Journal Homepage: http://ijcpe.uobaghdad.edu.iq
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 25 No. 1 (March 2024) 141 – 153
EISSN: 2618-0707, PISSN: 1997-4884

Analysis of Surge and Swab ECD of Herschel Bulkley Fluids in Rumaila Iraqi Oil Field

Fatima R. Salih [a, *], Farqad A. Hadi [b], Mortadha T. Al Saba [c]

a Basra Oil Company, Iraqi Ministry of Oil, Iraq
b Petroleum Engineering Department, College of Engineering, University of Baghdad, Baghdad, Iraq
c Petroleum Engineering Department, College of Engineering, Australian University-Kuwait, Kuwait

Abstract

Surge and swab pressures are frequently produced during various stages of well construction, including casing running and tripping operations. Managing downhole pressure within the mud window is crucial for mitigating the risks associated with drilling operations including wellbore failure, lost circulation, kicks, and well control issues. The primary objectives of this study are to emphasize the theoretical foundation of surge and swab pressures, forecast the optimum pipe and casing tripping speeds, as well as identify the changes in surge and swab pressures (i.e., equivalent circulating density-ECD) for both open-ended and close-ended drill strings. To achieve these goals, a steady state surge and swab model was used to simulate a case study in the Rumaila oil field, located in Southern Iraq, by utilizing landmark-well plan software. The results of this study support the evidence that the string trip speed plays a substantial role in controlling the swab and surge pressures. It was found that pulling out the 5" drill string from the 12 1/4" open hole section drilled with a 9.51 ppg water-based mud at a speed of 10 sec/stand resulted in a swab ECD below the formation pore pressure against all formations, thus resulting in a kick. Moreover, it was found that the annular clearance had a significant impact on the surge and swab ECD whereas the surge ECD at the bit was bigger than that obtained at the previous hole casing shoe. For example, in our case study pulling speeds ranging from 10-190 sec/stand for the 9 5/8" casing could cause the swab ECD to be below the formation pore pressure gradient at total depth (TD), which is 9.23 ppg. While it was safe to run the same casing through the same interval within 55-190 sec/stand. Furthermore, the results emphasized high trip speeds ranging between 10-30 sec/stand, where for close-ended drill strings, greater surge ECD was observed compared to the open-ended ones. The surge ECD of a 5" close-ended drill string at 30 sec/stand (60 m/min) at bit was 9.92 ppg, while an open-ended string at the same speed was 9.9 ppg.

Keywords: surge; swab; ECD; kick; lost circulation; tripping speed; Herschel Bulkley.

Received on 01/10/2023, Received in Revised Form on 13/12/2023, Accepted on 15/12/2023, Published on 30/03/2024

https://doi.org/10.31699/IJCPE.2024.1.14

1- Introduction

During the process of drilling, the drill string operates as a big piston that trip in and out of the borehole, resulting in additional pressures along the wellbore [1]. Normally, a tripping operation is needed while drilling operations to replace a worn part of the bit or the drill string. Because of that, surge and swab pressures may be exposed [2]. Surge pressure usually occurs if the drill string or the casing moves downward the hole quickly and suddenly [3]. In contrast, swab pressure is normally generated during the upward movement of the drill string [4]. When the surge pressure reaches the formation fracture gradient, it will fracture the formation and cause a lost circulation problem, which is considered one of the challenging problems while drilling [5]. On the other hand, the swab pressure has the potential to decrease the hydrostatic pressure of the drilling fluid and if the hydrostatic pressure becomes less than the formation pressure, a well kick will occur and could result in increasing the non-productive time [6].

A variety of approaches have been presented in the literature for identifying the surge and swab pressures [7]. These approaches have different requirements and underlying assumptions. Crespo and Ahmed [8] conducted an experimental investigation within a controlled laboratory environment to analyze the impact of various factors on surge and swab pressures, including pipe speed, fluid properties, hole geometry, fluid gelling, and pipe eccentricity. Vadim Tikhonov et al. [9] provided a mathematical model for computing the pressure fluctuations in the holes. They considered different influential parameters such as the elasticity of the wellbore, the compressibility of the drilling mud, and the longitudinal vibrations of the string. Abduljabbar et al. [10] conducted a study to determine the optimal tripping speed of a pipe that could effectively mitigate the occurrence of surging and swabbing during drilling operations. The study was primarily focused on elucidating the fundamental principle of the underlying surge and swab phenomena. Optimizing the maximum pipe-tripping speed was achieved through the utilization

*Corresponding Author: Email: fatima.raad2108m@coeng.uobaghdad.edu.iq
© 2024 The Author(s). Published by College of Engineering, University of Baghdad.
This is an Open Access article licensed under a Creative Commons Attribution 4.0 International License. This permits users to copy, redistribute, remix, transmit and adapt the work provided the original work and source is appropriately cited.

of diverse parameters as input values in the process of performing calculations. The results indicated that the dimensions of the bottom-hole assembly (BHA) and the annular space had a significant influence on the magnitudes of surge and swab pressures. Talleraas K. [11] also developed a steady-state model and conducted a sensitivity analysis of surge and swab pressures, where two well cases were used to estimate the equivalent circulating density (ECD). The results showed that the wellbore pressure will rise due to the surge effect and fall due to the swab pressure. Furthermore, downhole geometry (drill bit and BHA) had the greatest effect on the tripping speed. Furthermore, Pilgrim and Butt [12] demonstrated that switching from start/stop procedures to a continuous tripping process (CTP) can significantly reduce the number of starts and stops associated with conventional tripping. The simulation results showed that a continuous tripping system can be four times faster than a traditional tripping.

Rumaila oil field, located in Southern Iraq, has been selected in this study. This field is near the border with Kuwait and it is recognized as one of the largest oil fields globally [13]. It is approximately located 50 kilometers west of Basra and 30 kilometers west of Zubair oilfield [14]. It covers 1,600 square kilometers, roughly 80 km in the north-south, and 20 km in the west-east of the West-Qurna oilfield. This field is a supergiant field delivering approximately 33% of the overall oil supply in Iraq [15]. The estimated oil volume in this field is approximately 17 billion barrels, representing approximately 12% of the Iraqi total oil reserves. In the Rumaila oil field, 46% of the NPT is recorded due to the lost circulation problem [16]. This shows the importance of determining the surge ECD for controlling and minimizing the possibility of this costly problem.

The main objectives of this study are to enhance the understanding of surge /swab ECDs, minimize the time required for tripping in/out for the fear of surge/swab pressures, and employ the optimum tripping speed for improving the drilling efficiency and thus decreasing the non-productive time (NPT).

2- Research Methodology

Datasets of the one-directional well (R-A) in the Rumaila oil field have been collected, analyzed, and simulated using the Landmark-Well plan software as identified in Table 1. The Well Plan software primarily consists of eight modules, namely (Torque and Drag, Hydraulics, OptCem, Critical Speed, Bottom Hole Assembly, Well Control, Surge and Swab, and Stuck Pipe) [17]. A hydraulic module has been used in this study to build a steady-state swab and surge pressure model. The analysis employed various rheological models while maintaining the rheological mud properties, which are key parameters to control the margins of surge and swab pressures [18].

Based on the drilling reports, Well R-A was planned as an S-shaped well to 3378 m depth in three sections. The first section was drilled by a 17.5" PDC bit to a depth of 649 m MD through the formations of Dibdibba, Lower Fars, Ghar, and Dammam. The second section was drilled by a 12.25" bit to a depth of 1959 m MD through the formations of Rus, Umm Er Rad, Tayarat, Shiranish, Hartha, Sadi, and Tanuma. The third section was drilled by 8.5" bit using KCL polymer mud to 3378 m MD through Khasib, Mishrif, Rumaila, Ahmadi, Maudud, Nahr-Umr, Shuaiba and Zubair formations. The target of this well is to produce from the main pay of Zubair reservoir, as well as to obtain the open hole wireline logs, and measure the pressure data and cuttings to allow completion interval to be determined in the main pay of this reservoir.

Table 1. Inputs Parameters to the Well Plan Software

	Main Input Category					
	Datum Details	**Well Path**	**Hole Section**	**Drill String**	**Fluids**	**Subsurface**
Input Parameters	Wellhead Elevation Ground Elevation Datum Elevation Mean-Sea Elevation	Measured Depth Inclination Azimuth	Wellbore profile Risers Casing and Liners Open Hole OD	Components Length Component MD Component ID Components Weight	Rheology Density Viscosity	Pore Pressure Fracture Gradient Geothermal Formation Tops

3- Results and Discussion

In this section, the results of the study have been displayed to figure out how the tripping speeds could affect the surge and swab ECD in addition to highlighting the difference between the surge and swab ECD for the close-ended and the open-ended drill string as well as the difference between the surge and swab ECD for a 12 1/4" casing and 5" drill pipe.

This section presents the results of the simulation for well R-A graphically utilizing different plots. The analysis can be categorized based on two cases as follows:

3.1. Tripping the 5 " Drill String into the 12 1/4" Open Hole Section

The 12 1/4" open hole section was drilled using a 12.25" PDC bit with a length of 0.44 meters. The components of the drill string are shown in Fig. 1 and presented in Table 2. With respect to the drilling mud rheological properties, the selected mud type was gel/polymer mud, which has a density of 9.51 ppg, yield point (Yp) of 12 lb/100 ft^2, the fluid flow behavior index (n) of 0.6, and a consistency index (K) of 0.03 lb. s^n/ft^2. It is important to mention that the Herschel-Bulkley model was considered in this study since it is better in describing the behavior of non-Newtonian drilling fluids [19].

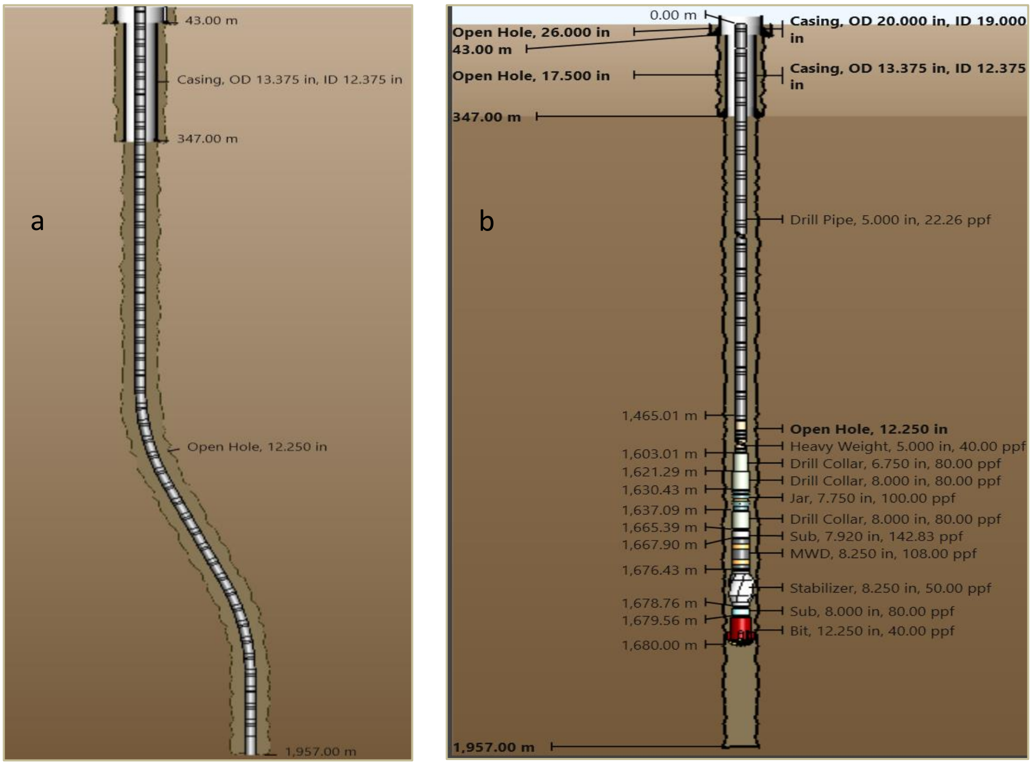

Fig. 1. A 12 ¼” Open Hole Section: a) Well Path and b) Drill String

Table 2. Components of 5” Drill String

Section Type	Length (m)	MD (m)	OD (in)	ID (in)
Drill Pipe	1,742.010	1,742.01	5.000	4.276
Heavy Weight	138.000	1,880.01	5.000	3.000
Drill Collar	18.280	1,898.29	6.750	2.870
Drill Collar	9.140	1,907.43	8.000	2.810
Jar	6.660	1,914.09	7.750	3.063
Drill Collar	28.300	1,942.39	8.000	2.810
Sub	2.510	1,944.90	7.920	3.240
MWD	8.530	1,953.43	8.250	3.250
Stabilizer	2.330	1,955.76	8.250	2.750
Sub	0.800	1,956.56	8.000	3.000
Bit	0.440	1,957.00	12.25	

- ECD vs. Trip Time (Open-Ended)

Fig. 2 presents the generated surge and swab ECDs when running the 5” open-ended D.S through the 12 ¼” open hole section (RIH) or pulling out of the hole (POOH) at specific depths at the previous casing shoe, at the bit, and at the total depth (TD).

It is obvious that the surge ECD curves are opposite to the swab ECD curves, meaning that as the trip speed increases (i.e., the time per stand decreases), the surge ECD increases and the swab ECD decreases. The increase in the surge pressure or the decrease in the swab pressure can be attributed to the annular pressure loss, which is already added to the original mud weight, thus producing the surge ECD, or it is subtracted from the original mud weight to estimate the swab ECD.

In this case study, the bit has been chosen to be tripped in against Hartha formation (1680 m-1756 m) MD for two reasons. The first reason is to distinguish the surge/swab ECD at the bit from that obtained at TD so that the two ECD curves do not overlay on each other as in the case when the bit is only at TD. The second reason is that the Hartha formation is a thief zone [20], this shows the importance of calculating the surge and swab ECD to control the tripping speed and avoid further tensile rock fracturing. The obtained results showed that the surge ECD at the bit is bigger than that obtained at TD and at the casing shoe in spite of the fact that the depth of TD is bigger than that of bit. This is mainly due to the fact that the annular clearance at the bit is smaller than that at TD and at the previous casing shoe, and vice versa is expected for swab ECDs.

- ECD vs. Trip Time (Close-Ended)

The generated surge and swab ECDs when RIH/POOH the 5” close-ended drill string through the 12 ¼” open hole section at specific depths are shown in Fig. 3.

The results showed that at high tripping speeds (30-10 sec/stand), the surge ECD for a close-ended drill string is relatively higher than that of an open-ended drill string. For instance, running the 5” close-ended drill string at a trip rate of (30 sec/stand) or (60 m/min) at the bit resulted in a surge ECD of 9.92 ppg, while running an open-ended string at the same speed resulted in a surge ECD of 9.9 ppg as outlined in Table 3. The reason is that the effective annular fluid velocity for a plugged pipe is bigger than that for an open-ended one [21]. As a result, a bigger surge in pressure for the closed-ended string is observed, which leads to a larger surge in ECD. On the contrary, at speeds lower than 30 sec/stand, i.e. (40-170 sec/stand), the surge and swab ECD are the same for both open-ended and close-ended strings.

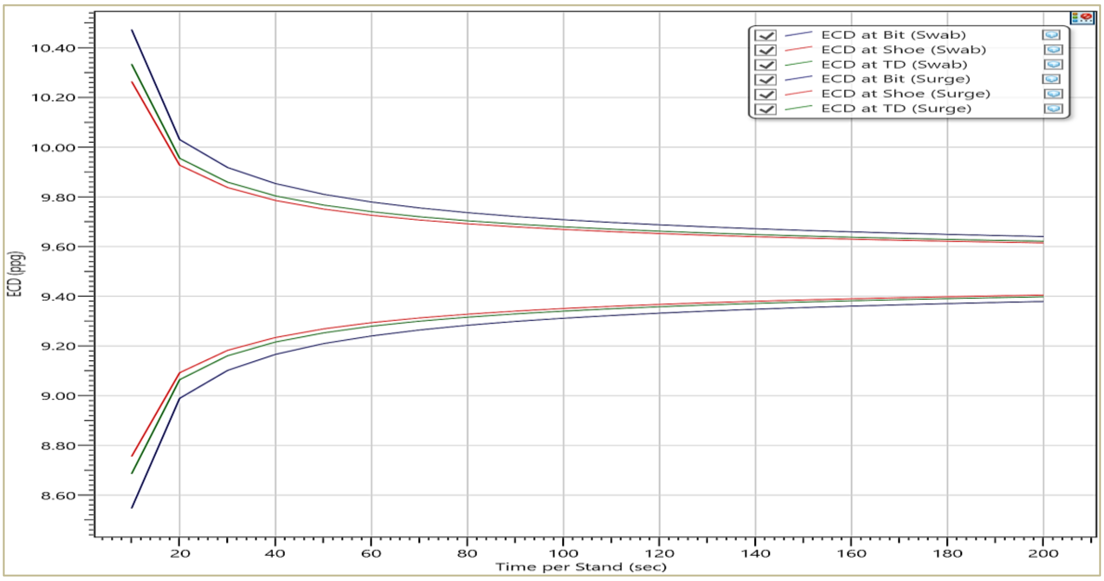

Fig. 2. ECD vs. Trip Time of Open-Ended Drill String

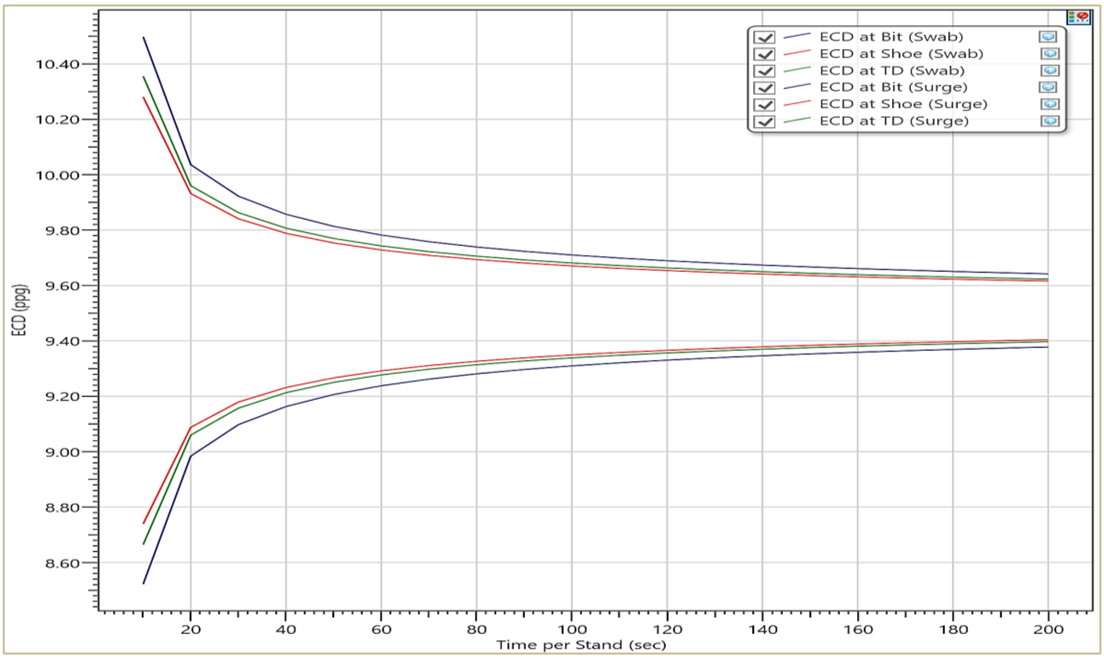

Fig. 3. ECD vs. Trip Time of a Close-Ended Drill String

Table 3. Surge /Swab ECD at Bit

Close-Ended			Open-Ended		
Time Per Stand	**ECD at Bit (Swab)**	**ECD at Bit (Surge)**	**Time Per Stand**	**ECD at Bit (Swab)**	**ECD at Bit (Surge)**
(sec)	(ppg)	(ppg)	(sec)	(ppg)	(ppg)
10	8.52	10.5	10	8.55	10.47
20	8.96	10.06	20	8.99	10.03
30	9.1	9.92	30	9.12	9.90
40	9.16	9.86	40	9.17	9.85
50	9.21	9.81	50	9.21	9.81
70	9.26	9.76	70	9.26	9.76
80	9.28	9.74	80	9.28	9.74
100	9.31	9.71	100	9.31	9.71
120	9.33	9.69	120	9.33	9.69
140	9.35	9.67	140	9.35	9.67
170	9.36	9.66	170	9.37	9.65
190	9.37	9.65	190	9.38	9.64
200	9.38	9.64	200	9.38	9.64

- ECD vs. Measured Depth (Open-Ended string)

The surge /swab ECDs that were generated because of running different pipe speeds versus the measured depths have been calculated at the bit and at the total depth (TD) for an open-ended drill string. They are presented to show the pore pressure and the fracture gradients as can be seen in Fig. 4 (a and b).

According to the results of Fig. 4, the original mud density of the 12 ¼" open hole section, which is 9.51 ppg, is close to the pore pressure gradient, which could cause a good kick [22], therefore using 10 sec/stand to POOH the bit will cause the swab ECD to be below the pore pressure gradient, thus a good kick event is possible. In contrast, RIH the bit at 10sec/stand is safe since the mud density in this case is far from the fracture gradient.

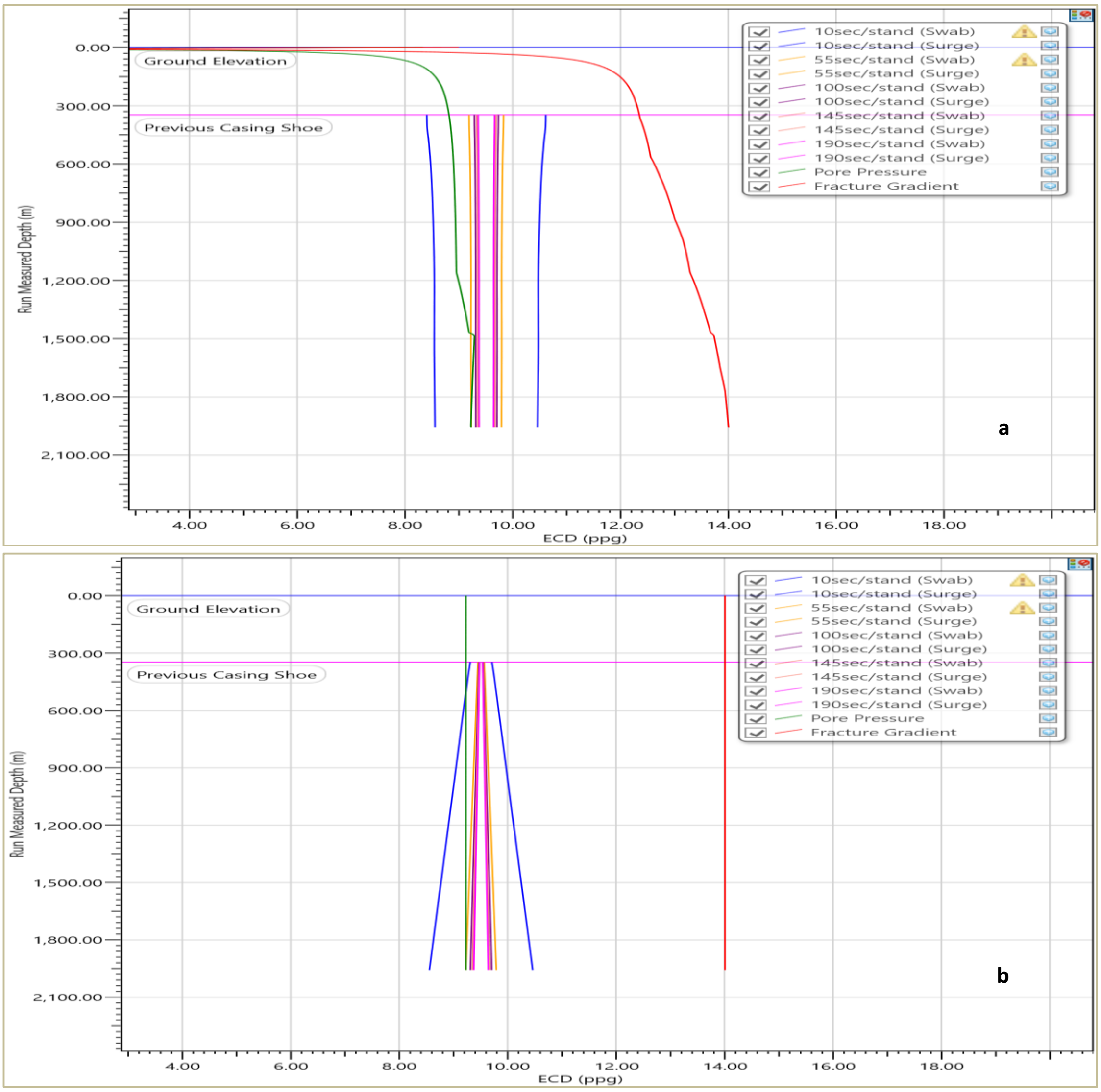

Fig. 4. ECD vs. Run Measured Depth of an Open-Ended Drill String: (a) at Bit, and (b) at TD

- ECD vs. Measured Depth (Close–Ended String)

The surge /swab ECDs that were generated for various trip speeds vs. run-measured depth have been calculated at the bit and at TD for the 5” close-ended drill string. The results are presented in Fig. 5 to perform a comparison with the pore pressure and fracture gradients of the Rumaila oil field.

- Swab/Surge Trip Schedule

Fig. 6 displays the calculated maximum allowed trip speed without exceeding the safe trip margin. The selection of a safe trip margin of 0.2 ppg is intended to minimize the gap between the pore pressure and the fracture pressure gradients, thereby enhancing the safety of tripping operations. In the case of a closed-ended drill string, it has been determined that a total of 4 stands, ranging from 1680 to 1570 m, need to be removed within a time frame of 80 seconds. Subsequently, the velocity is to be gradually increased until the point where 12 stands, ranging from 335 to 6.65 m, are to be pulled out within the duration of 10 seconds as presented in Table 4.

At some depths, the pulling speeds for an open-ended drill string are relatively higher than the obtained speeds for a closed drill string. This finding demonstrates that the utilization of a close-ended system might lead to a greater surge and swab effect. For example, it is recommended to pull 5 stands of a close-ended drill string within 60 sec, and then pull 6 stands within 70 sec. On the contrary, it is advised to pull 6 stands of an open-ended string within 60 sec, then 5 stands within 70 sec. This observation holds true when considering the surge pressure as depicted in Table 5.

3.2. Tripping the 9 5/8"casing through 12 1/4" Open Hole Section

A steady-state model was employed to simulate a case of tripping the 9 5/8” casing through a 12 1/4” open hole section as shown in Fig. 7. The mud properties are the same as used for tripping the 5” drill string in the 12 1/4” open hole section. The drill string components are listed in Table 6.

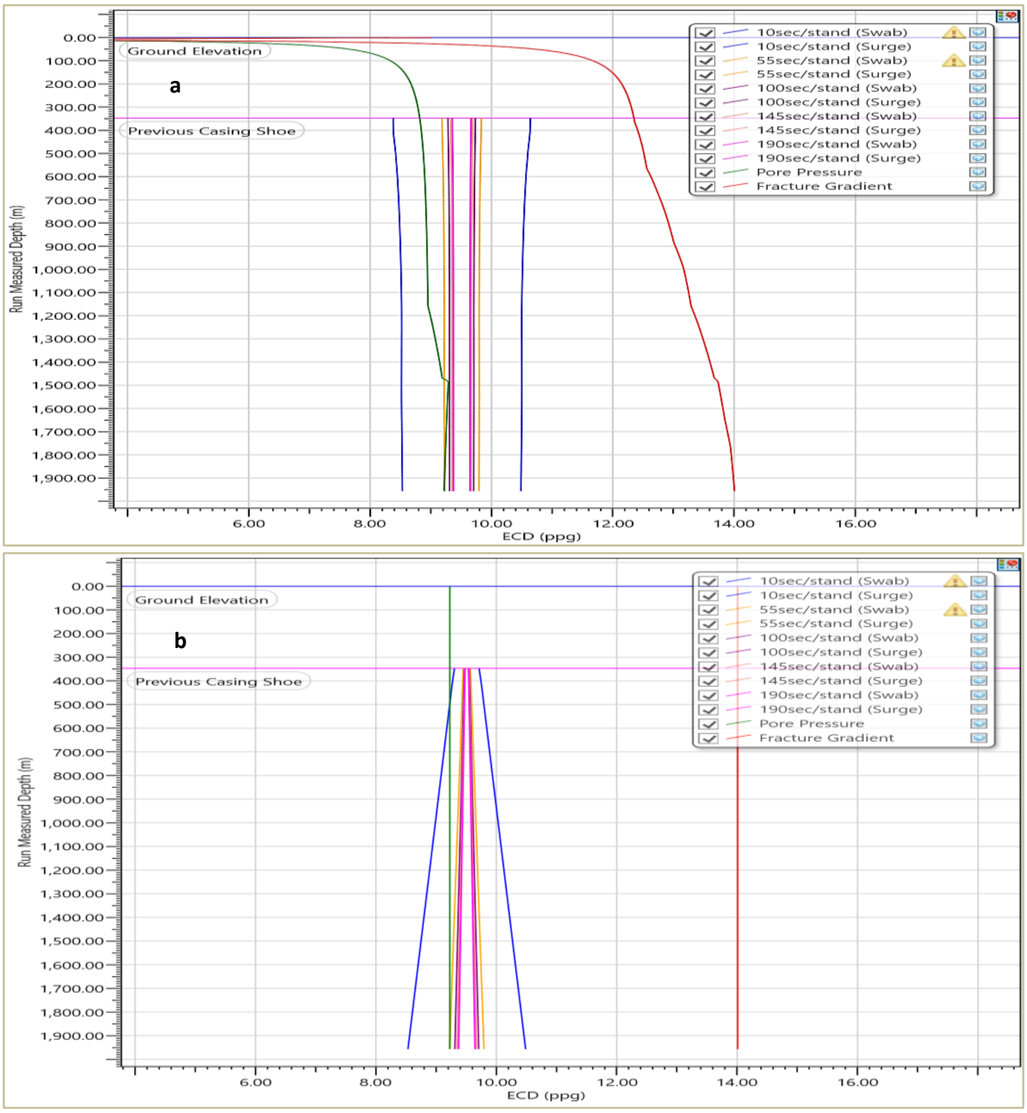

Fig. 5. ECD vs. Run Measured Depth of a Close-Ended Drill String: (a) at the Bit, and (b) at the TD

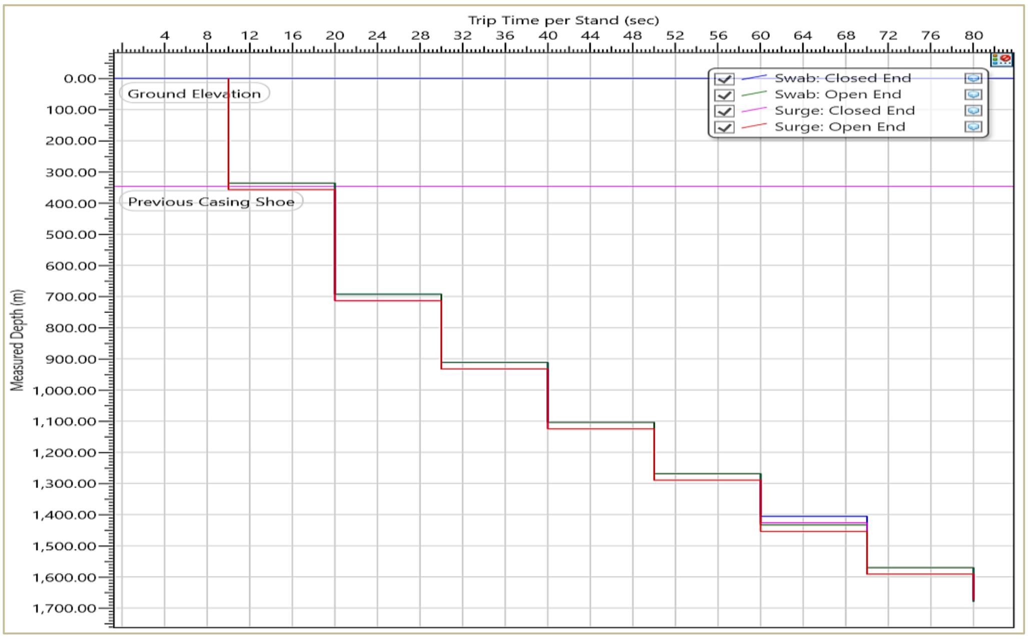

Fig. 6. Surge/Swab Trip Schedule for 5” Drill String

Table 4. The Swab Trip Speeds for a 5” Drill String

Closed-Ended			Open-Ended		
Measured Depth (m)	**Number of Stands**	**Trip Time per Stand (sec)**	**Measured Depth (m)**	**Number of Stands**	**Trip Time per Stand (sec)**
1,570.27	4	80	1,570.27	4	80
1,405.68	6	70	1,433.11	5	70
1,268.52	5	60	1,268.52	6	60
1,103.93	6	50	1,103.93	6	50
911.9	7	40	911.9	7	40
692.45	8	30	692.45	8	30
335.83	13	20	335.83	13	20
6.65	12	10	6.65	12	10

Table 5. Surge Trip Speeds for 5” Drill String

Closed-Ended			Opened-Ended		
Measured Depth (m)	**Number of Stands**	**Trip Time per Stand (sec)**	**Measured Depth (m)**	**Number of Stands**	**Trip Time per Stand (sec)**
356.62	13	10	356.62	13	10
713.23	13	20	713.23	13	20
932.69	8	30	932.69	8	30
1,124.71	7	40	1,124.71	7	40
1,289.30	6	50	1,289.30	6	50
1,426.46	5	60	1,453.90	6	60
1,591.06	6	70	1,591.06	5	70
1,673.35	3	80	1,673.35	3	80

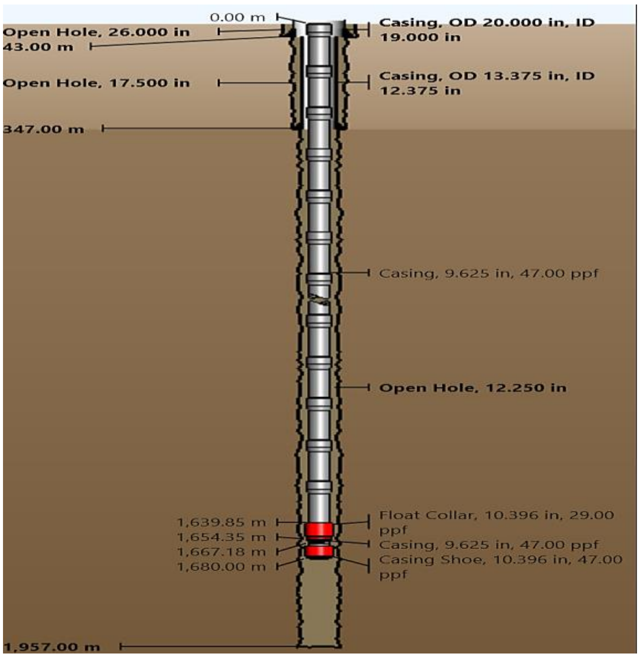

Fig. 7. A 9 5/8"Casing String

Table 6. The Components of 9 5/8" Casing String

Section Type	Length (m)	MD (m)	OD (in)	ID (in)
Casing	1,639.855	1,639.85	9.625	8.681
Float Collar	14.500	1,654.35	10.396	8.585
Casing	12.825	1,667.18	9.625	8.681
Casing Shoe	12.820	1,680.00	10.396	8.585

The results of tripping the 9 5/8” casing through the 12 1/4" open hole section can be categorized as follows:

- ECD vs. Trip Time (Open-Ended Casing String)

Fig. 8 illustrates the anticipated equivalent circulating density (ECD) for various trip speeds, ranging from zero to 200 seconds per stand, during the process of tripping in or tripping out with the 9 5/8” open-ended casing string.

The results revealed that the generated swab ECDs while pulling the 9 5/8 open-ended casing are smaller than that generated while pulling the 5" drill string because the annular clearance between the casing and the hole is smaller than that between drill pipe and the hole. Whereas pulling the 9 5/8" casing with tripping speeds ranging from 200-10 sec/stand could cause the swab ECDs to be below the formation pore pressure gradient. For example, pulling the casing from TD within 200 to 10 sec/stand resulted in a swab ECD ranging from 8.76 to 3.82 ppg that are below the pore pressure gradient at TD, which is 9.21 ppg. The reverse is true for surge ECD when running an open-ended 9 5/8" casing at a speed of 200 to 10 sec/stand, where the resulting surge ECDs at TD ranged from form10.26 -15.2 ppg, which are much higher than the surge ECD of the 5" open-ended drill string surge ECD which ranged from 9.63 -10.33 ppg.

- ECD vs. Trip Time (Close-Ended Casing String)

The expected ECD for trip speeds ranging from zero to 200 seconds per stand while tripping in (surge) or tripping out (swab) with a close-ended string are shown in Fig. 9. In this figure, the curve mentioned at the bit refers to the end of the 9 5/8" casing that lies in front of Hartha formation (1680 m MD). The generated surge ECD while tripping in the 9 5/8" casing within speeds ranging from 200 to 20 sec/stand at 1680 m were calculated and found to be ranging from 10.4 to 13 ppg. The obtained ECD values are still below the formation fracture gradient, which is 13.81 ppg at 1680 m MD of Hartha formation. Keeping the surge pressure below the fracture pressure is crucial to prevent rock failure [23, 24].

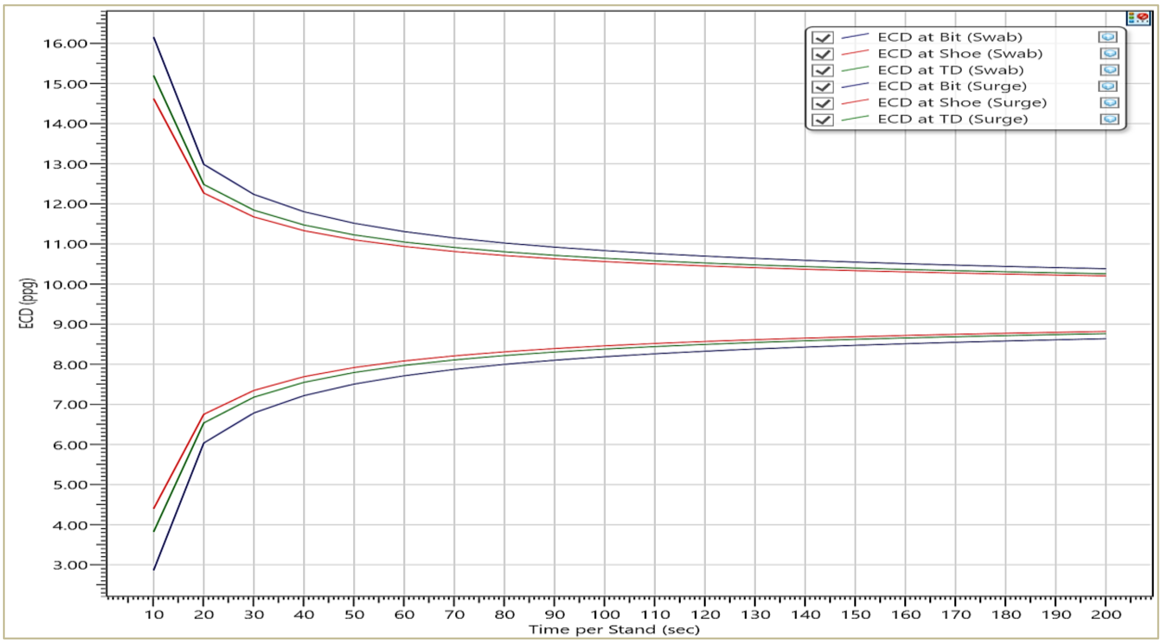

Fig. 8. ECD vs. Trip Time of Open-Ended Casing

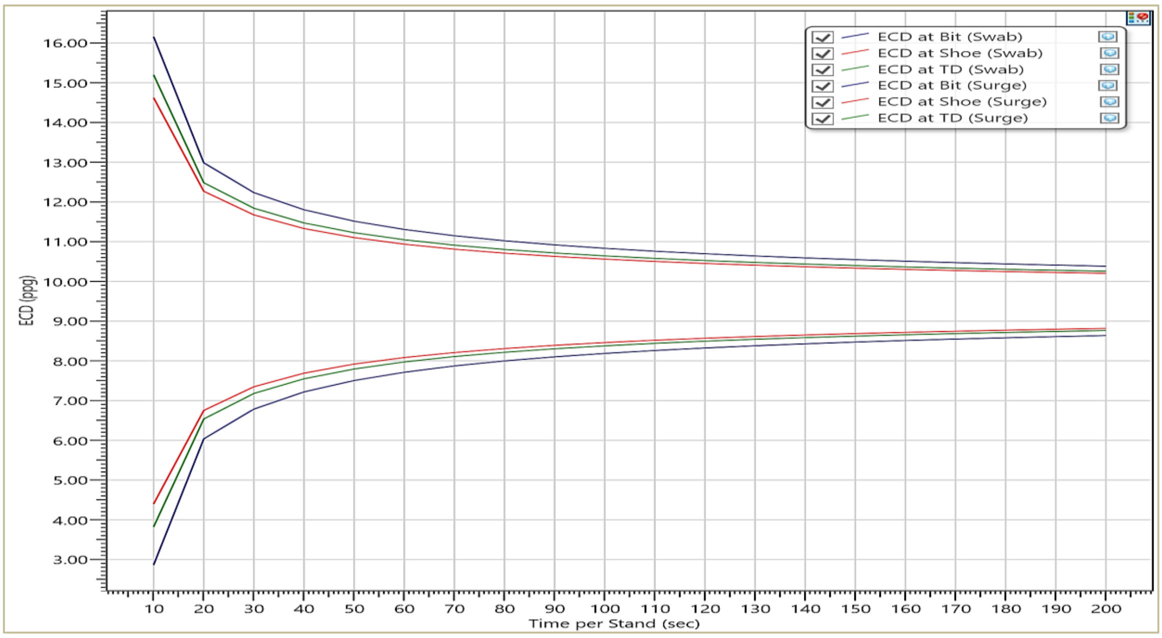

Fig. 9. ECD vs. Trip Time of Close-Ended Casing

- ECD vs. Measured Depth (Open-Ended Casing String)

Fig. 10 shows the ECD versus run depth of an open-ended casing string for different trip speeds per stand when tripping in (surge) or tripping out (swab), where the analysis in this figure was conducted at TD. It has been seen that running one stand of 9 5/8" casing at TD within 10 sec resulted in a surge ECD exceeding the fracture pressure gradient, which is 14 ppg. In contrast, the results showed that running the casing in the hole within speeds ranging from 190-55 sec/stand will not result in fracturing the formation. Another important point from Fig. 10 is that the pulling speeds of the casing as the trip speeds ranging from (190-10) sec/stands can cause the swab ECD to be below the formation pore pressure gradient at TD.

- ECD vs. measured Depth (Close-Ended casing string)

The equivalent circulating density (ECD) vs. the running depth of a closed-ended casing string has been investigated under different trip speeds per stand during tripping operations. The analysis was conducted at TD, as depicted in Fig. 11.

The results of optimum tripping speed for tripping a close-ended casing were obtained to be approximately the same as that for an open-ended casing (Fig. 10), except the fact that for the surge ECD that was generated during tripping a closed-ended casing is slightly bigger than that of an open-ended casing. The amount of difference in surge ECD between the close-ended casing and the open-ended casing increases with increasing the tripping speed. For example, tripping one stand of casing within 100 sec resulted in a surge ECD of 10.83 ppg for an open-ended casing while for a close-ended casing, it was found to be 11.03 ppg, i.e., the difference in ECD is about (0.2 ppg). In contrast, increasing the speed to 55 sec/stand resulted in a surge ECD of 11.41 ppg for an open-ended string and 11.69 ppg for a close-ended string, i.e., a difference of about 0.28 ppg was observed.

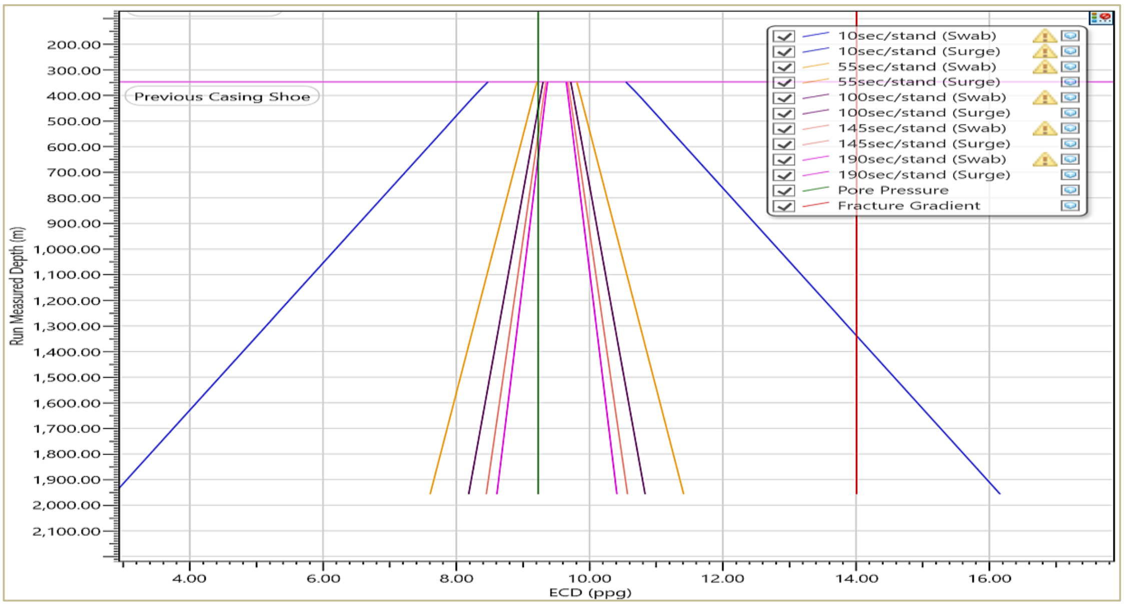

Fig. 10. ECD vs. Run Measured Depth of an Open-Ended Casing at TD

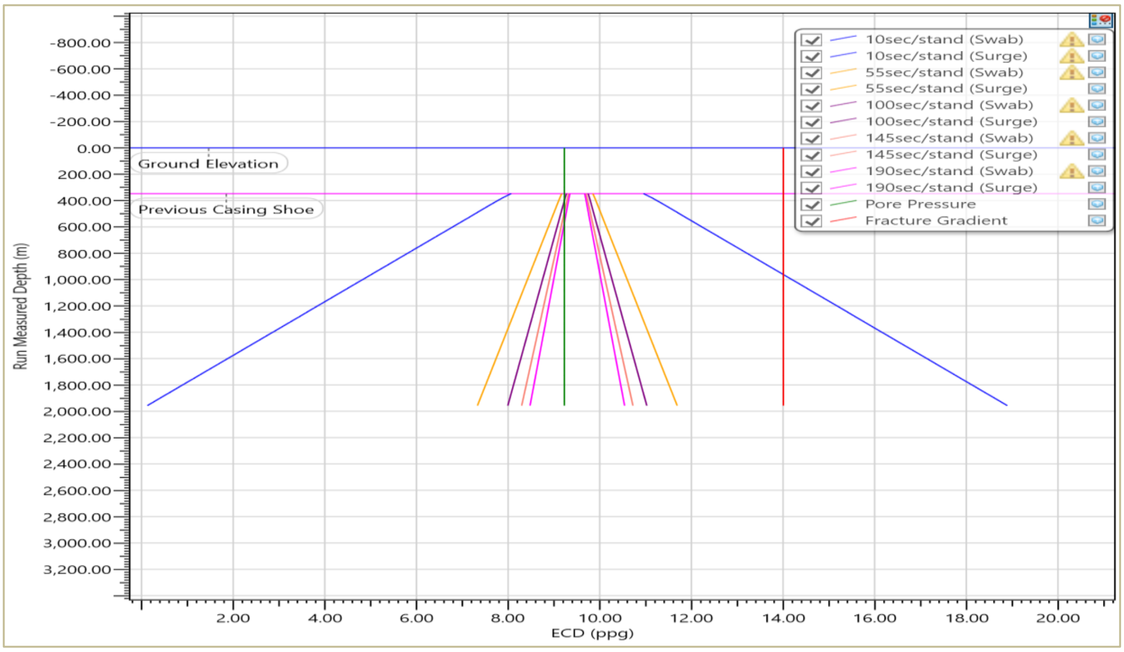

Fig. 11. ECD vs. Run Measured Depth of a Close-Ended Casing at TD

- Surge/Swab Trip Schedule

Fig. 12 presents the minimum trip time per one stand of the 9 5/8" casing while ensuring that the trip margin is not exceeded. The interpretation of this figure is tabulated in Table 7 and Table 8. In the case of pulling the casing and for a close-ended casing (Table 8), it has been calculated that a total of 36 stands have to be pulled at a speed of 200 sec/stand from 1680 to 384 m MD. Furthermore, the optimum tripping speed (v_p) to pull the casing -when necessary- from 384 to 348 is 170 sec/stand. On the other hand, it is allowed to pull the close-ended casing within high speeds ranging from 170 to 10 sec/stand through the interval from 384m MD to the surface since this interval is cased and cemented, i.e. no possibility of kicks and loss circulation.

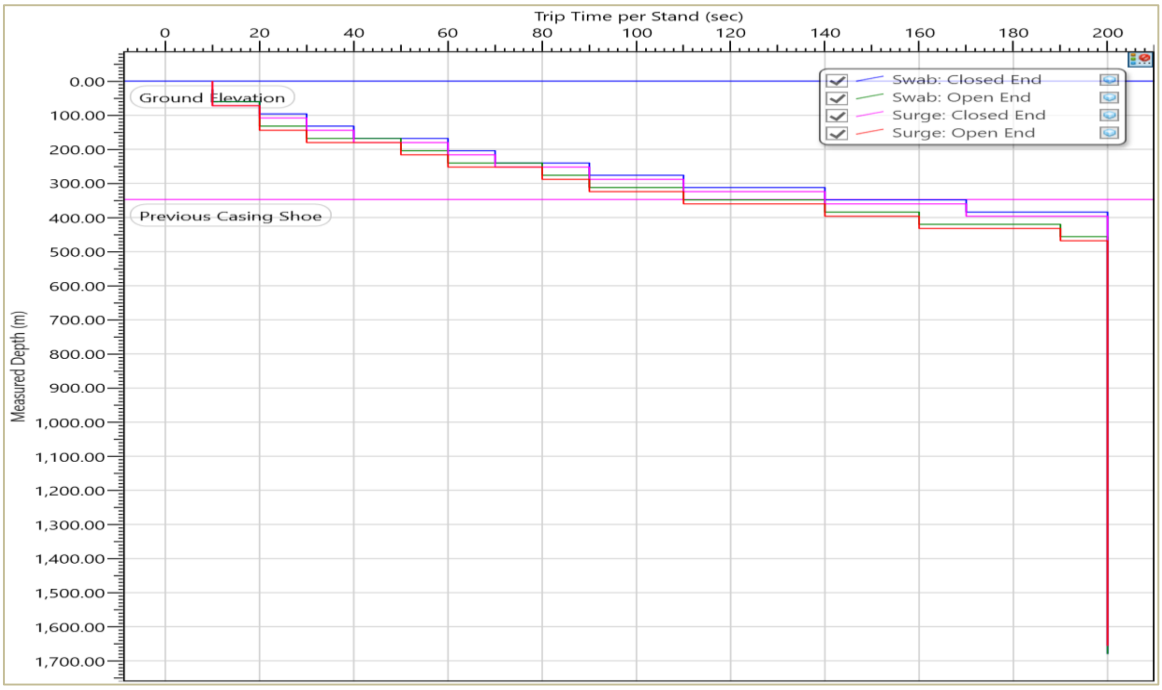

Fig. 12. Surge/Swab Trip Schedule of 9 5/8" Casing

Table 7. Swab Trip Speeds for 9 5/8" Casing

Close-Ended			Open-Ended		
Measured Depth (m)	**Number of Stands**	**Trip Time per Stand (sec)**	**Measured Depth (m)**	**Number of Stands**	**Trip Time per Stand (sec)**
384	36	200	456	34	200
348	1	170	420	1	190
312	1	140	384	1	160
276	1	110	348	1	140
240	1	90	312	1	110
204	1	70	276	1	90
168	1	60	240	1	80
132	1	40	204	1	60
96	1	30	168	1	50
60	1	20	132	1	30
24	1	10	60	2	20
			24	1	10

Table 8. Surge Trip Speeds for 9 5/8" Casing

Close-Ended			Open-Ended		
Measured Depth (m)	**Number of Stands**	**Trip Time per Stand (sec)**	**Measured Depth (m)**	**Number of Stands**	**Trip Time per Stand (sec)**
72	2	10	72	2	10
108	1	20	144	2	20
144	1	30	180	1	30
180	1	40	216	1	50
216	1	60	252	1	60
252	1	70	288	1	80
288	1	90	324	1	90
324	1	110	360	1	110
360	1	140	396	1	140
396	1	170	432	1	160
1,656.00	35	200	468	1	190
			1,656.00	33	200

In the case of running the casing and for an open-ended casing, it is suggested to pull a total of 34 stands from a depth of 1680 to 456 m MD within 200 sec/stand. But, for the depth interval of 1680 to 456 m MD, three stands can be pulled within 190,160 and 140 sec/stand. From the above results, it can be proven that the optimum tripping speeds for an open-ended casing are somewhat bigger than that for a close-ended casing.

4- Conclusions

The findings of this study can be summarized in the following points:

1. Determination of the optimum tripping speeds is an important step for reducing the surge and swab ECDs through drilling operations, which will help in reducing the potential of well kick or lost circulation problems.
2. The surge ECD increases as the annular clearance between the drill string and the open hole decreases, thus the surge ECD at the bit is bigger than that obtained at TD.
3. At high tripping speeds (30-10 sec/stand), the surge ECD for a close-ended drill string is slightly higher than that of an open-ended drill string.
4. When the used mud weight is close to the pore pressure gradient, the range of safe tripping out speeds for swab operation is smaller than that of surge operation to keep the swab ECD below the formation pore pressure gradient.
5. The optimum speed for tripping the 5” drill string through a 12 ¼ “open hole section filled with drilling mud of Herschel Bulkley flow behavior model at TD (1957 m) was found to be 80 sec/stand, while it was found to be 200 sec/stand at TD during tripping the 9 5/8" casing through the same open hole section.
6. With increasing the tripping speed, the difference between the surge ECD for the close-ended casing and the open-ended casing will increase.

7. The surge and swab ECD analysis in this study is limited to tripping the intermediate casing and the drill string through the 12 1/4" open hole section. Tripping through smaller open hole sections may lead to smaller allowed ranges of tripping speeds due to smaller annular clearance.
8. The steady-state model cannot be considered in analyzing the surge and swab pressures for fields that have narrow mud windows. Instead, the transient model would be more recommended for accurate results.

Nomenclature

DS	Drill String Diameter, in
ECD	Equivalent Circulating Density, ppg
K	Consistency Factor, lb.s^n/ft^2
n	Flow Behavior index
ρ	Mud weight, ppg
v_p	Trip speed, sec/stand
YP	Yield Point, lb/100 ft^2

References

[1] U. Mme and P. Skalle, "Effects of mud properties, hole size, drill string tripping speed and configurations on swab and surge pressure magnitude during drilling operations," *International Journal of Petroleum Science and Technology*, pp. 143+, 2012.

[2] A. A. Alhaleem, "Study the efficiency of drilling with casing operation in an Iraqi oil field," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 17, no. 2, pp. 47–52, 2016. https://doi.org/10.31699/IJCPE.2016.2.6

[3] J. Shi, B. Yu, X. Song, and Y. Guo, "Research on the law of surge pressure during tripping of HTHP wells under the influence of tool joints," *Energies*, vol. 15, no. 23, p. 8943, 2022. https://doi.org/10.3390/en15238943

[4] A. H. Assi, "Swab – surge pressure investigation, and the influence factors, prediction and calculation (review)," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 24, no. 3, pp. 141–147, 2023. https://doi.org/10.31699/IJCPE.2023.3.14

[5] A. K. Al-Delfi, F. H. M. Al-Mahdawi, Y. Mukhtar, and Y. Eltahir Bagadi, "Experimental study to investigate the effect of polyacrylamide gel to reduce the lost circulation," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 24, no. 1, pp. 79–88, 2023. https://doi.org/10.31699/IJCPE.2023.1.9

[6] S. Khudhair and F. H. M. Al-Mahdawi, "Optimization of drilling well design: A review," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 23, no. 4, pp. 91–99, 2022. https://doi.org/10.31699/IJCPE.2022.4.11

[7] S. S. Hadi, "Modeling of Surge and Swab Pressure," POLITECNICO DI TORINO, 2021.

[8] F. Cresp and R. Ahmed, "A simplified surge and swab pressure model for yield power law fluids," *Journal of Petroleum Science and Engineering*, vol. 12, 2013. https://doi.org/10.1016/j.petrol.2012.10.001

[9] V. Tikhonov, O. Bukashkina, V. Liapidevskii, and L. Ring, "Development of model and software for simulation of surge-swab process at drilling (Russian)," in *SPE Russian Petroleum Technology Conference and Exhibition*, 2016. https://doi.org/10.2118/181933-MS

[10] A. M. Al-Abduljabbar, M. E. Hossain, S. A. Gharbi, and M. Al-Rubaii, "Optimization of tripping speed to minimize surge & swab pressure," in *Day 3*, 2018. https://doi.org/10.2118/189331-MS

[11] K. M. H. Talleraas, "Surge and Swab Simulations," Norwegian University of Science and Technology NTNU, Jan, 2019.

[12] R. Pilgrim and S. Butt, "Mitigating surge and swab by changing tripping from a batch to a continuous process," in *Day 2*, 2022. https://doi.org/10.2118/208923-MS

[13] Z. A. Al- Humaidan, M. H. Al-Jaberi, H. K. Al-Mayyahi, and Z. A. Al-Mutouri, "Study of light and heavy minerals and their effect on oil aggregation in the Zubair formation for the Rumaila oil field in southern Iraq," *Iraqi Journal of Science*, pp. 3789–3803, 2022. https://doi.org/10.24996/ijs.2022.63.9.12

[14] M. S.Al jawad and G. N S Jreou, "Application of neural network in the identification of the cumulative production from AB unit in main pays reservoir of South Rumaila Oil Field," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 10, no. 2, pp. 37–46, 2009. https://doi.org/10.31699/IJCPE.2009.2.6

[15] W. H. ALateya, A. M. Handhal, and H. A. Hashem, "Prediction of porosity of the Zubair reservoir at Rumaila oil field, Southern Iraq, using the seismic inversion technique," in *Conference Proceedings of The First Virtual Conference of Al-Amarah University College On Oil And Gas-2022: AUCOGC2022 Conference Proceedings (Feb 01-02, 2022)*, 2023. https://doi.org/10.1063/5.0143531

[16] A. Salih and H. A. Abdul Hussein, "Artificial intelligent models for detection and prediction of lost circulation events: A review," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 23, no. 4, pp. 81–90, 2022. https://doi.org/10.31699/IJCPE.2022.4.10

[17] H. A. Neamah and A. A. A. A.Alrazzaq, "Torque and drag forces problems in highly deviated oil well," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 19, no. 3, pp. 19–31, 2018. https://doi.org/10.31699/IJCPE.2018.3.3

[18] F. Hadi, A. Noori, H. Hussein, and A. Khudhair, "Development of new models to determine the rheological parameters of water-based drilling fluid using artificial neural networks," *Iraqi Geological Journal*, vol. 55, no. 1C, pp. 66–79, 2022. https://doi.org/10.46717/igj.55.1C.6Ms-2022-03-25

[19] M. A. Muherei, "Common versus Herschel-Bulkley drilling fluid models: Effect of their rheological parameters on dynamic particle settling velocity," *ASRJETS-Journal*, vol. 16, no. 1, pp. 155–177, 2016.

[20] H. H. Alkinani, "A comprehensive analysis of lost circulation materials and treatments with applications in Basra's oil fields, Iraq: Guidelines and recommendations," Missouri University of Science and Technology, 2017.

[21] T. Tan, H. Zhang, X. Ma, and Y. Chen, "Study on the surge-swab pressure considering the effect of the cutting plug in shale drilling," *Geofluids*, vol. 2021, pp. 1–15, 2021. https://doi.org/10.1155/2021/9446293

[22] A. K. AlHusseini and S. M. Hamed-Allah, "Estimation pore and fracture pressure based on log data; Case study: Mishrif formation/Buzurgan oilfield at Iraq," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 24, no. 1, pp. 65–78, 2023. https://doi.org/10.31699/IJCPE.2023.1.8

[23] H. Steer, F. Hadi, and A. Ellafi, "2D and 3D modeling of rock mechanical properties of Khasib formation in East Baghdad oil field," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 24, no. 3, pp. 33–43, 2023. https://doi.org/10.31699/IJCPE.2023.3.4

[24] Z. Bashara, F. Hadi, and M. Kasing, "Interpretation of mud losses in carbonates based on cuttings description, well-logging, seismic and coherency data," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 24, no. 4, pp. 17–30, 2023. https://doi.org/10.31699/IJCPE.2023.4.2

تحليل الكثافة المكافئة لضغوط Surge and Swab لسوائل الحفر ذات موديل جريان Bulkley–Herschel في حقل الرميلة النفطي العراقي

فاطمة رعد صالح [١، *]، فرقد علي هادي [٢]، مرتضى تركي السبع [٣]

١ شركة نفط البصرة، وزارة النفط العراقية، العراق
٢ قسم هندسة النفط، كلية الهندسة، جامعة بغداد، بغداد، العراق
٣ قسم هندسة النفط، كلية الهندسة، الجامعة الاسترالية، الكويت

الخلاصة

تعد إدارة الضغط في قاع البئر أمرًا بالغ الأهمية من أجل التخفيف من المخاطر المرتبطة بتكسير التكوينات وفقدان دورة سائل الحفر والركلات ومشكلات التحكم في البئر. لقد لوحظ منذ فترة طويلة ان ضغوط surge and swab لها دور مهم في إدارة ضغط قاع البئر. تم اختيار نموذج Herschel–Buckley باعتباره النموذج الريولوجي المفضل نظرًا لقدرته على تمثيل خصائص تدفق مائع الحفر بدقة. الهدف الأساسي من هذه الدراسة هو التأكيد على الأساس النظري لضغوط surge and swab، والتنبؤ بالسرعات المثلى لسحب و تنزيل انابيب و بطانات الحفر، وتحديد التغييرات في الكثافات المكافئة لضغوط surge and swab لكل من خيط الحفر ذو النهاية المفتوحة والمغلقة. وكذلك البطانة ذات النهاية المفتوحة وذات النهاية للمغلقة. ولتحقيق هذه الأهداف، تم استخدام نموذج the steady state surge and swab model لمحاكاة دراسة حالة في حقل الرميلة النفطي من خلال استخدام برنامج هاليبرتون التجاري (LANDMARK–Well plan). وتشير نتائج الدراسة إلى أن سرعة السحب و الانزال لخيط الحفر او للبطانة تلعب دورا كبيرا في حدوث ظاهرتي surge and swab.

الكلمات الدالة: surge، swab، كثافة التدوير المكافئة، الرفسة، فقدان سوائل الحفر، سرعة السحب والانزال.