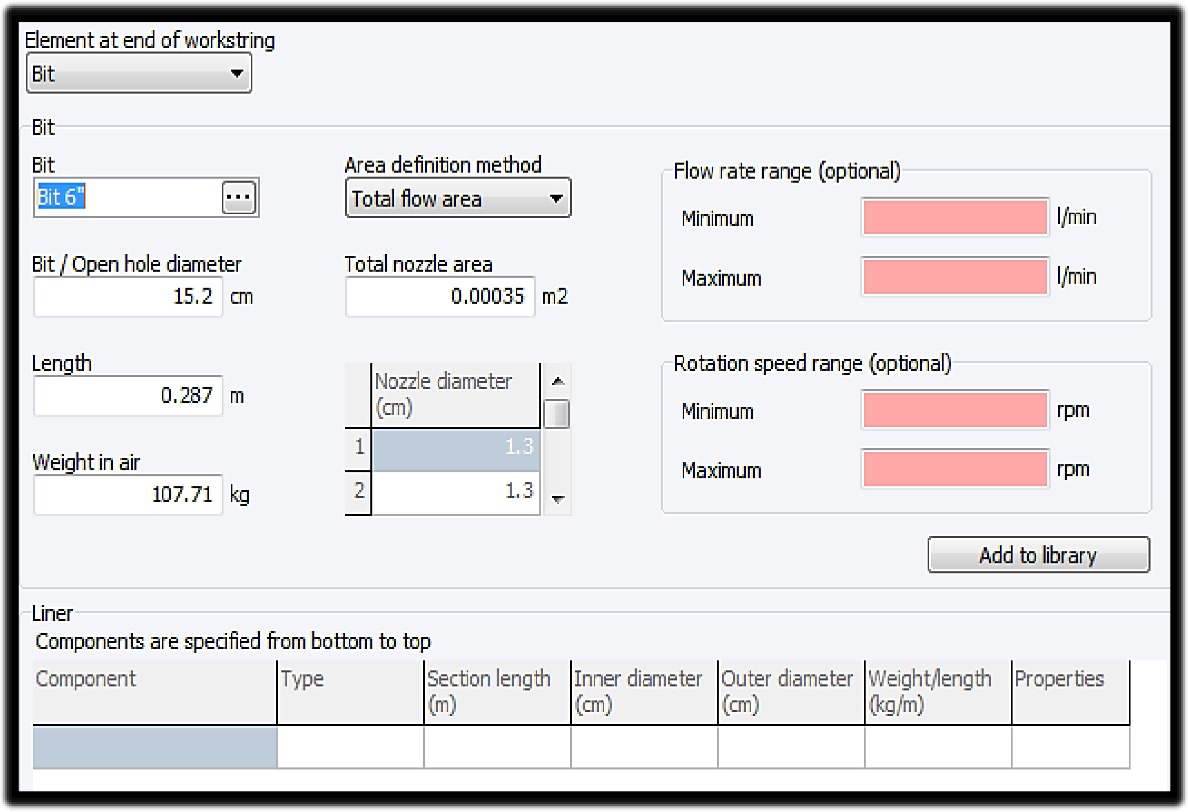

Fig. 6. Input Parameters of Drill Bit

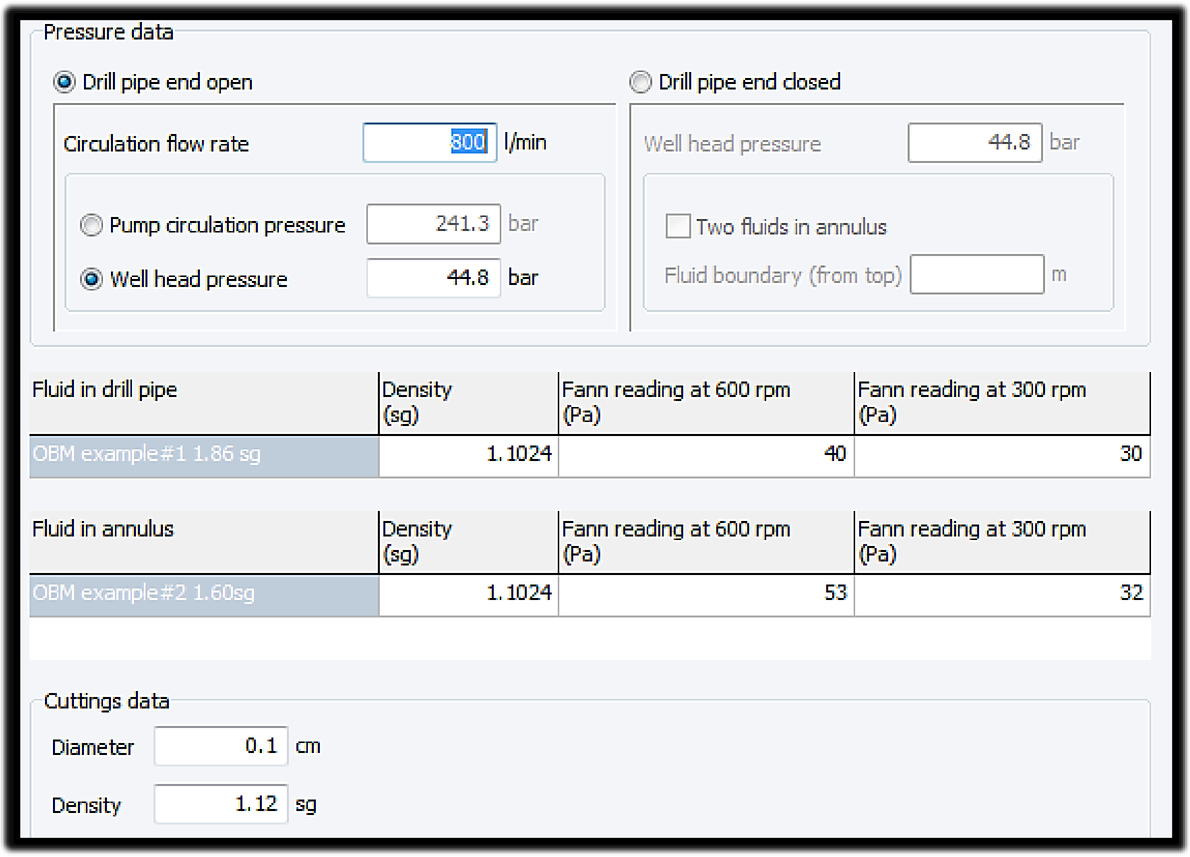

Fig. 7. Input Parameters of Drilling Fluid

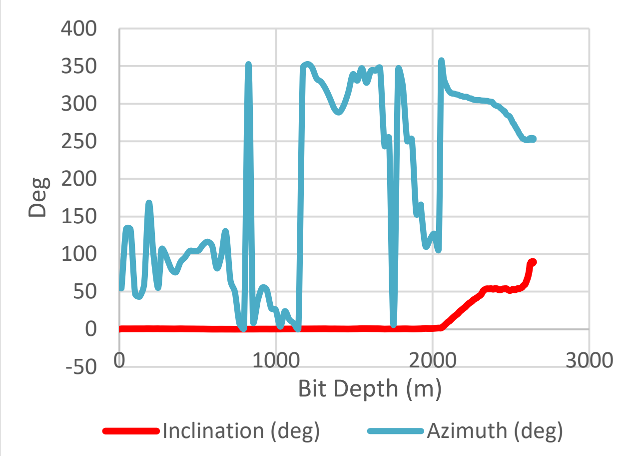

Fig. 8. Bit Depth versus Inclination and Azimuth

4.1. Hook Load during Pick-up/Slack off

Fig. 9 shows the measured hook loads during pick-up and slack-off. A hook load is the real weight of the drilling string seen at the surface which is a function of drill string length, well geometry, and bottom hole assembly. Various trends will appear depending on the well path and work string configuration. It is evident from the graph that the tensions along the string during slack-off and pick-up increase around 120 KN and 145 KN respectively within the vertical section, which increases as depth increases. Regarding the Curved and horizontal sections, the hook load weight will increase slightly during the pick-up operation at about 205 KN at the beginning of the withdrawal drill string and decrease during slack off to 95 KN at the final depth because while the drill string moving upward, the friction action between the string and the wellbore took place.

However, as the drill string moves downward (slack-off), the hook load will decrease to about 11.4 tons at the end of the wellbore because the string will push itself downward due to the gravity effect and a part of the string will lean on one of the wellbore sides which eventually decreases the hook load weight reading.

4.2. Elongation during pick up and slack off

The length of the drill pipe changed by axial forces and/or temperature at a specific measured depth is known as elongation. Because of the temperature in the bottom hole, the drill string will elongate. When the temperature rises to 100 degrees Fahrenheit, the pipe will stretch by around 0.83 inches every 100 feet. Calculating pipe elongation requires knowledge of both the surface and bottom hole temperatures. Eqs. 4, 5, and 6 are used to determine pipe elongation [20]:

$$\text{Average Temperature} = (\text{Bottom Hole Temperature} + \text{Surface Temperature}) \div 2 \quad (4)$$

$$\Delta\ \text{Temperature} = \text{Average Temperature} - \text{Surface Temperature} \quad (5)$$

$$\text{Pipe Elongation} = (L \div 100) \times (\Delta\ \text{Temperature} \div 100) \times 0.83 \quad (6)$$

Where: Average Temperature, Bottom Hole Temperature, and Surface Temperature are in F degree, Pipe Elongation is in inch. L is the total length in feet.

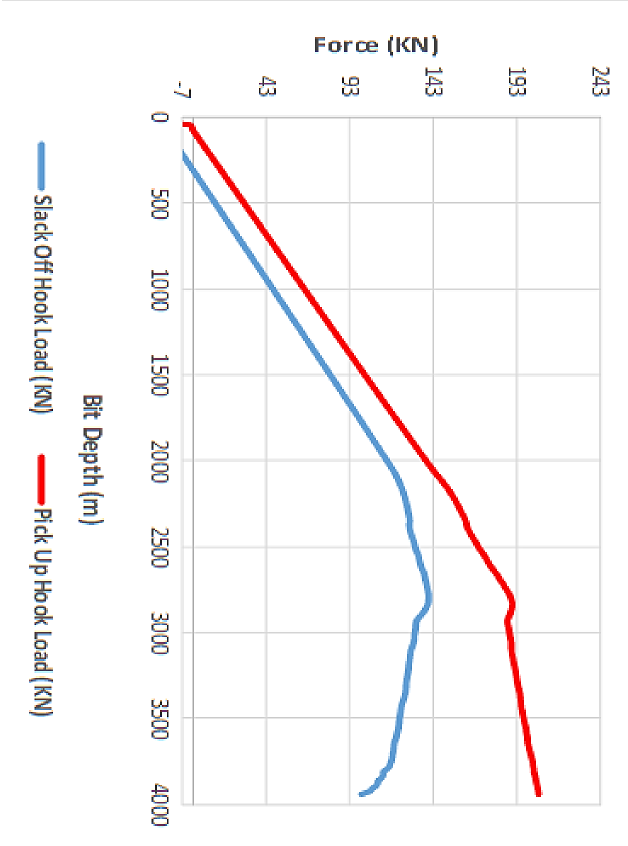

Fig. 9. HookLoad versus Bit Depth during Pick-up and Slack-off

Fig. 10 shows pipe elongation during pick-up and slack-off. Generally, the elongation is a function of the force applied on the drill pipe, length of the pipe, material elasticity, and cross-section area of the pipe. The formation temperature plays an important role in elongation, and this can be proved using the thumb rule which states that "Pipe will elongate per 100-degree Fahrenheit increase in temperature". It is usual that the temperature will increase as the pipe moves downwards and this is proven in the mentioned figure at the open hole section. This in turn will affect the elongation of drill string as well the CT has different body physical properties and is less rigid compared to the conventional drill string, which will allow more temperature effect on the string. As shown in Fig. 10, the patterns of pick-up and slack-off curves are different noticeably. While slack off, from the surface to the end of the curved section, a dramatic increase in elongation was witnessed by almost one meter. Up to the end of the hole, the elongation decreased to 0.2 m owing to string compression because of drag and weight on bit-provided actions which increases friction issues in the open hole section and therefore minimizes hook load reading. On the other hand, the string had a considerable elongation due to pulling force during the pick-up operation by 2.1 m at the target and decreased steadily up to the surface. This is because while pick up, the contact force between the string and formation increases as the inclination angle increases.

4.3. Relative Stress during pick-up and slack off

For the purpose of calculating an equivalent stress resulting from the different load sources, the von Mises Stress criteria were applied. Along with the stress brought on by axial force, torque, hydraulic forces (ballooning), and a potential increase in axial force owing to helical buckling are all taken into consideration. To obtain the Relative von Mises Stress, the von Mises Stress is first divided by the yield stress at the actual measured depth. Fig. 11 shows the relative von Mises stress along the well section intervals. It can be noticed that the acting stresses on the drilling string increase as the bit depth increases.

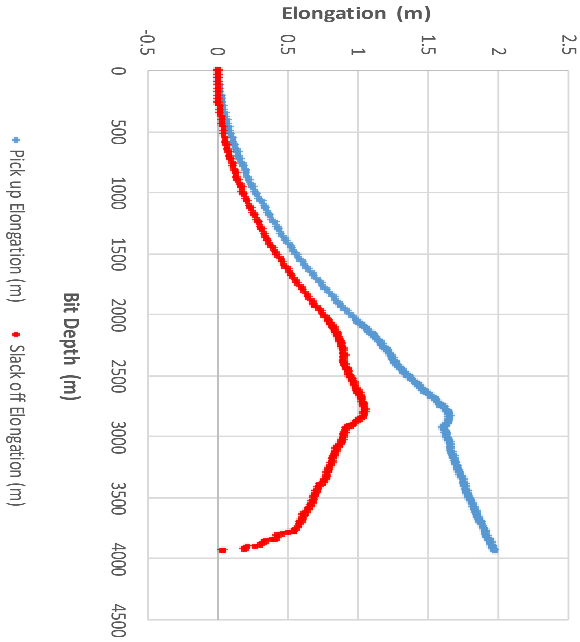

Fig. 10. Elongation versus Bit Depth during Pick-up and Slack-off

4.4. Force

An important simulation output is to check whether buckling occurs or not. This can be checked by running force distribution and looking at the axial and helical force versus the measured depth plot. Buckling occurs in the part of the drilling string that is under compression and only occurs when the compression exceeds the critical buckling value of this part. Fig. 12 presents the axial and helical force in the given measure depth. Axial force is force that directly acts on the center axis of the drilling string and Helical is a critical buckling force of the drill string at a given depth. It can be noticed that axial force gradually decreases to zero at 1800 m, and then the value becomes negative in the remaining interval. Meaning that the drilling string after 1800 m is under compression. However, the helical (critical buckling force) curve had a high negative value in the build section from (2025-2960) m and low and almost fixes negative values in the horizontal section. Overall, the value of axial force is more than the helical force along the well except the intervals ranged from (1900-2030) and (2400-2620) ft which possibly will have sinusoidal buckling due to the fact that the difference between the two forces is not too much. Nevertheless, this can be eliminated by reducing weight by a bit or changing the drill string configuration by adding an additional part to the bottom hole assembly which in turn will provide more weight for the drill string to keep itself in tension and therefore avoid string buckling manner.

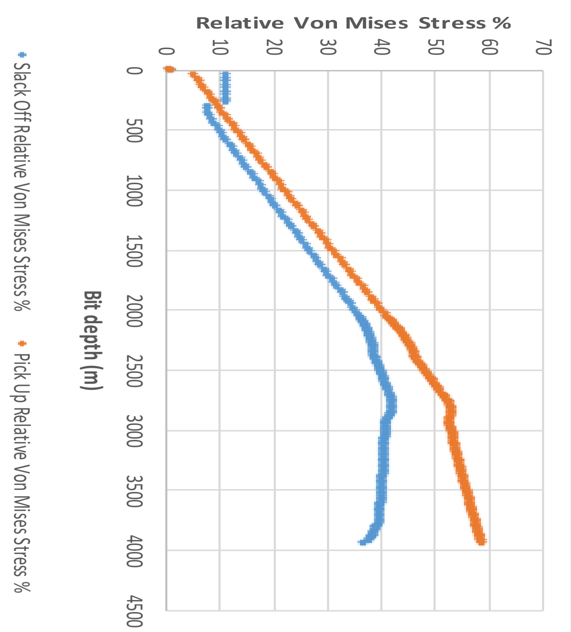

Fig. 11. Relative Von Mises Stress versus Bit Depth during Pick up and Slack off

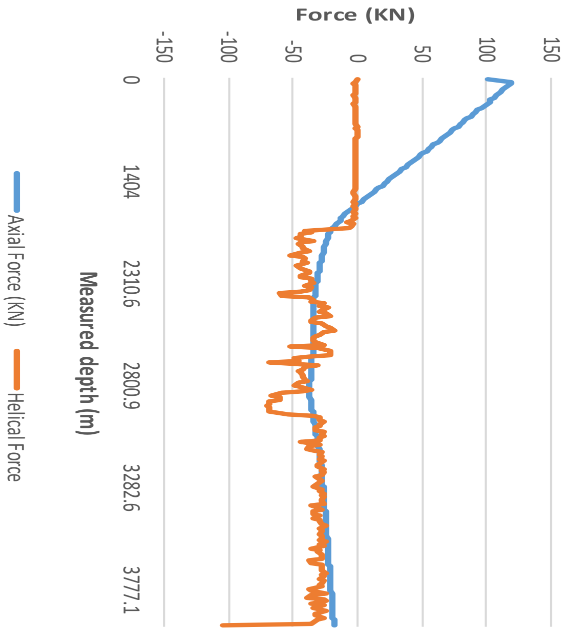

Fig. 12. Axial and Helical Force versus Measured Depth

4.5. Relative stress

Relative mechanical stress is the axial stress (axial force divided by string area) divided by yield stress at the actual measured depth. Fig. 13 shows the relative mechanical stress. The figure reveals that the relative mechanical stress is high at the vertical and build sections as well, but it decreases gradually to reach the minimum value at the target depth.

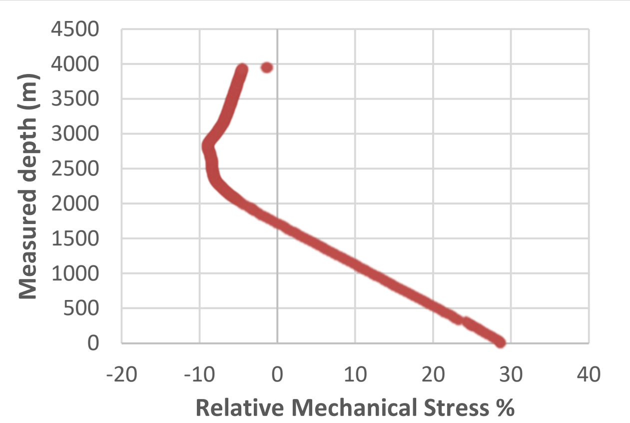

Fig. 13. Relative Mechanical Stress versus Measured Depth

4.6. Pressure

Fig. 14 presents the pressure in the fluid circulation at a given depth. Drilling hydraulics is an important factor of success in the drilling operation. Hydraulic capabilities are limited in CT drilling. The internal diameter of a CT string is relatively small, creating a large frictional pressure drop. The tubing has a maximum allowable working pressure, and the pump pressure must be kept well below this value to minimize tubing fatigue. As evident from the figure, in terms of pipe pressure, the pressure increases dramatically in the vertical section and curved section as well to reach a peak of 378 bar before decreasing in horizontal section (open hole section) to about 350 bar at the end of well bore due to the fact that throughout horizontal sections, the friction coefficient will raise rapidly compared to the vertical section as discussed earlier, therefore, most of the pressure loss occurred throw the drill bit nozzles. Regarding the annulus, the pressure behavior is quite similar to the pressure inside the string pipe in terms of vertical and curved sections. However, at the horizontal section, the pressure remains increasing to reach approximately 334 bar at the end of the drilled hole, this is because of the hydrostatic pressure of the mud column in the annulus.

4.7. Flow rate

Fig. 15 shows the critical flow rate versus measured depth. The critical flow rate is the lowest rate needed to transport the cuttings to the surface and it is considered a key parameter in determining effective hole cleaning. From the figure, we can notice that the required flow rate is low in horizontal and curved sections as well at about 8 (L/min). However, in annulus up to the depth of 260 m, an 18 (L/m) is sufficient to transfer the cutting. Whereas (44-120) L/min is required in the remaining interval of 7" casing up to the surface.

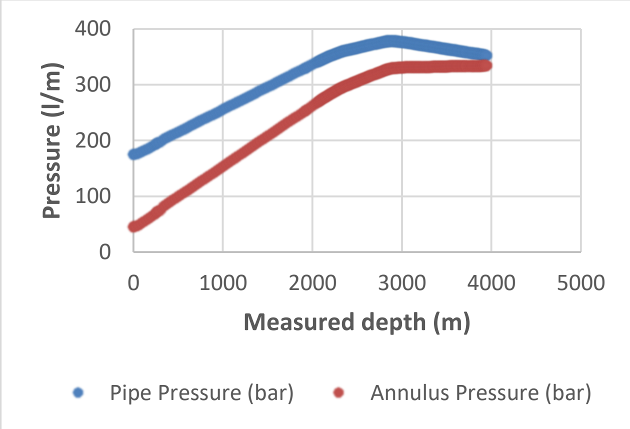

Fig. 14. Pressure versus Measured Depth (Inside Drilling String and Annulus)

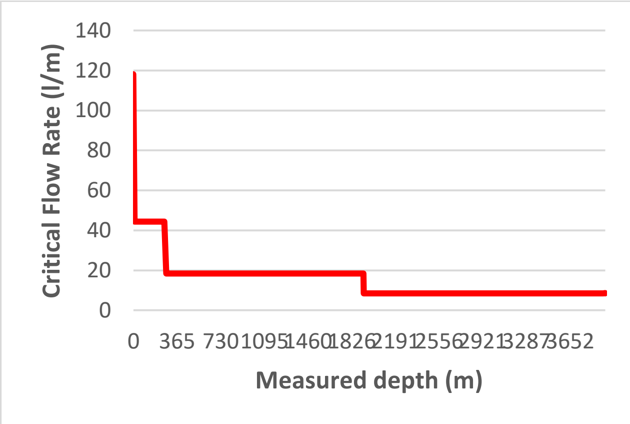

Fig. 15. Flow Rate versus Measured Depth

4.8. Friction Coefficient

The Drill String Friction Coefficient is a crucial component in determining the amount of normal force that is converted to drag or torque in a wellbore. The weight indicator is used to determine the pickup load. Data on wellbore geometry, the tension at the top of the drill pipe, and the drill string are entered into the computer software. Using various coefficients of friction, the software determines the tension needed to pick up the drill pipe until the estimated tension equals the tension indicated by the indicator. For that particular wellbore, the appropriate coefficient of friction is the one at which the observed tension and the estimated tension are identical [21]. Fig. 16 presents the friction coefficient versus hook load. In this good scenario, the cased hole friction factor for 20",13/38",9/58", and 7" casing are 18%,17%,19%, and 15% respectively. Whereas the open-hole friction factor is 14%. Running a sensitivity analysis can highlight whether the friction factor is appropriate corresponding to different hook load readings. As evident from the graph, the friction coefficient increases stepwise as the hook load decreases. The hook load decreases slightly while still maintaining effective weight on the bit. High motor rotation speed has an impact in decreasing friction factor which indirectly keeps the hole clean allowing successful drilling operation. It is without doubt that reducing the friction factor by any amount could significantly increase the opportunity for the driller to reach the planned target within a reasonable rate of penetration. Eventually, the friction factor for the entire well section is perfect and within the industry limit.

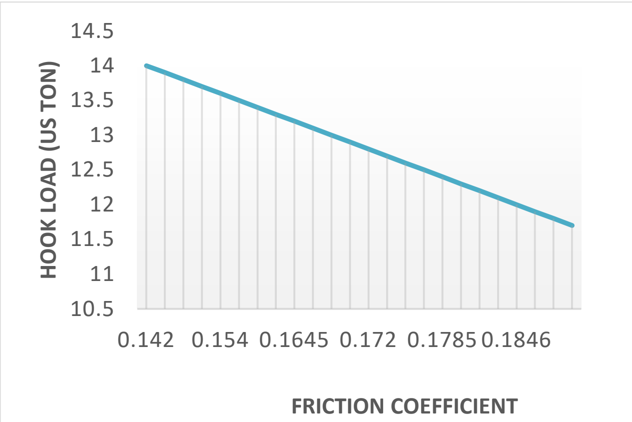

Fig. 16. Friction Coefficient versus Hook Load

5- Conclusions

The conclusions drawn from this study can be summarized in the following points:

- CTD can successfully be used as an alternative for conventional drilling rigs to deep existing vertical or horizontal wells.
- This paper presents a simulation method for the extended reach limit of CT with initial bending curvature in a horizontal wellbore, utilizing the buckling model and contact force model. The study shows the decrease in the extended reach limit is more significant when the initial configuration is helical buckling compared to sinusoidal buckling.
- The results enable accurate predictions of hook load, friction coefficient, and maximum horizontal section.
- The simulation results indicate that reducing the friction factor can effectively increase the extended reach limit of CT.
- Using Larger, heavier-wall tubing is essential for providing the necessary weight for effective drilling, as it can endure torque and wear during drilling due to its higher tensile strength.
- Optimization concerning the fluid type, string design, and chosen bits are all crucial for applying CTD for extended reach limits in horizontal wells.
- Controlling Weight on the bit factor plays a key issue in providing more weight on the drill string to keep itself in tension and therefore avoid string-buckling manner.
- Other factors for future works such as the effect of formation type with its existing stress have to be considered to have a full conception of CTD drilling capabilities.

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تحليلات عزم الدوران والاعاقة للآبار الافقية المحفورة سابقا وإمكانية تعميقها باستخدام تقنية الانابيب الملفوفة

مصطفى محمد العزي [١، *]، علي قادر [٢]، ايهم صالح خضر [١]

[١] شركة نفط الشمال، هيئة الحقول، قسم الحفر، كركوك، العراق
[٢] قسم الهندسة الميكانيكية، جامعة سالفورد، المملكة المتحدة

الخلاصة

ان من اهم التحديات التي تواجه استخدام تقنية الانابيب الملفوفة في حفر الابار الافقية هي مقدار العمق الممكن الوصول اليه. في هذه الدراسة تم اختيار أحد الابار المحفورة افقيا في حقل الاحدب في العراق واجراء محاكاة لعملية الحفر لزيادة عمق البئر باستخدام تقنية الانابيب الملفوفة بالاعتماد على أحد البرامج المستخدمة لهذا الغرض DRILL BENCH بالاعتماد على قوة الالتصاق والموديل الالتوائي. وبذلك يمكن مستقبلا الاعتماد على تقنية الانابيب الملفوفة والمستخدمة في هذه الدراسة لغرض تعميق الابار الافقية من خلال وضع التصميم الهندسي المناسب لعملية الحفر من خلال محاكاة العوامل المناسبة لذلك من خيط الحفر – سائل الحفر– الهيدروليكية– فقدان الضغط ....الخ. تم حفر مقطع بقطر ٦ انج والذهاب به الى نقطة اعمق في البئر المختار لهذه الدراسة (٣٧٥٥– ٣٩٨٦) متر. النتائج اشارت الى تطابق الميل والسمت في المقطع المحفور. بالنسبة لحمولة الخطاف, ازدادت الى ٢٥ طن خلال عملية سحب خيط الحفر وقلت بمقدار ١١طن تقريبا خلال عملية التنزيل ضمن المقطع المنحني نتيجة لعامل الاحتكاك. فيما يتعلق باستطالة خيط الحفر والاجهاد النسبي, شهد الخيط زيادة بسيطة خلال السحب في المقطع المنحني نتيجة لتاثير الحرارة والاحتكاك وقيمة قليلة اثناء التنزيل بفعل الاعاقة. فقدان الضغط في المقطع المنحني شهد معدلات قليلة مقارنة بالمقطع العمودي بفعل عامل التصريف لفتحات الحافرة. عامل الاحتكاك كان ضمن المعدلات المقبولة. أخيرا تم الوصول الى العمق المخطط له باستخدام الانابيب الملفوفة في هذا البئر الافقي.

الكلمات الدالة: الحفر بالأنابيب الملفوفة، عزم الدوران، الإعاقة، الابار الافقية، العمق الممتد.