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Investigate the Effects of Formation Cutting Transportation in Inclined Wells to Prevent the Occurrence of Mechanical Stuck Pipes in an Iraqi Oilfield

Mustafa A. Issa[1,2*], Muntadher A. Issa[2,3], Ali A. Al-Zuobaidi[1], Ayad A. Alhaleem A. Alrazzaq[2]

[1]Basra Oil Company, Ministry of Oil, Basra, Iraq.

[2]Petroleum Engineering Department, University of Baghdad, Baghdad, Iraq.

[3]Iraqi Drilling Company, Ministry of Oil, Basra, Iraq.

[*]Corresponding Author E-mail: m.issa1908m@coeng.uobaghdad.edu.iq

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Abstract

During drilling operations, cutting removal in deviated and vertical wells is one of the most significant challenges. It can cause high torque and drag, mud circulation loss, casing installation difficulties, poor cementing operations, and mechanical pipe sticking. These challenges can potentially increase non-productive time (NPT) and well costs. This study utilized Well Plan™ software to establish a hole-cleaning model for a specific well situated in the southern Iraqi oilfield. Thus, the minimum flow rate and cutting bed height necessary to ensure efficient cutting transportation from the borehole were calculated, resulting in the elimination or reduction of the mechanical pipe sticking problem. Subsequently, the influence of the drilling parameters on the removal of cuttings was examined by determining the minimum flow rate. The study's findings indicate that there is a direct relationship between the minimum flow rate and certain drilling parameters, i.e., plastic viscosity, penetration rate, well inclination, and cutting density. While inverse relationship with other parameters, i.e., yield point, drilling mud weight, and rotation speed of drill string. Additionally, the minimum flow rate that is obtained from Well Plan™ software is greater than the actual flow rate. For instance, during the run-in hole where pipe stuck occurs in the Tanuma Formation, the actual flow rate was 713 gpm, while the minimum flow rate and the cutting bed height that are calculated from this model are 970 gpm and 1.77" respectively. Ultimately, the research findings can be utilized to financially support upcoming drilling operations in the surrounding area of the study.

Keywords: Hole cleaning, Cutting removal, Minimum flow rate, Mechanical pipe sticking, Drilling parameters.

دراسة تأثير عملية نقل القطع الصخرية المحفورة لتقليل من حدوث الألتصاق الميكانيكي للأنابيب في أحد حقول النفط العراقية

الخلاصة:
تعد إزالة القطع الصخرية المحفوره من الآبار الاتجاهية والعمودية أحد أهم التحديات اثناء عملية الحفر. يمكن ان تسبب فقدان دورة طين الحفر، وصعوبات تجليس البطانات، وعمليات التسميت الضعيفة، و الالتصاق الميكانيكي للانابيب.من المحتمل أن تؤدي هذه التحديات إلى زيادة الوقت غير الإنتاجي (NPT) ونفقات حفر البئر. استخدمت هذه الدراسة برنامج Well Plan™ لإنشاء نموذج لتنظيف تجويف البئر لبئر محدد يقع في احد الحقول النفطية بجنوب العراق. حيث تم حساب الحد الأدنى لمعدل التدفق وارتفاع طبقة القطع اللازمين لضمان كفاءة نقل القطع من البئر مما يؤدي ذالك إلى التخلص أو تقليل مشكلة التصاق الأنابيب الميكانيكية. وبعد ذلك، تم فحص تأثير معاملات الحفر على إزالة القطع الصخرية المحفورة من خلال تحديد الحد الأدنى لمعدل التدفق. تشير نتائج الدراسة إلى أن هناك علاقة طردية بين الحد الأدنى لمعدل التدفق وبعض عوامل الحفر، أي اللزوجة البلاستيكية، ومعدل الاختراق، وميل البئر، وكثافة القطع الصخرية. في حين أن هناك علاقة عكسية مع المعاملات الأخرى، أي نقطة الخضوع، ووزن طين الحفر، وسرعة دوران سلسلة الحفر. بالإضافة إلى ذلك، فإن الحد الأدنى لمعدل التدفق الذي تم الحصول عليه من برنامج أعلاه، هو أكبر من معدل التدفق الفعلي. على سبيل المثال، اثناء تنزيل خيط الحفر الى داخل تجويف البئر، حدث التصاق في خيط الحفر في تكوين التنومة، و عندها كان معدل التدفق الفعلي 713 جالونًا في الدقيقة، في حين أن الحد الأدنى لمعدل التدفق وارتفاع مستوى القطع الصخرية المتراكة الذي تم حسابه من هذا النموذج هو 970 جالونًا في الدقيقة و1.77 انج على التوالي. واخيرا، يمكن استخدام نتائج البحث لدعم وتقليل تكاليف عمليات الحفر القادمة في المنطقة المحيطة بالدراسة.

1. Introduction

One of the most prevalent and complicated topics in drilling operations is cutting removal. It must be carefully monitored and managed during the well drilling operation. The drill cuttings are formed when the drill bit smashes the rock formation. Therefore, drilling mud circulation is an important aspect of the drilling operations. It is pumped into pipes and then returned through the annulus for cuttings transportation to surface facilities. The ability of drilling mud to transfer cuttings is referred to as a system's carrying capacity [1]. Improper hole cleaning and cutting bed accumulation can contribute to many drilling problems, especially when the minimum hydraulic requirements are not achieved. These issues include high torque and drag, poor cement job, lost mud circulation, difficulties running casing, and mechanical pipe sticking [2], [3]. The significant cuttings settling in the annulus may be the cause of these issues. In order to successfully drill directional and horizontal wells, hole cleaning is essential [4].

Cuttings and caves in deviated wells drop to the lower side of the hole, generating strata known as solid beds or cutting beds. As a result, the solid bed traps the drill string. Major factors that influence cutting removal in deviated wellbores, i.e., eccentricity, hole diameter, drill string diameter, hole angle, mean particle diameter, particle size distribution, particle shape, mud property, and operational variables. Incorporating all of these factors and their implications into a comprehensive mathematical model poses a significant and arduous issue[5], [6]. Moreover, many cutting removal case studies were first done in applications relating to vertical wells. The most essential factors that affect the wellbore cleaning in these case studies are the settling velocity, annular fluid velocity, and penetration rate [7]–[9]. Additionally, several researchers have conducted experiments to determine the factors influencing hole cleaning in horizontal and inclined wells. They concluded that hole cleaning effectiveness is influenced by drill pipe rotation, temperature, and the rheological qualities of the drilling mud [10]–[13]. Consequently, the challenge of cutting removal is substantially more problematic in inclined wells than in vertical wells [14].

Mechanical pipe sticking problems may be produced by an increase in cuttings collection in the annular area as a result of improper hole cleaning, particularly in deviated well drilling, when a stationary cuttings bed can form on the borehole's low side [15]. In this study, a mathematical model (hole cleaning model) was developed employing the Well Plan™ software. This model is based on the examination of the drilling parameters that influence cutting transport (i.e., plastic viscosity (PV), rate of penetration (ROP), well angle, yield point (YP), drill string rotation speed (RPM), mud weight (MW), and cutting size and density). Also, it may be utilized to calculate the minimum fluid flow rate necessary to avoid stationary cutting beds from forming through a deviated drilling operation and to study the impact of cutting transport on pipe sticking problems that occurred in one of the selected Iraqi oil fields through the different operations wells to minimize the cost and time.

2. Methodology

2.1. Area of Study

This study employed a field case in southern Iraq to address the issue of mechanical pipe sticking during drilling operations by identifying the optimum drilling flow rate that is required to remove the drill cutting effectively from the wellbore to the surface. The geologic column that includes many Iraqi oilfields spans from the Tertiary to the Upper Jurassic Ages, specifically extending from the Dibdiba Formation to the bottom of the Sulaiy Formation, as depicted in Figure (1). The composition primarily consists of substantial carbonate strata interlaced with clastic rocks. The Nahr Umr Formation (shale black), the Mishrif Formation (carbonate), and the Zubair Formation (clastic) are all important oil reservoirs in the southern Iraqi oilfield. Together, they hold large amounts of hydrocarbons that mostly come from the Cretaceous Period [16]. The investigation concentrated on the problematic section, i.e., the intermediate hole section (12.25") that spans from the Sadi to Shuaiba strata, as illustrated in Figure (1).

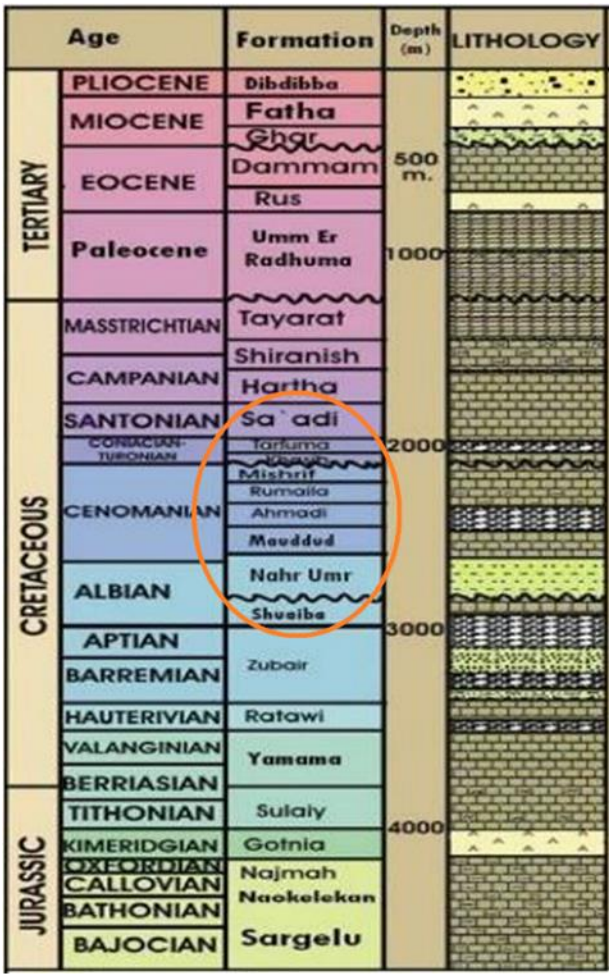

Fig. (1): Geological column of the southern Iraqi oilfields [17].

2.2. Statement of the Problem

Several well-related problems occurred during the drilling operation in the southern Iraqi oilfield. One of the challenges is mechanical pipe sticking, which arises from insufficient hole cleaning and borehole instability. Hence, the expenses and non-productive time (NPT) associated with drilling the wells will escalate. The area of interest in this investigation was the intermediate hole (section 12.25") that extended from the Sadi Formation to the top of the Shuaiba Formation (i.e., from 1850 to 3150 m), which exhibited very tricky and challenging intervals. An examination of the data's time distribution revealed that the duration required to drill section 12.25" accounted for approximately 28% of the total time, Figure (2). Approximately 20% of the total time (28%) allocated for drilling this hole section was squandered due to the NPT associated with the wellbore instability problems (i.e., tight hole, shale caving, loss mud circulation, and stuck pipe). While 80% of the total consumed time is attributed to the drilling time, tripping, well logs, etc. Furthermore, these issues can result in hole collapse, shale caving, inadequate hole cleaning, and tight spots, which can lead to drill string sticking. Therefore, the motivation behind this study was to mitigate the issue of mechanical pipe sticking.

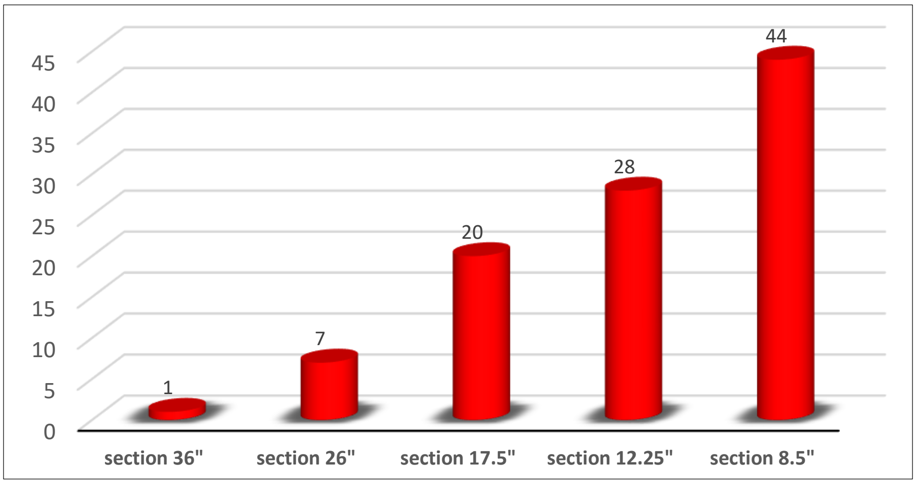

Fig. (2): Time distribution for drilling each section.

2.3. Hole Cleaning Model (Well Plan™ Software Model)

The Well Plan™ software model is one of the landmark programs of Halliburton Company. It is employed to determine the minimum fluid flow rate necessary to avoid stationary cutting beds during a deviated drilling operation. Additionally, it can analyze several drilling parameters, such as flow rate, fluid density, fluid viscosity, drill string rotation speed, hole inclination, rate of penetration, and cutting characteristics. Then, using this model, it is possible to examine the impact of these variables on the minimum flow rate. Figure (3) illustrates the input parameters that should be used to construct the hole cleaning model using Well Plan™ software, i.e., calculate the minimum flow rate and cutting bed height, thus achieving the best cutting transportation.

The design of the drill string and the geometry of the wellbore that was used to drill the well (section12.25”) were established utilizing Well Plan™ software, as depicted in Figures (4) and (5), respectively. The total depth of this well is 2762m, and it's drilled to the Mishrif formation with a maximum inclination of 57.47°. The section 12.25” of this wellbore is drilled to 2442m with an inclination angle of 56.12°.

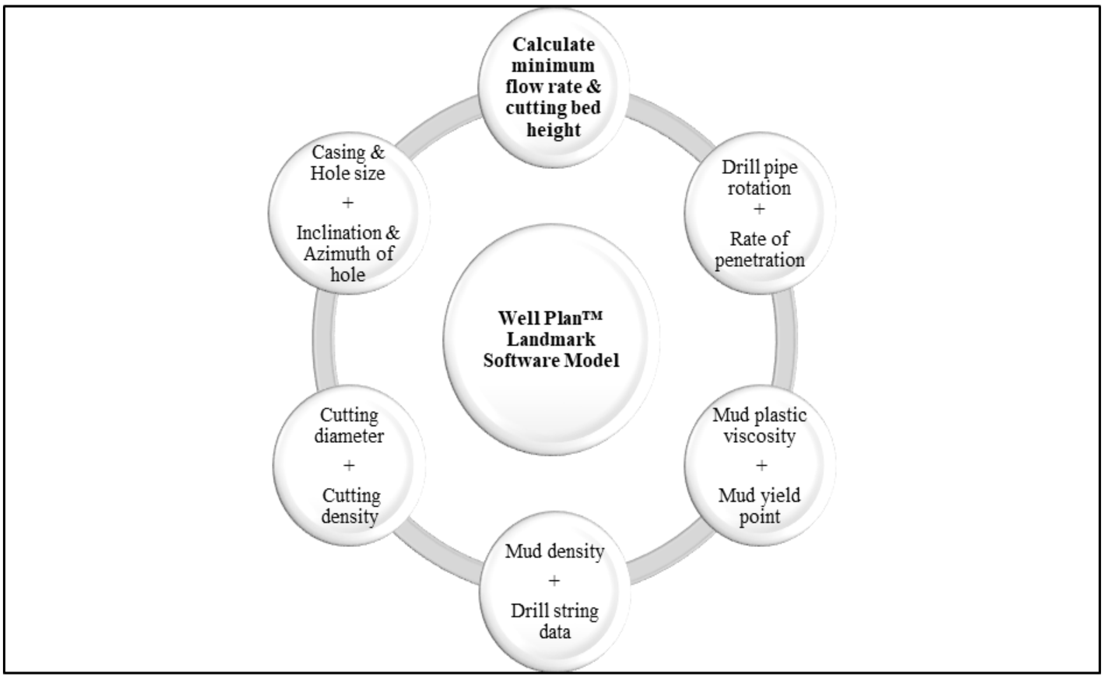

Fig. (3): Input and output drilling parameters in Well Plan™ software model.

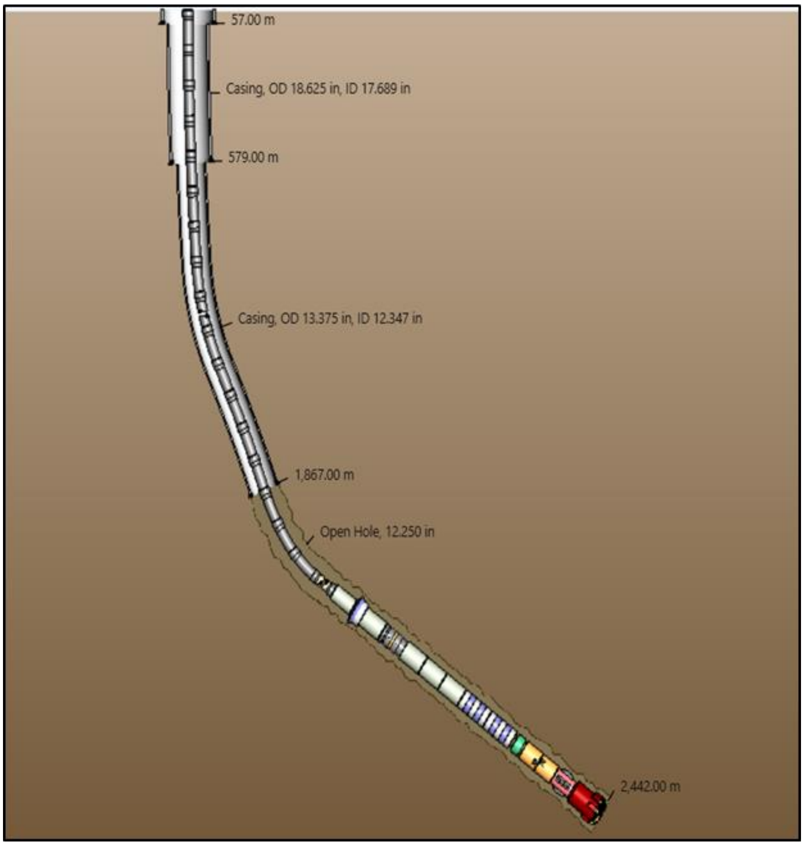

Fig. (4): Actual wellbore geometry section 12.25”.

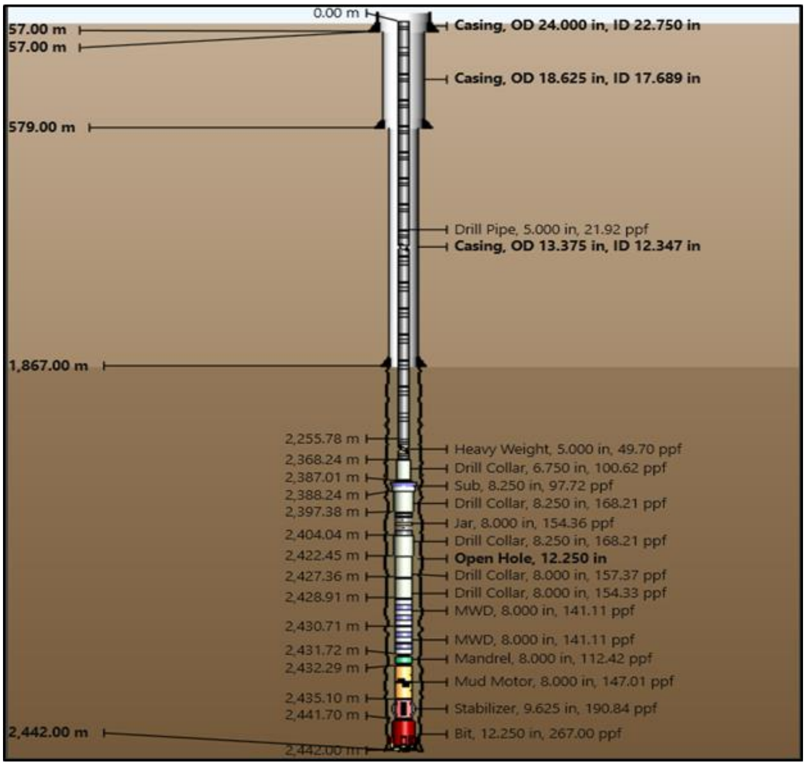

Fig. (5): Configuration of the drill string section 12.25”.

3. Results and Discussion

The minimum flow rate and cutting bed height of the borehole (12.25") for one well located in a south Iraqi oilfield were computed using the Well Plan™ software to ensure effective hole cleaning. The data for the input field through the pull-out of the hole (POOH) and run-in hole (RIH) are presented in Table (1). Additionally, the results of the minimum flow rate calculation for this well section 12.25" are also included in this table.

Many tight spots and instances of stuckness and slippage were detected at varying depths, exhibiting a range of overpull values ranging from 10 to 15 tons. For example, at depth 2387m (Tanuma formation), the drill string got stuck during RIH with reaming down and pumped out operation. This is due to the nature of the Tanuma formation, which consisted of shale (grysh olv grn, grysh grn, frm to sltly hp, fissl to sbfissl, sbbik, non-calc, and splntry), which is exposed to drilling fluid for a long period, thus the hole caving happened and a subsequent mechanical pipe sticking problem occurred. Moreover, upon conducting a comparison between the actual flow rate and the minimum flow rate that determined through the utilization of the well plan software, it was discovered that the value of the minimum flow rate (970 gpm) exceeded the actual flow rate (713 gpm). Simultaneously, the cutting bed height was measured to be 1.77 inches during the RIH operation. It is worth mentioning that, at the same depth, the actual flow rate observed during the drilling operation was 792 gpm, which falls below the minimum flow rate determined by the well plan software, which was 928 gpm. Additionally, the cutting bed height was measured to be 1.19 inches.

Ultimately, the most effective hole cleaning occurs when the actual flow rate exceeds the minimum flow rate. In this investigation, a comparison was conducted between the minimal flow rate derived from the well plan software and the actual flow rate observed during operation, and the findings indicated that the observed flow rate is lower than the minimum flow rate. Consequently, the occurrence of mechanical pipe sticking may occur under these conditions at any time.

Table (1): Presents the field data and results for the minimum flow rate and cutting bed height in section 12.25".

Formation	MD (m)	Angle	Fluid density (ppg)	YP (lb/100 ft²)	PV (cp)	RPM	ROP (m/hr)	Cutting density (gm/cc)	Cutting size (in)	Actual flow rate (gpm)	Minimum flow rate (gpm) by Well plan software	Cutting bed height (in) by Well plan software	Notice
POOH with back reaming & pump out													
Sadi	2045	29.8	10.43	24	18	90	3.5	2.71	0.245	634	730	1.56	Tight spots and stuck & slip
Sadi	2035	29.3	10.43	24	18	90	3.5	2.71	0.245	634	725	1.5	
Sadi	2026	28.7	10.43	24	18	90	3.5	2.71	0.245	634	722	1.46	
Sadi	2015	28.3	10.43	24	18	90	3.5	2.71	0.245	634	718	1.41	
Sadi	2006	28	10.43	24	18	90	3.5	2.71	0.245	634	715	1.37	
Sadi	1993	27.5	10.43	24	18	90	3.5	2.71	0.245	634	711	1.32	
Sadi	1933	26.5	10.43	24	18	90	3.5	2.71	0.245	634	700	1.16	
RIH with reaming down & pump out													
Tanuma	2387	55.97	10.43	24	18	60	3.5	2.6	0.245	713	970	1.77	Stuck pipe
Drilling operation													
Sadi	2045	29.8	9.85	23	17	80	6.2	2.71	0.245	766	809	0.71	
Sadi	2035	29.3	9.85	23	17	80	6.2	2.71	0.245	766	797	0.54	
Sadi	2026	28.7	9.85	23	17	80	6.2	2.71	0.245	766	793	0.49	
Sadi	2015	28.3	9.85	23	17	80	6.2	2.71	0.245	766	788	0.43	
Sadi	2006	28	9.85	23	17	80	6.2	2.71	0.245	766	785	0.38	
Sadi	1993	27.5	9.85	23	17	80	6.2	2.71	0.245	766	779	0.3	
Sadi	1933	26.5	9.85	22	15	60	6	2.71	0.245	740	766	0.5	
Tanuma	2387	55.97	10.43	24	18	90	4.5	2.6	0.245	792	928	1.19	

Regarding the investigation of the impact of the drilling parameters on hole cleaning through the utilization of the Well Plan™ software model, as shown in Table (2). In this case, an investigation is being conducted to analyze how different variables impact the efficiency of cutting transport. This is achieved by estimating the minimum flow rates while altering the drilling parameters. Let's consider a scenario where there are three data points at a specific depth for section 12.25" and examine the impact of the drilling parameters on hole cleaning by changing one parameter while maintaining the others constant, followed by calculating the minimum flow rate.

Table (2): Presents all the input data used to study the effect of the drilling parameters on hole cleaning.

MD (m)	hole size (in)	Angle	Fluid density (ppg)	YP (lb/100 ft^2)	PV (cp)	RPM	ROP (m/hr)	Cutting density (gm/cc)	Cutting size (in)	Minimum flow rate (gpm) by Well plan software
2250	12.25	30	10	25	18	60	8	2.7	0.245	✓
2250	12.25	30	10	25	18	60	8	2.7	0.245	✓
2250	12.25	30	10	25	18	60	8	2.7	0.245	✓

This section focused on discussing the impact of fluid density, whereas the results for other drilling parameters were presented in Figure (6).

Drilling mud weight or density (MW) is essential to maintaining the wellbore stable enough to prevent breakout and breakdown failures. The proper fluid density that is utilized in the drilling operation should be selected carefully. So, the wrong selection of fluid density may lead to excessive cutting collection, which can cause the pipe sticking problem, as well as excessive torque and drag. As illustrated in Figure (6), the value of the minimum flow rate will increase as the MW decreases; on the other hand, at 2250 m measured depth (MD), three valves of MW were selected, i.e., 10, 10.4, and 10.8 ppg, and the values of the minimum flow rate were 814, 783, and 753 gpm, respectively. Moreover, as the fluid density decreases, the hole-cleaning problem will increase. Increasing mud weight, annular velocity, and drill pipe rotation, as well as, if possible, decreasing hole angle, will reduce the number of cutting beds.

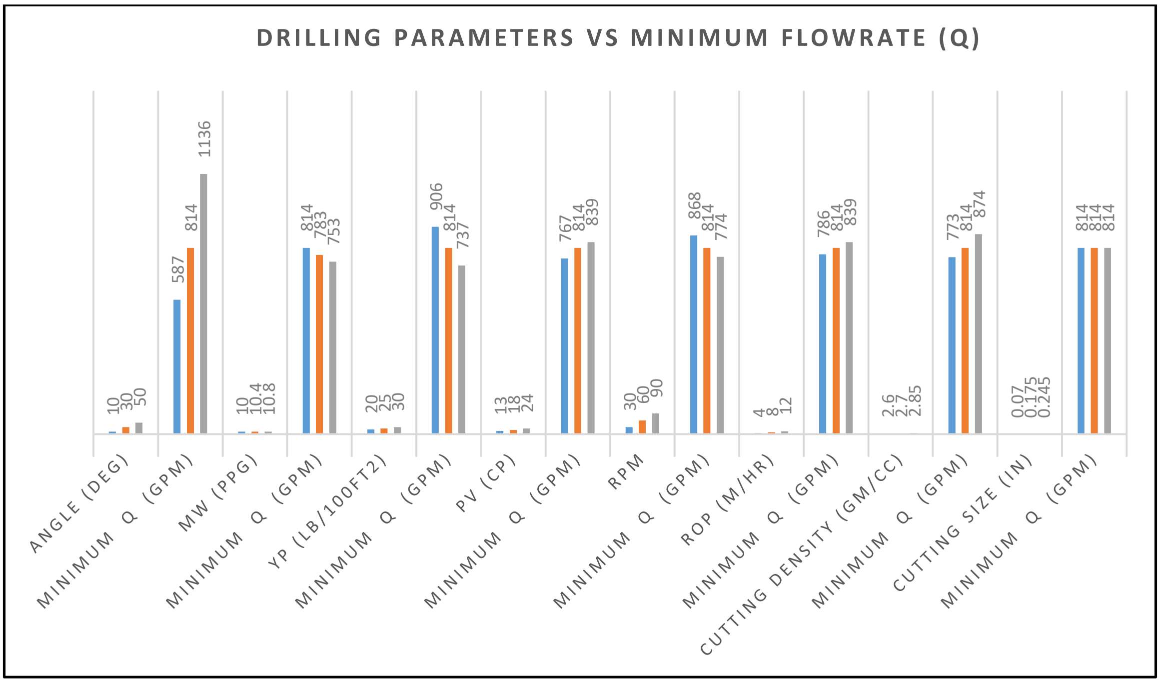

Fig. (6): Shows the relationship between drilling parameters and minimum flowrate.

4. Conclusions

After evaluating the data for one of the Iraqi oilfields and conducting the necessary computations, the following findings have been derived:

- The mechanical pipe sticking issues might arise because the minimum flow rate that was calculated using the Well Plan™ software model is higher than the wells' actual flow rate.
- In order to obtain optimal hole cleaning and eliminate hole issues, especially mechanical pipe sticking issues, the actual flow rate should be higher than the minimal flow rate. This will minimize the cost and time of drilling wells.
- The Well Plan™ software is suitable for field use due to its ability to generate precise outcomes.
- To avoid the occurrence of mechanical pipe sticking while conducting directional drilling, it is necessary to increase the flow rate, especially as the well's inclination becomes higher.
- Maintaining the highest possible density of the drilling fluid while avoiding fracturing the formation is an essential step in the drilling process. It reduces both the rate at which the cuttings are lifted to the surface and the height of the cuttings bed in the well.
- Well inclination and fluid density are considered major parameters for affecting hole cleaning or cutting removal.
- The values of other parameters, such as mud rheology (YP, PV), drill string rotation speed, penetration rate, and cutting density, have an impact on flow rate values.

- In this study, the cutting size was unaffected by the computed minimum flow rate.

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Conflict of Interest

The authors do not have any conflicts of interest related to this article that need to be disclosed.

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