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ANALYSIS OF MUD DENSITY BY USING CUTTING CAPACITY ANNULUS METHOD

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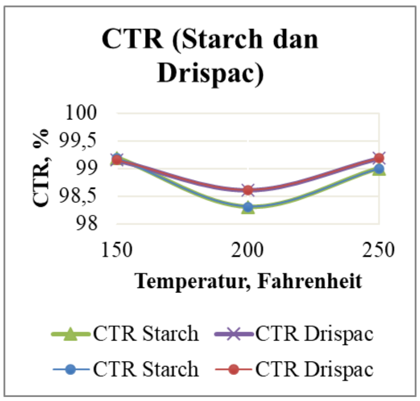
Graphical abstract



Abstract

Drilling mud has an important role in drilling operations, as well as lifting the cutting to the surface, controlling the pressure of the formation, and preventing the collapse of the borehole. Therefore, the drilling operations can be continued without obstacles. The function of the drilling mud depends on the conditions of the formation to be drilled for optimal results. One of the main functions is to lift cutting from a bottom hole to the surface. In the annulus, the minimum speed for lifting the cutting to the surface was calculated. The Cutting Capacity Annulus (CCA) is the value of the level of solids in the annulus. The proper concentration of cutting in the annulus is not more than 5%, to avoid drilling problems, such as decreased rate of penetration (ROP), increased drag and torque, and stuck pipe related to hole cleaning problems. In analyzing the lifting ability of cutting, CCA is very suitable to be used because it accounts for the parameters of ROP value. This study conducted a comparison of two types of natural polymers that have a function to help the hole cleaning in the drilling process. The two types of polymers are cellulose polymers (drispac) and polysaccharide polymers (starch). Furthermore, it also had been tested on a field scale using the cutting transport ratio (CTR) method to find out how much ratio is obtained in the two types of polymer mud. Based on the test of the two mud samples on the cutting removal process in the CCA method at a temperature of 150ºF, the mud samples containing starch ranged from 1.0731% to 1.0792%, while the mud samples containing drispac ranged from 1.0730% to 1.0793%. At 200ºF the mud samples containing starch ranged from 0.7357% to 1.3604%, while the mud samples containing drispac ranged from 0.7357% to 1.3603%. At a temperature of 250ºF, the mud samples containing starch ranged from 0.2652% to 0.4903%, while the mud samples containing drispac ranged from 0.265178% to 0.4907%. Although the density of the starch-containing mud sample was greater than drispac, the CCA value did not have much effect due to the difference in density of the two mud samples of 0.1 ppg. Both samples were able to optimally lift the cutting above the surface because the CCA value was less than 5%.

Keywords: drilling, mud, cutting, starch, drispac.

1.0 INTRODUCTION

Drilling mud plays an important role in the oil and gas drilling process. One of the main functions is to lift cutting from a bottom hole to the surface. Drilling mud must be able to properly move the cutting from the bottom of the hole to the surface. If the cutting process is not optimal, deposits can form at the bottom of the well, which can lead to problems such as a stuck pipe. A stuck pipe is a condition in which a part of the drill pipe is stuck in the drill hole. In practice, drilling does not always operate smoothly and drill pipes are often squeezed. An important parameter of drilling mud is a value for the physical properties of the drilling mud. The physical property that affects the removal of cuttings is density. Therefore, additives are needed that can keep the values of the physical properties of the sludge in good condition during the cutting removal process.

This study compares two types of natural polymers that can assist in the hole cleaning process during the drilling process. The two types of polymers are cellulosic polymers, or drispac, and polysaccharide polymers, or starch. The two drilling mud samples were tested for the physical properties of the mud under the influence of temperature changes, therefore the two drilling mud samples can represent the state of the mud in the well. The ratio of the two polymer slurry types was tested on a field scale using the cutting transport ratio method. [1-4]

Drilling mud is mud that circulates inside a well and is designed to remove the cutting from the drilling hole. The purpose of the use of drilling mud is to ensure that drilling operations take place safely, successfully, and economically without any problems or interruptions during the drilling process. [5]

Drilling mud is the most important material in drilling operations. The main purpose includes preventing the loss of the wellbore, lifting the drill bit to the surface, cooling the bit, and keeping the formation pressure from blowing out or gas explosions that can cause fires and damage to drilling equipment and accident to workers. [6]

In drilling operations, using a rotary drilling system is very important for the selection of the right drilling equipment, which can lead to optimal results, especially in the penetrated formation. The components of rotary drilling systems are the main equipment for forming drill holes. The components consist of a drill pipe, drill collar, bottom hole assembly (BHA), and drill bit, which are in direct contact with the penetrated formation. The rock will be eroded with drill bit (drilling bits) to form a hole and produce cutting. [7]

Drilling mud has an important role in drilling operations, as well as lifting the cutting to the surface, controlling the pressure of the formation, and preventing the collapse of the borehole. Therefore, the drilling operations can be continued without obstacles. The function of the drilling mud depends on the conditions of the formation to be drilled for optimal results. [8]

In the annulus, the minimum speed for lifting the cutting to the surface was calculated. [9] The Cutting Capacity Annulus (CCA) is the value of the level of solids in the annulus. The proper concentration of cutting in the annulus is not more than 5%, to avoid drilling problems, such as decreased rate of penetration (ROP), increased drag and torque, and stuck pipe related to hole cleaning problems. In analyzing the lifting ability of cutting, CCA is very suitable to be used because it accounts for the parameters of ROP value [10-11].

This study conducted a comparison of two types of natural polymers that have a function to help the hole cleaning in the drilling process. The two types of polymers are cellulose polymers (drispac) and polysaccharide polymers (starch). The two mud samples had been tested for their physical properties, with the influence of temperature changes. Therefore, the two drilling mud samples represent the mud condition in the wellbore. Furthermore, it also had been tested on a field scale using the cutting transport ratio (CTR) method to find out how much ratio is obtained in the two types of polymer mud. The specification standards for KCl polymer mud against various temperatures are shown in Table 1.

Table 1 Specification of Mud

No	Properties	Temperature (°F)			Unit
		150	200	250	
1	Density	9.0 – 9,5	9,5 – 10.0	10.0 – 11.0	ppg
2	Funnel Viscosity	15 - 25	25 - 35	35 - 45	sec/quartz
3	Plastic Viscosity	15 - 25	25 - 35	35 - 45	centipoise
4	Yield Point	15 - 20	20 - 25	25 - 30	lbs/100sqft
5	Gels Strength	4–10 / 10-18	4–10 / 10-18	4–10 / 10-18	lbs/100sqft
6	Filtration Loss	<=10	<=10	<=10	ml

2.0 METHODOLOGY

According to the flow chart in Figure 1, the methodology used in this study had two stages. The first stage was in terms of making mud and the second stage was the process of calculating the removal of the cutting. The first stage was made of two mud samples; starch and drispac. Starch and drispac have the same chemical composition with CMC (Carboxy Methycellulose) (CH_2OH)

2.1 Composition of Mud

Tables 2 and 3 is explain the materials used for this experiment such as KOH, bentonite, starch, drispac, KCl, soltex, barite, and defoamer.

Table 2 Starch Mud Composition

Bahan	S.G	% Vol (350 ml)	lb/bbl	350 ml	Weight (gram)
Aquades (ml)	1	89.37	311.1	312.80	312.80
KOH (gr)	2.13	0.10	0.7	0.35	0.75
Bentonite (gr)	2.6	0.77	7	2.69	7
Starch (gr)	1.10	3.51	13.4	12.27	13.5
KCL (gr)	1.72	2.82	16.9	9.88	17
Soltex (gr)	1.40	0.82	4	2.86	4
Barite (gr)	4.20	2.04	29.8	7.14	30
Defoamer (ml)	1	0.57	2	2	2
Total		100	385	350	387

Table 3 Drispac Composition

Bahan	S.G	% Vol (350 ml)	lb/bbl	350 ml	Weight gram
Aquades (ml)	1	92.23	321.1	323.81	322.81
KOH (gr)	2.13	0.10	0.7	0.35	0.75
Bentonite (gr)	2.6	0.77	7	2.69	7
Drispac (gr)	1.55	0.65	3.5	2.26	3.5
KCL (gr)	1.72	2.82	16.9	9.88	17
Soltex (gr)	1.40	0.82	4	2.86	4
Barite (gr)	4.20	2.04	29.8	7.14	30
Defoamer (ml)	1	0.57	2	2	2
Total		100	385.01	350	387

2.2 Methods

After mixing the material, a hot rolling oven was carried out at temperatures of 150ºF, 200ºF, and 250ºF for 16 hours, therefore it had results that relate to the conditions in the well.

After the mud sample was carried out in a hot rolling oven, the mud was tested for its physical properties. One of the tests was the mud density value test, by used mud balance. If the results of the physical properties of the two samples are not by the specified standard specifications, then additional materials such as barite will be carried out. After that, the analysis was carried out again based on the addition of materials by the specified standard values. In the second stage, the process of CCA calculation requires several data components such as Q pump, ROP (Rate of Penetration), Hole Size, and CTR. The CTR value was obtained from the calculation between V*slip*, which had been corrected based on the drilling inclination angle and the type of flow that exists, and the value of the annular velocity. [12] After that, the calculation is carried out if the results of the removal of cuttings get a value of <5%, then the process of removing the cuttings on the drilling is going well. [13-14]

For equation of *Cutting Concentration in Annulus* (CCA) we can use this formula

$$\mathrm{AAP} = \frac{\mathrm{Hole\ Size}^2 - \mathrm{OD}^2}{1029.4} \quad (1)$$

$$\mathrm{V_{min}} = \frac{\mathrm{ROP}}{36 \times \left[1 - \left(\frac{\mathrm{OD}}{\mathrm{Hole\ Size}}\right)^2\right] \times \mathrm{C_{Conc}}} + \mathrm{V_{slip\ koreksi}} \quad (2)$$

$$\mathrm{Q_{min}} = \mathrm{V_{min}} \times \mathrm{AAP} \times 60 \times 42 \quad (3)$$

$$\mathrm{CCA} = \frac{\mathrm{ROP} \times \mathrm{Hole\ Size}^2}{14.7 \times \mathrm{CTR} \times \mathrm{Qmin}} \times 100\% \quad (4)$$

For knowing the CCA value we needed ROP (Rate of Penetration) value, the size of drilling hole, CTR (Cutting Transport Analysis) value and Qmin (Minimum Pump Rate). For Qmin value we need AAP value and Vmin value with the equation 1 and 2. Figure 1 are Flowchart of Starch and Drispac Density Analysis on Cutting Lifting Process Using CCA Method.

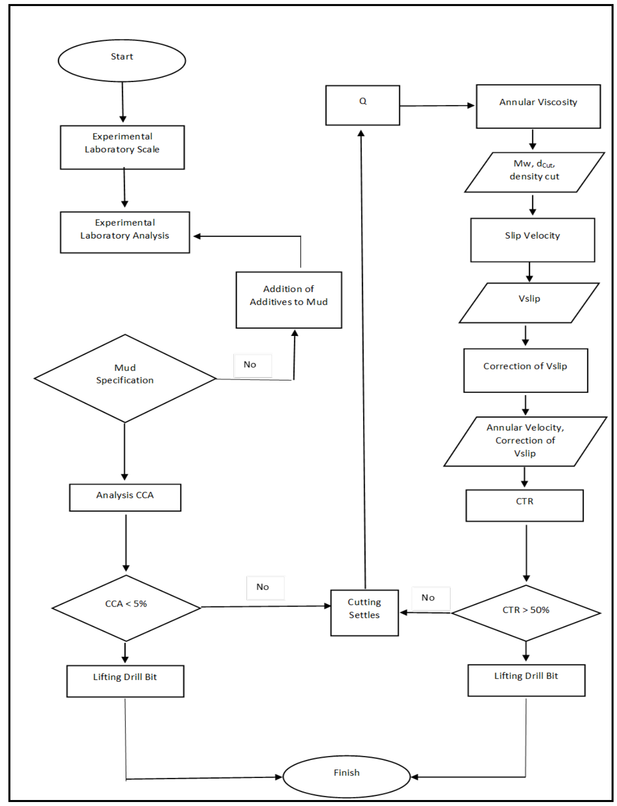


Figure 1 Flowchart of Starch and Drispac Density Analysis on Cutting Lifting Process Using CCA Method

3.0 RESULTS AND DISCUSSION

In the cutting removal process, there are three very influential physical properties of the mud; density, plastic viscosity, and yield point. [15-16] These physical properties have a role in the cutting removal process, therefore suitable additives are needed to produce hole cleaning in wells. Density has meaning as the relationship between mass and volume. An object that has a large density will have a large mass density. That way, the closer the particles that make up an object, the greater the density value for the same object. [17]

Determination of the density has a role in removing cuttings during drilling circulation which is influenced by the lifting power of the drilling mud. The higher the density, the higher the cutting ability of the well, but the density must be following the specifications used in the field. If it is not, it will cause various problems, sort of sloughing shale or lost circulation. In this laboratory study, the density physical properties were tested on starch and drispac. This density had a specification value, for a sample temperature of 150ºF it had a density of 9.0-9.5 ppg, for a temperature of 200ºF it had a density of 9.5-10 ppg, while for a temperature of 250ºF it had a density of 10-11 ppg. From the results of these specifications, a result requirement was made to obtain the density for the two samples. Changes in the density values of the two mud samples are shown in table 4. Table 5 shows the change in the value of density with various temperatures after the addition of solids and polymers.

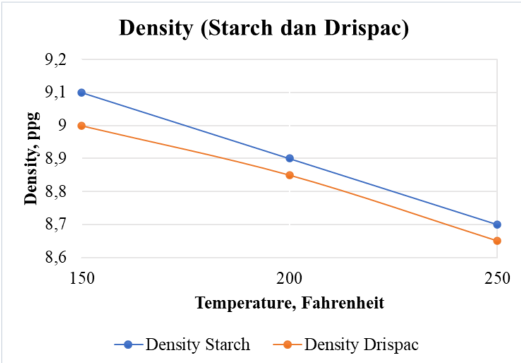


Figure 2. Density Measurement Results Against Various Temperatures

Figure 2 shows the results of the decrease in each mud sample. This happened because of the hot rolling factor in each of these samples. If an object is heated, it will expand, therefore based on the value of the sample, treatment was needed. Especially for the mud sample at a temperature of 150ºF, no treatment is needed because it has resulted in following the specifications for the mud. In the 200ºF and 250ºF samples, treatment was needed by adding barite to each of these samples. The addition of barite to starch and drispac for a temperature of 200ºF was 60 grams, while for a temperature of 250ºF was 120 grams. After the treatment, the results are obtained in the Figure 3.

Table 4 Density Measurement Results Before Treatment

Polymers	Temperatures (ºF)			Units
	150	200	250	
Starch	9.1	8.9	8.7	ppg
Drispac	9	8.85	8.65	ppg

Plastic viscosity is a reduction in the reading of a dial reading of 600 RPM with a dial reading of 300 RPM. Plastic viscosity can also be interpreted as flow resistance caused by particle friction [18]. The content of solids and polymers in the mud can affect the value of plastic viscosity. The more solids and polymer content in the mud, the higher the plastic viscosity value. Every change in temperature results in a change in the value of the plastic viscosity. Changes in the plastic viscosity values of the two mud samples are shown in table 6.

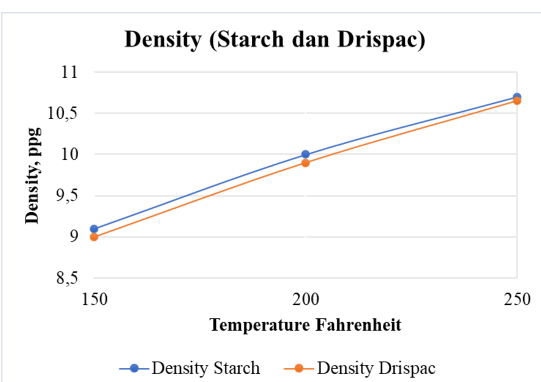


Figure 3. Density Measurement Results After Adding Barite

Table 5 Density Measurement Results After Treatment

Polymer	Temperature (ºF)			Unit
	150	200	250	
Starch	9.1	10	10.7	ppg
Drispac	9	9.9	10.65	ppg

The changes of plastic viscosity against various temperatures on the two natural polymers can be shown in Figure 4 below.

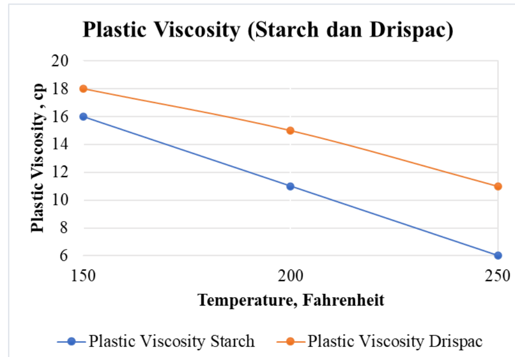


Figure 4. Plastic Viscosity Measurement Results Before Adding Barite

Table 6 Measurement Results of Plastic Viscosity Before Treatment

Polymer	Temperature (ºF)			Unit
	150	200	250	
Starch	16	11	6	cp
Drispac	18	15	11	cp

Figure 4 shows that for every increase in temperature, the plastic viscosity decreased. This is because the number of solids in the mud settle at the bottom of the aging cell surface, therefore the friction between the solid particles with each other was getting smaller. The decrease in the value of plastic viscosity on the other hand can occur due to the use of natural polymers. Its effectiveness decreased with every increase in temperature. The decrease in the effectiveness of the use of natural polymers can reduce the surface area of the particles, therefore the frictional force between the particles is reduced and causes the plastic viscosity value to decrease. At a temperature of 150ºF, the two natural polymers followed the standard specifications of the mud, therefore no material was added to the mud. This can be seen from the value of plastic viscosity produced from mud containing starch was 16 cp and drispac was 18 cp. At a temperature of 200ºF, the plastic viscosity value of mud containing starch was 11 cp and drispac was 15 cp. At a temperature of 250ºF, the plastic viscosity value of mud containing starch was 6 cp and drispac was 11 cp.

At temperatures of 200ºF and 250ºF, the two natural polymers were not following the standard mud specifications shown in table 1, because the solids in the mud settle below the surface of the aging cell after a hot rolling oven for 16 hours. The effectiveness of the use of natural polymers was decreasing, therefore solids and polymers must be added to each mud. Solids such as bentonite, as well as starch or drispac, were added to each mud to increase the frictional forces between the particles in the mud. Increasing the frictional force between the particles in the mud can increase the plastic viscosity value at various temperatures. Increasing the value of plastic viscosity can help the cutting removal process to be optimal. Table 7 shows the change in the value of plastic viscosity with various temperatures after the addition of solids and polymers.

Table 7 Plastic Viscosity Measurement Result After Treatment

Polymer	Temperature (°F)			Unit
	150	200	250	
Starch	16	33	35	cp
Drispac	18	35	38	cp

The changes in the value of plastic viscosity with various temperatures on the two natural polymers after the addition of materials such as bentonite and polymer, is shown in Figure 5.

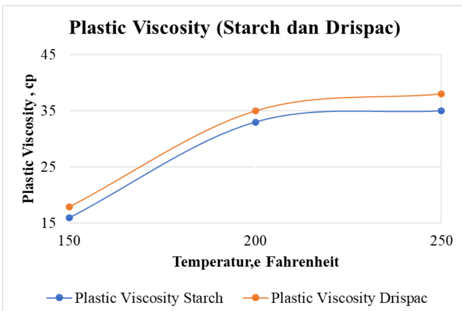


Figure 5. Plastic Viscosity Measurement Results After Adding Barite

Table 7 shows the increase in the value of plastic viscosity at various temperatures due to the addition of solids and polymers into each mud with a different composition and must be adjusted to the applicable standard mud specifications. At a temperature of 150°F, no additional treatment was carried out on each mud because it was following the applicable mud specification standards. At a temperature of 200°F bentonite was added as much as 12 grams at low speed for 4 minutes and 15 grams of starch at low speed for 2 minutes into the mud containing starch. 8 grams of bentonite was added at low speed for 4 minutes and 1 gram of drispac at low speed for 2 minutes into the mud containing drispac. The increase in the plastic viscosity value obtained after adding solids and polymer was 33 cp for the mud containing starch and the viscosity obtained from the mud containing drispac was 35 cp.

At a temperature of 250°F bentonite was added as much as 18 grams at low speed for 4 minutes and starch as much as 20 grams at low speed for 2 minutes into the mud containing starch. 12 grams of bentonite was added at low speed for 4 minutes and 1.5 grams of drispac at low speed for 2 minutes into the mud containing drispac. The increase in the value of plastic viscosity obtained after adding solids and polymer was 35 cp for mud containing starch and from mud containing drispac was 38 cp. The increase in the value of plastic viscosity was influenced by the addition of solids and polymers in the mud.

The yield point is the resistance to flow which was affected by the attractive forces between particles in a dynamic state. The attractive force between particles is due to the charge of the particles. Factors that affect the yield point of the mud, such as the volume concentration of the solids content and the amount of particle charge. Yield point changes can be affected by temperature [19-20]. The yield point value in the mud must be following the standard mud specifications shown in table 1 because it can lift the cutting above the surface optimally. Changes in yield points with various temperatures on the two natural polymers can be shown in table 6.

Table 8 Yield Point Measurement Result Before Treatment

Polymer	Temperature (°F)			Unit
	150	200	250	
Starch	19	13	9	lbs/100 sqft
Drispac	20	17	13	lbs/100 sqft

Table 8 shows a decrease in the yield point value for every increase in temperature due to the decrease in the number of particles that attract each other. The reduction in the attractive forces between the particles is caused by the deposition of solids in the mud after a hot rolling oven for 16 hours and a reduction in the effectiveness of the use of both natural polymers for each temperature increase. At a temperature of 150°F, the starch-containing mud sample has a yield point value of 19 lbs/100sqft and 20 lbs/100sqft that contain drispac. At a temperature of 150°F, the mud containing starch and drispac is following the standard mud specifications shown in table 4 so that no additional additives are needed in the mud. At a temperature of 200°F, the starch-containing mud sample has a yield point value of 13 lbs/100sqft and 17 lbs/100sqft that contain drispac. At a temperature of 250°F, the starch-containing mud sample has a yield point value of 9 lbs/100sqft and that contains 13 lbs/100sqft of drispac. The changes in yield point values with various temperatures on the two natural polymers can be shown in Figure 6.

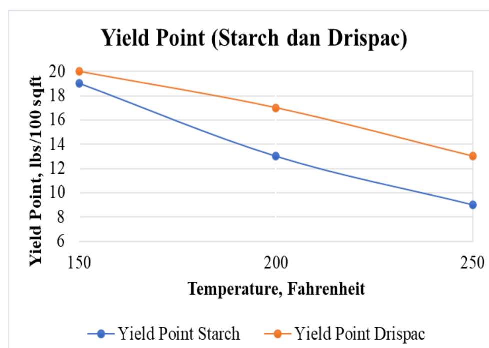


Figure 6. Yield Point Measurement Results Before Adding Barite

At temperatures of 200°F and 250°F, the mud containing starch and drispac does not meet the standard mud specifications shown in table 1, therefore both must be added with additives. Additives added to the mud are bentonite, starch, and drispac with the aim of increasing the attractive forces between particles in a dynamic state. Table 9 shows the value of the change in yield point after the addition of materials.

Table 9 Yield Point Measurement Result After Treatment

Polymer	Temperature (°F)			Unit
	150	200	250	
Starch	19	21	25	lbs/100 sqft
Drispac	20	24	29	lbs/100 sqft

The changes in the yield point value for various temperatures after the addition of materials can be shown in Figure 7.

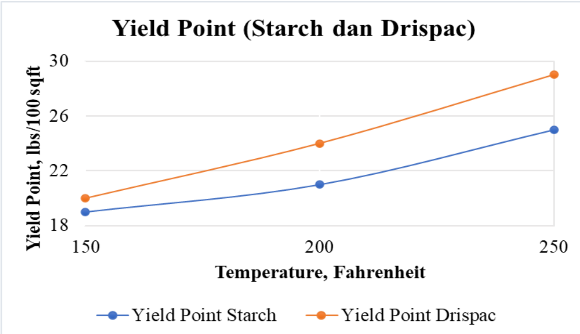


Figure 7. Yield Point Measurement Results After Adding Barite

Figure 7 shows an increase in the yield point value for the two natural polymers studied. The increase in yield point is due to the addition of material into the mud, therefore the attractive force between particles in the mud became greater. At a temperature of 150ºF, the mud was not given additional treatment because the two natural polymers studied were following the standard specifications shown in Table 1. At a temperature of 200ºF, the mud was treated by adding bentonite and 15 grams of starch into the mud containing starch. At a temperature of 200ºF, the mud containing drispac was treated by adding 8 grams of bentonite and 1 gram of drispac. The results were obtained at a temperature of 200ºF, mud containing starch got a yield point value of 21 lbs/100sqft and mud containing drispac got a yield point value of 24 lbs/100sqft. At a temperature of 250ºF both muds were subjected to additional treatment so that the yield point value was following the standard specifications shown in Table 4. Mud contained starch at a temperature of 250ºF and was added with 18 grams of bentonite and 20 grams of starch to produce a yield point value of 25 lbs/100sqft. At a temperature of 250ºF the mud containing drispac was subjected to additional treatment by adding 12 grams of bentonite and 1.5 grams of drispac to produce a yield point value of 29 lbs/100sqft. The yield point value in the mud sample containing drispac is greater than in the mud sample containing starch, this happens because the attractive force of the drispac particles is greater than the starch.

After testing the physical properties in the laboratory, a cutting removal test was carried out using the cutting concentration in the annulus method. This method is used to determine the cutting concentration in the annulus. Several components need to be considered, there are V*slip*, average speed, CTR, ROP, hole diameter, and Q*min* at each drilling depth.

In the table 10 there is a correction V*slip* value because the field sample used in the study was influenced by the inclination angle. If there is an inclination greater than or less than 45 degrees, correction of the slip velocity in BHA is required. The results obtained on a starch sample for temperatures of 150ºF – 250ºF are 0.0105 – 0.0318 ft/s. Meanwhile, for drispac sample are 0.0111 – 0.0261 ft/s and its shown on table 11. The decrease in the value of V*slip* indicates the difference between the minimum fluid velocity in the annulus so that the cutting can be lifted above the surface (V*min*), and the cutting speed in the annulus (V*cut*), was getting smaller and vice versa. The V*slip* value was expected to get a small value, therefore when the V*cut* value approaches the V*min* value, the cutting has lifted to the surface approaching the mud velocity in the annulus, which indicates the mud is thick and the CTR increases.

Table 10 Slip Velocity Measurement Results on Starch and Drispac Mud Samples

Polymer	Temperature	BHA	V*ann*, ft/s
Starch	150ºF	DP (OH)	1.3067
	200ºF	DP (OH)	1.8851
	250ºF	DP (OH)	2.6610
Drispac	150ºF	DP (OH)	1.30667
	200ºF	DP (OH)	1.8851
	250ºF	DP (OH)	2.6610

Besides the V*slip*, another factor to consider is the average velocity of a drilling series. The average velocity has components that need to be considered, including the size of the outside diameter of the pipe, pump flowrate, and hole diameter. In each BHA, the value of the annulus velocity (V*ann*) is different, because the outside diameter of the pipe is different. The larger the outer diameter of the pipe, the greater the V*ann* and vice versa. An increase in the outer diameter of BHA will cause the diameter of the annulus to shrink and the flow rate inside the annulus to increase.

Table 11 Average Velocity Measurement Results on Starch and Drispac Samples

Polymer	Temperature	V*slip*, ft/s	V*slip* correction, ft/s
Starch	150ºF	0.006316	0.010547
	200ºF	0.015388	0.031818
	250ºF	0.011968	0.026503
Drispac	150ºF	0.006682	0.011066
	200ºF	0.012734	0.026129
	250ºF	0.009778	0.021573

After getting the slip velocity and average velocity, it can be determined the value of cutting lift on starch and drispac mud samples by using the CTR method. Below is a figure of the results of the removal of cuttings on starch and drispac mud samples.

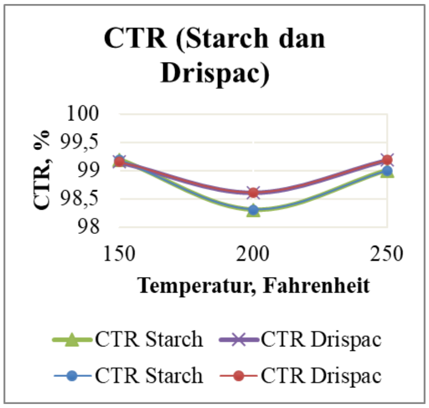


Figure 8. Cutting Lifting Results with the CTR method on Starch and Drispac

After getting the slip velocity and average velocity, it can be determined the value of cutting lift on starch and drispac mud samples by using the CTR method. Figure 8 are the results of the removal of cuttings on starch and drispac mud samples.

Table 12 Measurement Results of Annular Area Point, V*min* and Q*min* on Starch and Drispac

Poly-mer	Tempe-rature	BHA	Annular Area Point, bbl/ft	V*min*, ft/s	Q*min*, gpm
Drispac	150	DP* (OH)	0.2732	1.7043	1173.3986
	200	DP* (OH)	0.1215	1.8879	574.4252
	250	DP* (OH)	0.1215	1.8606	566.9122
Starch	150	DP* (OH)	0.2732	1.7037	1173.0411
	200	DP* (OH)	0.1215	1.8935	579.7243
	250	DP*(OH)	0.1215	1.8655	571.15172

Table 12 shows the annular area point values for the two mud samples, ranging from 0.1215 bbl/ft to 0.2732 bbl/ft. The factor causing the annular area point is the same because the two mud samples studied used the same BHA. The value of the annular area point affects the diameter of the annular hole. The larger the diameter of the annulus, the greater the value of the annular point and vice versa. The diameter of the annulus is influenced by the outer diameter of each BHA. The larger the outer diameter of the BHA, the smaller the annulus diameter and vice versa.

Table 10 shows that the V*min* value of the two mud samples is different because the correction V*slip* value of the two mud samples is different. The factor that affects the value of V*min* is the value of the correction V*slip*, the greater the value of the correction V*slip*, the greater the value of V*min*. The V*min* values of the starch-containing mud samples ranged from 1.7037 ft/s to 1.8935 ft/s, and those containing drispac ranged from 1.7043 ft/s to 1.8879ft/s. The V*min* value of the mud sample containing drispac was greater than the starch. This is because the correction V*slip* of mud containing drispac is higher than starch. Sludge containing starch is thicker than mud containing drispac.

Table 12 shows the different Q*min* values. The value of Q*min* depends on the annular area point and V*min*. The smaller the V*min* and the annular area point, the smaller the Q*min* value and vice versa. The Q*min* value of the starch-containing mud samples ranged from 579.5694 gpm to 1173.3986 gpm and the mud samples containing drispac ranged from 566.9122 gpm to 1173.3986 gpm. The Q*min* value at 150ºF of the starch-containing mud sample is smaller than that of drispac, because in this route the starch-containing mud sample is thicker than drispac, therefore the minimum pump flow rate in the drispac-containing mud sample must be higher for optimal cutting removal and the concentration of cuttings in the annulus is reduced. While the Q*min* values at temperatures of 200ºF and 250ºF from mud samples containing drispac are smaller than starch because the mud samples containing drispac are thicker than starch. The minimum pump flow rate in mud samples containing starch must be higher, therefore the removal of cuttings is optimal and the concentration of cuttings in the annulus is reduced.

The relationship between the calculation of annular area point, V*min*, and Q*min* contained in the CCA method is to reduce the concentration of cutting content in the annulus. In achieving this, V*min* and Q*min* are needed so that the cutting is lifted to the surface optimally. An annular area point affects Q*min*, the larger the annular area point, the greater the Q*min* value. V*min* and Q*min* are inversely proportional to the CCA value, the lower the Q*min* and V*min*, the higher the CCA value.

Table 13 CCA Measurement Results on Starch and Drispac

Polymer	Temperature	BHA	CCA
Starch	150 ºF	DP (OH)	1.0791
	200 ºF	DP (OH)	0.7358
	250 ºF	DP (OH)	0.2652
Drispac	150 ºF	DP (OH)	1.0792
	200 ºF	DP (OH)	0.7357
	250 ºF	DP (OH)	0.2654

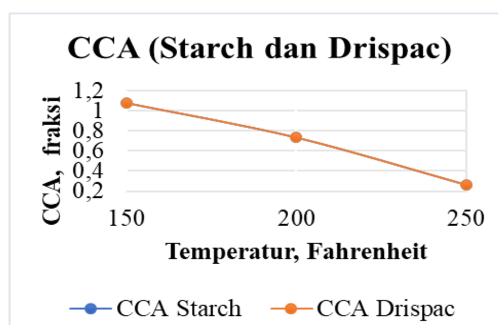


Figure 9. Cutting Lifting Results with CCA method on Starch and Drispac

Based on the test of the two mud samples on the cutting removal process in the CCA method at a temperature of 150ºF, the mud samples containing starch ranged from 1.073073% to 1.0792%, while the mud samples containing drispac ranged from 1.0730% to 1.0793%. At 200ºF the mud samples containing starch ranged from 0.7357% to 1.3604%, while the mud samples containing drispac ranged from 0.7357% to 1.3603%. At a temperature of 250ºF, the mud samples containing starch ranged from 0.2652% to 0.4903%, while the mud samples containing drispac ranged from 0.2652% to 0.4907%.The results are shown on Table 13 and Figure 9.

Although the density of the starch-containing mud sample was greater than drispac, the CCA value did not have much effect due to the difference in density of the two mud samples of 0.1 ppg. Both samples were able to optimally lift the cutting above the surface because the CCA value was less than 5%.

4.0 CONCLUSION

The results of the measurement of the physical properties of the mud containing starch and drispac, have results that are close to the standard mud specifications for lifting cuttings with KCl mud. Furthermore, with the CCA method, which is calculated at temperatures of 150ºF, 200ºF, and 250ºF, the CCA results range from 0.2652 to 1.3604%. The value is less than 5%, which indicates optimal results for the mud to lift the cuttings.

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