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CUTTING ANALYSIS ON HORIZONTAL DRIILING USING CUTTING CARRY INDEX, CUTTING TRANSPORT RATIO AND CUTTING CONCENTRATION IN ANNULUS METHOD ON A WELL G FIELD S

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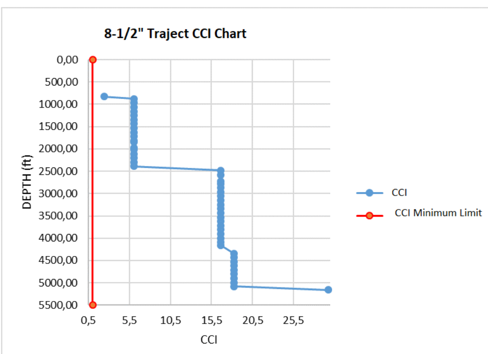
Graphical abstract



Abstract

The basic principle of the drilling operation is to grind the rock formations with bits which will later become drill cuttings. In this process, fluid is needed as a conveying medium, commonly known as drilling mud, because the deeper the drilling, the more drill flakes are produced. One of the prominent functions of drilling mud is lifting the drill shale up to surface. The purpose of this analysis is to quantitatively prove whether the cutting has been successfully lifted to the surface or not, and to determine the elements of the fluid's physical properties and the drilling mud fluid's rheology. This analysis was carried out using three methods including; the cutting carry index, which the value required is greater than one; the cutting transport ratio, which the value required is greater than 50%; and the cutting concentration in annulus, which the value required is less than 5%. If the value of the quantitative calculation already has a value above the standard, it can be concluded that the drill cuttings can be lifted optimally. The value of the cutting carry index has to be greater than one, because if it is less than one the solid value in the mud is still lacking, causing a low density so it will affect the carrying capacity of cutting in 1 gal of mud. The value of cutting concentration in annulus should not be more than 5, it is feared that if it exceeds this limit, it can affect the rate of penetration and can cause a stuck. As for the value of the cutting transport ratio should not be less than 50% because if it is less than that the hydrostatic pressure below will be large and can cause formation fractures. In this case, we will discuss the analysis of cutting removal on the 8.5 inch route at 4290 to 5174 ft depth, with a slope of 66.29^{o} from the starting point of the borehole.

Keywords: Cutting Carry index, Cutting Transport Ratio, Cutting Concentration in Annulus, drilling mud

1.0 INTRODUCTION

In order to optimize drilling operation, it is necessary to use the drilling mud. Therefore, maintaining and controlling physical properties due to confirm the desired specification is necessary (Wastu et al., 2019) . The drilling fluid is circulated through a well in order to remove cuttings from a wellbore. A well can be drilled successfully, safely and economically because of the role of drilling mud that can fulfill many functions. The prominent functions are removing cuttings from under the bit, carrying cuttings through the hole and up to the surface, releasing cuttings in the fluid when the surface equipment is processed, and allowing cuttings to settle out the surface (Baker Hughes, 1995).

During operations, it is very important to conduct the cleaning of the hole, in order to enhance the rate of drilling. The cleaning of the hole must be engineered. Therefore, an emerging challenge can be ensured by hole cleansing optimization in the sections of hole that has been drilled. Deciding several factors between the failure and success during drilling is occurred evenly. The cascading in drilling rate lost circulation, the instability of wellbore, ECD's cascading trends, wiper trips that occurred often, back rearming, cement jobs' low quality, bit balling, extension of the operations time, and rising in the cumulative cost of drilling operations are the effects of insufficient hole cleaning. Since cleaning beneath the bit relates to drilling rare, therefore all other factors that relate to drilling rate (such as density, hydraulics, mud properties, etc.) should be considered simultaneously.

S is a field located in the middle of the sea or commonly known as off-shore. This offshore well is a development well. This field has a horizontal wells structure so that when lifting the cutting on the well the angle of inclination greatly affects the process. The difference between the G well S field is that it has a fairly large inclination, where later this inclination can affect the cutting removal process. This can be prevented by taking into account several factors. In the process of removing cuttings apart from indications, there are several important factors to consider in order to achieve a successful removal of cuttings, sort of the mud's physical properties in the form of mud density and rheology, type of flow, surface tension, ROP (Rate of Penetration) and jet velocity of the pump's ability. The most important factor to consider in development well A is when calculating the correction slip speed, the value of which will vary according to the level of inclination of the slope. (Agus Alexandri, 2016; Mohammadsalehi & Malekzadeh, 2011; Subraja, Lestari, & Husla, 2022; Subraja, Lestari, Husla, et al., 2022; Sunaryo et al., 2022)

In drilling on this route, the drilling fluid used is High Performance Water Base Mud (HPWBM), which has similar characteristics to Oil Base Mud (OBM) mud. This type of mud is often used when drilling at large depths and also the formation area has a lot of shale, so that swelling does not occur, drilling is carried out with this High-Performance Water Base Mud (HPWBM) mud. Below this table 1 Performance Comparison of Drilling Fluid

Table 1 Performance Comparison of Drilling Fluid

No.	Parameter Testing	Type Fluids	
		Oil Base Mud	HPWBM
1	Plastic Viscosity (mPa/s)	Average	1
2	Average Viscosity (mPa/s)	Average	2
3	Yield Point (Pa)	Average	3
4	Gel Strength	Equal	4
5	API Filter Press	Average	5
6	PH Contamination	-	6
7	Contamination Test Contaminant Factor: Sea Water, clay, and Limestone	Average	7
8	Quantitative Shale Recovery	Good	8

In High Performance Water Base Mud shale inhibitors that are most often used are of the Poly Amine type. Shale inhibitors are most often used because this composition is the most effective in inhibiting clay hydration and minimizing the potential for bit balling, and this composition can be directly added to the sludge system without changing the fluid characteristics (Jung et al., 2013). Poly Amine or commonly known as polyamine, apart from having a function to suppress hydration, is resistant to high pressure and temperature. This composition also functions as a clay hydration barrier, due to its property of reducing cavities between clays so that water molecules will not penetrate and cause swelling of the clay. additives provide good shale inhibition and reduce dilution rates (Gholizadeh-Doonechaly et al., 2009; Jung et al., 2013; Pino et al., 2018; Sunaryo et al., 2022)

In drilling activities, the drill bit used is useful for grinding rock formations and the results of this grinding produce cuttings. The deeper the drilling, the more cutting will be produced so that the cutting must be lifted above the surface perfectly so as not to cause problems such as pinched pipes and so on. Fluid flow, density, and rheology in the mud affect the cutting removal process. In the mud circulation process, the mud will enter the drill pipe and exit through the nozzle on the bit then pass through the annulus while lifting the cutting above the surface. Drilling mud assist the cutting process by means of laminar or turbulent fluid flow. Several problems in drilling can occur if the cutting cannot be completely lifted above the surface and then the cutting will settle back to the bottom of the well.

Cutting Carry Index (CCI) is one of the methods used in the world of drilling, especially in the use of circulating drilling mud. The purpose of calculating Cutting Carry Index is to find out whether the ability to lift cuttings by drilling mud in a well is working optimally or not. The success rate of lifting in this method is if the Cutting Carry Index (CCI) value is greater than one, then the cutting is lifted optimally. However, if the Cutting Carry Index (CCI) value is less than one, the cutting will settle. The value of Cutting Carry Index (CCI) is very influential on the velocity in the annulus of the borehole, mud density, and constant power law. (al Rubaii, 2018; Rudi Rubiandini, 2010)

Cutting Transport Ratio (CTR) is a method of lifting cuttings (drill cuttings) to normalize the value of VTransport. Removal of cuttings is said to be optimal if the Cutting Transport Ratio is more than 50% and if it is less than 50% then the cuttings settle. Vtransport is the pure velocity of the cutting being lifted to the surface. (al Rubaii, 2018; Rudi Rubiandini, 2010)

Cutting Concentration in Annulus (CCA) is a method of lifting cuttings, which is used to calculate the contents value of solids in the part of annulus. Cutting concentration's value (drill cuttings) must be less than 5% because it can cause problems, for example ROP decreased, drag and torque increased, and tightness of the pipe. In analyzing the cutting ability of cuttings, this method is very appropriate because it takes into account the value of penetration rate (ROP) and Cutting Transport Ratio. (al Rubaii, 2018; S. , Bridges & Robinson, 2020; S. Bridges & Robinson, 2020b, 2020a; Hossain, 2016; Moore, 1986; Prassl, 2014; Ramsey, 2019b, 2019a; Rudi Rubiandini, 2010; Walangitan et al., 2020)

2.0 METHODOLOGY

The research conducted in this final project uses quantitative and descriptive analysis. Where in the early stages, qualitative analysis was carried out for data collection and correlation between variables. These variables are the drilling parameters used in the sequences of lifting cuttings from the base of the well to surface.

In this final project, the focus is more on the use of the mud itself, especially on the removal of cuttings. There are variable data needed to support the calculation of drill cuttings' removal such as the value of the flow velocity in the annulus, the value of the slip velocity, and the critical velocity of the mud. Where the data variables are PV (Plastic Viscosity), YP (Yield Point), drilling mud density, borehole diameter, cutting density, cutting diameter, and the outer diameter of the drill pipe. After obtaining the mud rheology value data, it is used as a basis to find flow velocity in the annulus, slip velocity value, cutting speed to rise to the surface, and minimum flow velocity so that cuttings can be lifted to the surface without any cutting falling back to the bottom of the hole. drill. Usually, these values are also influenced by the type of mud flow, cutting diameter, and also the lithology of the rock itself.

The successful removal of drill cuttings to the surface in this final project was using three parameter methods including: CCI, CTR, and CCA method. The CCI method's value played a role in the drilling mud whether the cutting at the bottom of the well G borehole to the surface can be lifted by the mud. The optimum result occurred if the CCI (Cutting Carrying Index) value is greater than one. The value of the Cutting Transport Ratio Method is the amount at the bottom of the borehole to find out what percentage of the number of cuttings lifted from the overall cutting at the bottom of the borehole well G, the results can be said to be optimal if the CTR value is higher than 50%. The CCA method value is the size of the borehole G of the well to determine the solids content in the annulus. Where the concentration value will greatly affect the ROP because if this value is not in accordance with the standard CCA (Concentration in Annulus) value then the cutting will be difficult from Daily Mud Report data, drilling parameters such as Rate of Penetration (ROP) and also Rate per Minute (RPM) can be seen from Daily Drilling Report (DDR) report data. And finally, drilling cutting data can be obtained from the final report value and solid control default to lift and cause problems, the CCA (Concentration in Annulus) value cannot be more than 5%.

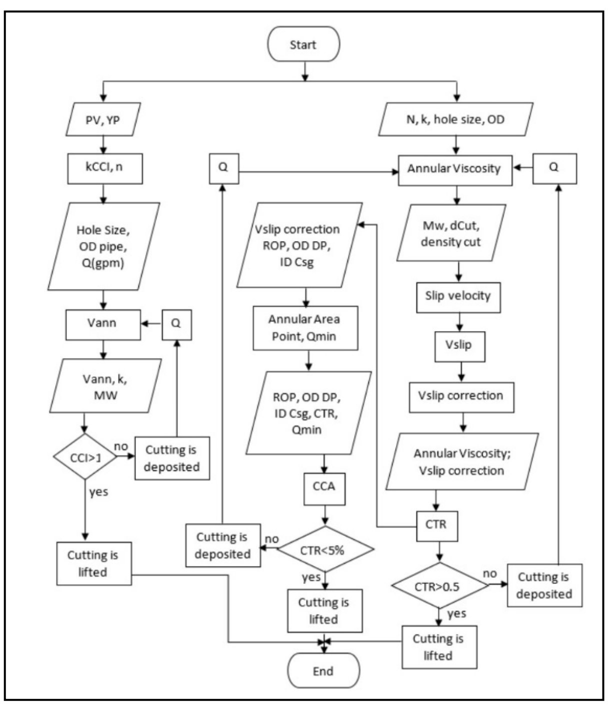


Figure 1. Flowchart of Cutting Lifting Research.

In the Figure 1, it can be seen that, the initial stage in this research is the implementation of data from the data obtained. These data include readings of rheological values and physical properties of mud

After implementing all the required data, the next step is to perform calculations and analyze using the three methods where the first thing to analyze is the Cutting Carry Index (CCI) value that has to be greater than one. CTR value has to be higher than 50%. After getting these two parameters, the last step is to calculate the value of CCA, which has to be lower than 5%.

3.0 RESULTS AND DISCUSSION

The type of rock lithology encountered in this 8.5-inch drilling route is grindstone. Where from a depth interval of 4290 ft to 5174 ft, we found grindstone, from the calculation of the removal of these cuttings it will be seen whether these different rock types will affect the process of successful removal of cuttings or not. Before carrying out the analysis of cutting removal using the CCI, CTR, and CCA methods. The primary step was interpretation of additional variables for cutting removal was carried out, consisting the rheology of drill mud, density and diameter's cutting, angle of inclination, rate or penetration and rate per minute.

The data that had been used to determine the analysis of cutting lift calculation on the 8.5-inch route at a 4290-5174 ft depth on 29 June 2018 can be seen as follows:

Table 2 Drilling Mud Parameters on the 8.5" route at a depth of 4290ft - 5174 ft

Parameter	Value
Mud Density, ppg	9.4
Inclination, °	90
Plastic Viscosity, cp	10
Yield Point, lb/100 ft2	27
n (Flow Behaviour Index)	0.345
K (Power Law Constanta)	4.299
Kcci	2197.001
Cutting Density, ppg	20.658
Cutting Diameter, inch	0.125
C concentration, (%)	0.894
Rate per Minute	120
Rate of Penitration, (ft/hrs)	50
Flow Rate, (gpm)	627

According to Table 2, to obtain other supporting parameters, further analysis can be carried out. Therefore, the removal of cuttings using the CCI, CTR, and also CCA on route 8.5 inch at 4290ft to 5174 ft depth can be implemented. The following calculation was to calculate annular area point, annular volume, velocity average, critical velocity and slip velocity. As the results appear in table 3.

Table 3. Parameter Result Calculation of Determination of Flow Type on Route 8.5” at 4290-5174 ft depth

BHA	Vann (ft/s)	Vcrit (ft/s)	Flow Type
Jars	11.0118	7.5221	Turbulence
Sub	9.5934	7.2841	Turbulence
HWDP	5.8771	6.4463	Laminar
DP (OH)	6.0958	6.5096	Laminar
DP(CH) 9-5/8”	5.1858	6.3116	Laminar
HWDP(CH) 9-5/8”	5.3554	6.3674	Laminar
DP (CH) 13-3/8”	2.0259	5.4527	Laminar
DP (CH) 13-3/8”	0.7741	4.7568	Laminar

According to the calculation on Table 4, the result showed the value of Vann (Velocity average), annular (annulus viscosity), Vcrit (critical speed), and also the flow type from each depth of BHA (Bottom Hole Assembly). The result of critical velocity value and average velocity comparison was affecting the flow type in annulus hole, if critical velocity value is greater than the average velocity value, it will produce a laminar flow pattern. Otherwise, according to the table above, it showed that the flow pattern was laminar and turbulent. This turbulent flow pattern is often encountered in the annulus of the drill bit, this turbulent flow pattern is due to the large flowrate and small area, causing a chaotic and irregular flow pattern. The flow pattern is most often encountered in drill bits, where this flow pattern is to provide pressure in all directions so that the attached drill bits can be released from the drill bit. As for this laminar flow pattern, it is often found in the BHA circuit from the drill collar upwards. This flow pattern directed towards the surface and did not collide, therefore the cutting that is already in the annulus can be lifted optimally. The use of this flow pattern is used in order to minimize the problems during drill holes, sort of regrinding, caving, and even stuck pipes.

Calculating other parameters repeatedly were conducted in this analysis, because in the Z field, one of the types which is the A well is horizontal well. Then the calculation of the Vslip correction to the slope’s degree of the drill hole is carried out, which serves to determine the absence of Vcut at that slope’s degree. On top of calculating the correction Vslip, there were conducted numbers of calculations, including slip velocity based on patterns of flow, Reynold number particle, and loss of pressure. The following is the result of the calculation analysis

Table 4. Calculation of Slip Velocity and Pressure Loss on the 8.5” Route at a depth of 4290 ft – 5174 ft

BHA	Vslip Correction (ft/sec)	NRE Particle	Pressure losses (psi)
Jars	0.1948	0.4207	0.1832
Sub	0.1948	0.4207	0.0290
HWDP	0.0317	0.0684	1.7546
DP (OH)	0.0331	0.0714	3.6833
DP(CH) 9-5/8”	0.0282	0.0609	7.3927
HWDP(CH) 9-5/8”	0.0293	0.0633	3.5977
DP (CH) 13-3/8”	0.0121	0.0199	9.5206
DP (CH) 13-3/8”	0.0053	0.0038	3.9886

From the calculation of the analysis above, it is obvious that the Reynold number value of the particles resulting decent indication. As long as the value is less than 3, indication result of the flow from the Reynolds number calculation suggests as laminar. It is possible to be achieved because of the parameters from numbers of calculation already sufficient, likewise cutting density, area of hole and diameter of cutting which is not too large. Meanwhile, the Vslip calculation and Vslip correction shows a relatively cascading in value, which is sufficient in the process of lifting the cutting. As the result, that there is no further identification of the failure on the removal of cutting in holes that consist degree of slope.

As further consideration, the analysis continues with ECD (Equivalent Circular Density) calculation results for an 8.5-inch route from 4290 feet to 5174 feet deep. The aim of calculation was to figure out whether the formation at a depth of 5174 ft can still withstand hydrodynamic pressure from the mud or not, especially when the density value increases close to the formation fracture gradient. This table below shows the result of the calculation.

Table 5 ECD calculations on Route 8.5” at a depth of 4290 ft – 5174 ft.

P*hydrodynamic* (psi)	Total Pressure Loss (psi)	ECD (ppg)
2368.50	26.16	10.62

In general, the calculation of the ECD (Equivalent Circulating Density) has an extra value as compared to the preliminary density value whilst the drilling mud is inserted. This is due to the fact the density value has been stimulated with the aid of using the rock density value, in any other experience it is far enabled with the aid of using solids in dissolved elements. The ECD (Equivalent Circulating Density) value in the calculation in table 5 is sufficient due to the fact the value is extra than the preliminary mud weight value, which suggests that the reduction is properly combined and may be lifted. This is stimulated by using the value of plastic viscosity that could unite the reducing and drilling mud fluid.

Then after attaining all of the variables and additionally the helping parameters investigate the reducing lift. Then the calculation of the elimination of cuttings at the 8.5-inch path from a 4290-5174 toes depth, the use of 3 methods, namely; CCI, CTR, and additionally CCA.

Table 6 Calculation Result of Drill Cutting Lifting with Three Methods on Route 8.5'' at a depth of 4290 ft – 5174 ft.

BHA	CCI	CTR %	CCA %
Jars	34.11	96.18	0.58
Sub	29.72	95.62	0.54
HWDP	18.21	98.84	0.35
DP (OH)	18.88	98.83	0.37
DP(CH) 9-5/8”	16.06	98.83	0.33
HWDP(CH) 9-5/8”	16.59	98.82	0.34
DP (CH) 13 -3/8”	6.28	99.02	0.17
DP (CH) 13-3/8”	2.40	99.51	0.08

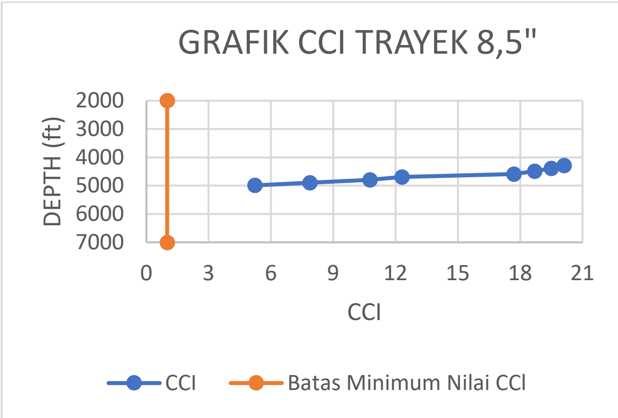


Figure 2. Calculation Result of Drill Cutting Lifting with CCI Methods on Route 8.5'' at a depth of 4290 ft – 5174 ft.

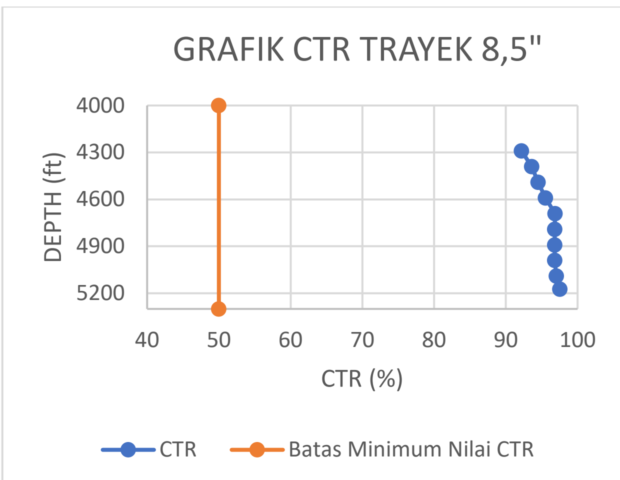


Figure 3. Calculation Result of Drill Cutting Lifting with CTR Methods on Route 8.5'' at a depth of 4290 ft – 5174 ft.

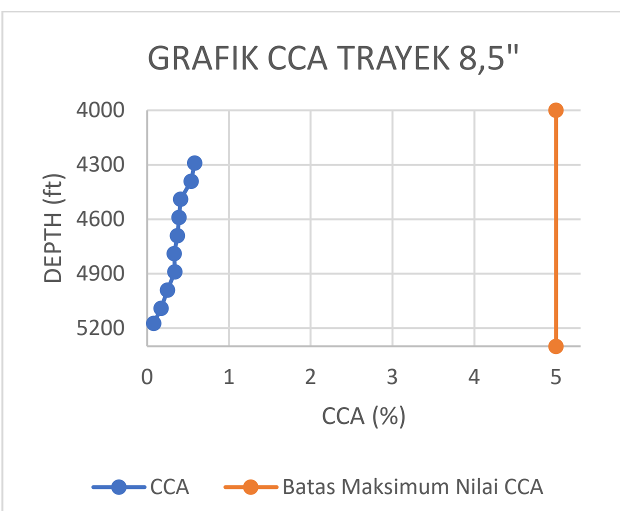


Figure 4. Calculation Result of Drill Cutting Lifting with CCA Methods on Route 8.5'' at a depth of 4290 ft – 5174 ft.

The table 6 and figures 2 ,3 and 4 shows the calculated stripping from well G, field S for the first section 8.5-inch route from 4290 feet to 5174 feet. This analysis was calculating the removal for each BHA (Bottom Hole Assembly) series. The values obtained from the CCI (Cutting Carry Index) calculation show that the average value for this calculation is 17.78, which is within the safe limit of 1. In the calculation of CTR (Cutting Transport Ratio), the average value of CTR (Cutting Transport Ratio) is 98.203% with a value above the limit of 50% and CCA (Cutting Transport Ratio) value still sufficient. It is found that the maximum CCA (annulus cutting concentration) value should be less than 5% with an average of 0.343%. From the results of the drill cut calculations by the three methods, it can be concluded that the S-field G-well drilling was fully lifted with a stretch of 12.5 inches at the initial spacing depth. This can be achieved by several factors, one of that by using HPWBM (High-Performance Water Base Mud) mud, which is already in the good category. The factors are the physical properties of the mud (mud weight and rheology), and drilling parameters (penetration rate, velocity per minute, and section density). The 8.5-inch route has value in each of these factors, namely the physical properties of the mud. Density values of 8.5 ppg - 10.5 ppg, plastic viscosity values of 8 cp - 13 cp, yield values of 17 lbs./100ft2 - 30 lbs./100ft2. Regarding the drilling parameters, the speed per minute (RPM) value ranges from 40 to 112 and the rate of penetration (ROP) value is 4 ft/hr. - 37 ft/h, mud flow rate ranges from 652 gpm - 990 gpm.

4.0 CONCLUSION

The analysis of cutting displacement using well A field Z on the route with a depth of 8.5 inches with a depth interval of 4290 feet - 5174 feet, is influenced by several factors, one of which is the value of the physical properties of the mud (flowrate) and mud rheology. The type of mud High Performance Water Base Mud used here is Poly Amine, this is used to prevent hydration of the clay. The calculation of the Equivalent Density value on the 8.5-inch route was obtained at 10.617 ppg, where this value when compared with the initial Mud Weight (MW) value was greater so that it can be concluded that the cutting has mixed well with the drilling fluid. using 3 methods as parameters for the success of cutting elimination including Cutting Carry Index (CCI) > 1 where the value on the 8.5-inch track is 17.781, Cutting Transport Ratio (CTR) > 50% where from the calculation the value is 98.204% and, the Cutting Concentration method in Annulus (CCA) < 5%, the calculation result is 0.334%. Therefore, it can be concluded that the cutting has been lifted optimally

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