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Better Hole Cleaning In Highly Deviated Wellbores

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Abstract. Many drilling problems (lost circulation, hurdle in running casing, poor cement jobs, high torque and drag and the necessity of re-drilling and, mechanical stuck caused by cutting accumulation in the wellbore) can be avoided by good hole cleaning during drilling operation especially in directional wells.

In this experimental work, the cutting transport ratio (CTR) in hole inclined (60 degree) from vertical was estimated by using three values of drilling mud viscosities, three annular velocities, two types of cuttings size and two rotation speed of inner pipe (RPM). Note that the rig consisted from PVC outer casing 4 1/2 inch as OD diameter and inner drill pipe 2 inch as OD diameter.

The experimental results showed that the Cuttings Transport Ratio (CTR) increased with increasing the annular velocity and better hole cleaning which obtained from the third velocity (3.247 ft/sec) for all cases. Moreover, increasing the mud yield point (YP) helped to improve the cuttings transport ratio; however increasing the mud yield point slightly affected with increased the annular velocity. Furthermore, it was noticed that the rotation of drill pipe (RPM) is one of the most important parameter for cuttings removal especially in laminar flow and transition flow. The cuttings sizes 1.7 mm are also easier to transport than 3.35 mm cuttings sizes for all cases except low yield point (YP).

Keywords: Cuttings removal efficiency; cuttings transport ratio; drill cuttings; drilling fluid; hole cleaning.

1. Introduction

In drilling of direction a wells, the gravity force has impact on motion drilling cuttings. It causes the settling cuttings along the bottom side of the wellbore. When accumulative of drill cuttings to form bed that it can lead to indicate of drilling problems such as: stuck pipe, lose circulating, hardly running casing, bad cement, slow rate of penetration, excessive over-pull on trips, high torque and drag [1]. For example, one stuck pipe leads to waste more time and money. Therefore, the main aim of study is hole cleaning and cutting transport ware to minimum the cost of drilling operation.

The most significant parameters effecting on the carrying capacity of drilling mud can be brief as annular velocity of muds, rotation of drill pipe, inclined of hole, hole geometry, penetration rate, pipe/hole eccentricity, mud properties and cuttings characteristics [2,3]. Therefore, annular mud



velocity is the most factor that impact on hole cleaning because it is overcome on gravity forces of drill cuttings [4]. So, high annular mud velocity gives better hole cleaning but cannot be used because of hydraulic constraint.

Also, fluid yield point improves cuttings transport ration and then good hole cleaning. Moreover, rotation of drill pipe assists to remove cuttings transport because it is improved the flow regime profile and it improves annular velocities lowers than critical annular velocities to remove has drilling cuttings[5].

The type of drilling formation is effect on hole cleaning especially soft formation because it accumulated more cuttings comparison with hard information. Moreover, the small size of cuttings is easier to remove but the larger size and heavier cutting made hole cleaning more difficult and require higher pump rates for high- yield point fluids [6, 7].

In general, altering cutting size alone does not have significant role in enhancing hole-cleaning actually because in drilling operations we can't control the cuttings size while drilling.

In this study, most factors that effect in hole cleaning are taken in the one hole inclined angle (60 degree). Some researchers are considered the hole inclined (from 40 degrees to 60 degrees) as worst angles comparison with another hole angles.

The problem of cuttings transport in directional wells was the object of research in petroleum engineering. Initially, the researchers concentrated on the impacts of drilling factors on the removal of cuttings for oil and water based drilling muds. Thus, more experimental and theoretical researches, that are wanted in order to realize the mechanism of motion of cuttings and to determine the significant of drilling muds properties inside annulus.

The aim of this research study is knowing as the effect of most parameter that related with cuttings transport performance such as: annular fluid velocity, mud yield point, cuttings size, hole inclination and drill pipe rotation. The fluid velocity is very important because it is more contributed in hole cleaning. In this study all flow regimes laminar, transition and turbulent flow are investigated. Also the fluid yield point that has been tested to estimate the effect of fluid yield point on hole cleaning and knowing the best value of fluid yield point for better hole cleaning. The drill pipe has more impact especially in high hole inclination. Also, the high hole inclination has impact in drilling cuttings transport because the increase in hole inclination is assisted the rolling force of forward.

2. Experimental work

The experimental data are obtained from loop system that was built to investigate the cuttings transport. Elaborations of each part was summarized and discussed in this section:

2.1 Cuttings transport flow loop

The rig has the possibility to run all set of experiments in a normal pressure and normal temperature system (Figure 1). This rig was simulation for field condition by assumed drilling bit 8.5 inch (215.9 mm) and the drill pipe 5 inch (127 mm). Therefore, the rig designed to be 14 m (46 ft) as long from PVC which fits the test section that long of 5.5 m (18 ft) consists of two pipes outer pipe: outer diameter was 4½ in (110 mm) (inner diameter 4 inch) and inner pipe: 2 in (50.8 mm) outer diameter. The inner pipe designed to be centralized and has the ability to rotate.

The solid-liquid mixture is provided from a 1.5 m³ (1500 liters) container (Feed basin) where the liquid pumped and combined with the drilling cuttings. The mixer's impeller is grebes pump at the bottom depth inside the basin. A 10 H.P. centrifugal pump used to pump the muds and meet with the cuttings inoculated into the test section. This pump is convenient for situations where dissolution of the solid particles has to be avoided. The pump has been chosen to overlay the prospective range of operational conditions, which supplies 150 m³/hr (660 gpm).

The coarse sands taken from Nassiriya field from depth 1650 m to 1700 m were selected as solid particles. After cuttings, they were sift and washed and separated for two size 1.7 mm and 3.35 mm then weight of 204 g (0.449743 lb) as test sample. The total amount of sift cuttings which were ready prior to each run exceeded 15 kg (33.07 lb).

2.2 Drilling Mud

The drilling muds consisted of bentonite, caustic soda (Sodium hydroxide) and water to be used in this experimental work. Adding bentonite to water and mixing at a high speed for five hours and finally, drilling mud has been mixing at a middle speed.

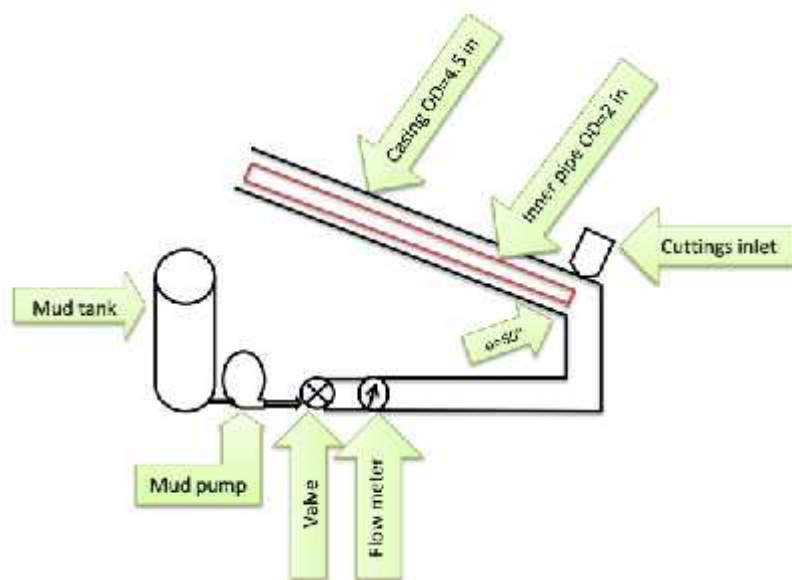


Figure 1. Cutting Transport Flow Loop

2.3 Experimental procedure

After sieving and cleaning the drill cutting and then weight them to 204 g (0.449743 lb). Each run was consisted of 6 experiments and was set up for high inclination angle (60 degree). All of these experiments were run with one rotating speed of inner pipe (80 rpm) and without rotating speed (0 rpm) for three flow rates (44, 66, and 92.46 gpm). For the next experiment, the same parameters were followed except using a new size of cuttings. After all experiments the termination of first run were completed, the second run was done with a new mud yield point (higher yield point). To do so, caustic soda was used as another yield point control agent.

Percentage of recovery is calculated using the following equation:

$$\text{Recovery (\%)} = (\text{Final dried weight} \times 100) / (\text{Initial dried weight}) \quad (1)$$

3. Results and discussion

3.1 Effect of yield point (YP)

According to this study, two types of cutting 3.35 mm and 1.7 mm, cuttings transport ratio (CTR) improved to increase mud yield point (YP) as showing in Figures (2 a – b).

Both figure (2a) for 3.35 mm cuttings size and figure 2b for 1.7 mm cutting size, the CTR is drew with multiple mud viscosities (YP) for three annular velocities. Each curve in the diagram describes a constant muds velocity for the three characteristic of drilling mud with three various viscosities YP (8, 21, and 28 lbf/100ft²). It is visible from Figures (2a - b) that primary increasing yield point from (YP=8 lbs/100ft²) to (YP=21 lbs/100ft²) results in better CTR for all the three different flow rates. Also the secondary increasing yield point from (YP=21 lbs/100ft²) to (YP=28 lbs/100ft²) results in better CTR for all the three different flow but has less effect in the primary increasing yield point. Therefore, the increase in YP is the main reason for increase they the amount of cuttings removal for both cuttings size, Also the effect of yield point is decreased with the increase in annular velocity.

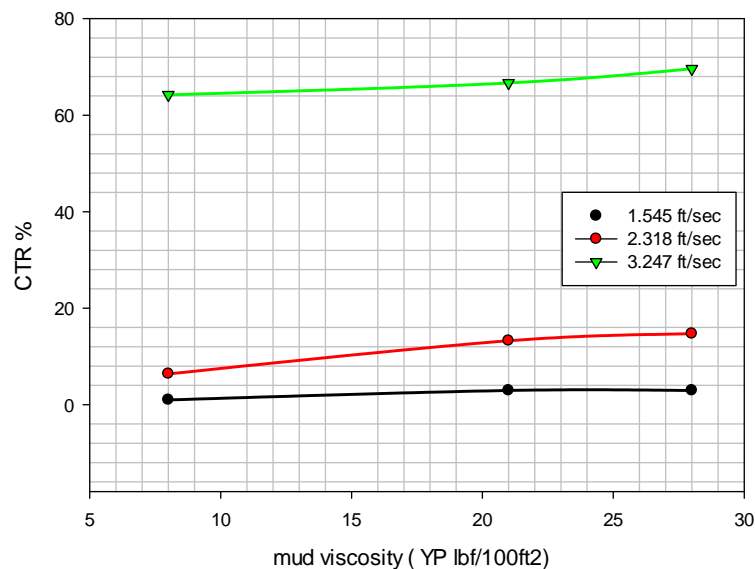


Figure 2a. cutting size 3.35 mm with RPM=0

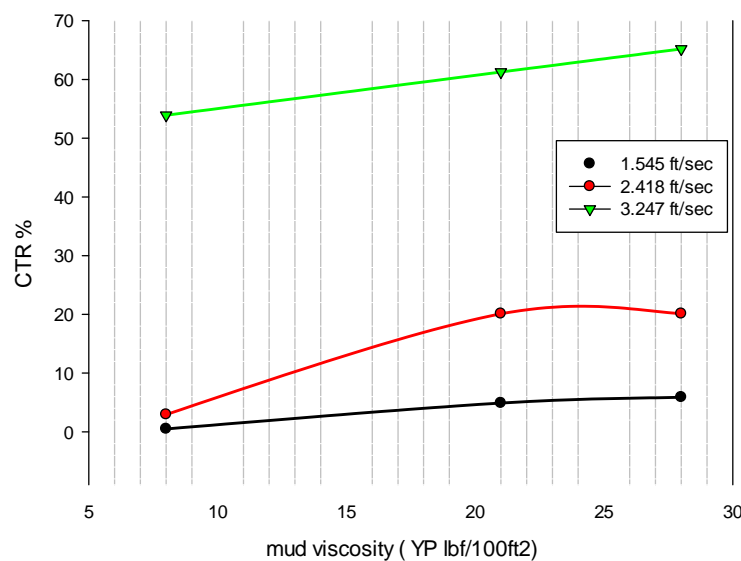


Figure 2b. cutting size 1.7 mm with RPM=0

3.2 Effect of annular fluid velocity

Annular fluid velocity has significant impact on cutting transport ratio as it showed in Figures (3 a – b). Figure (3a) for 3.35 mm cuttings size and Figure (3b) for 1.7 mm cuttings size in which, the CTR is drew with multiple annular velocities for three mud viscosities (YP).

As it can be seen in figures, any small increase in annular velocity will have more increased in CTR for the same yield point. Moreover, the increase in CTP, when the laminar flow converted to transient and then to turbulent flow regime.

The CTR was increased with the increased of annular velocity and raise maximum value in the third annular velocity (3.247 ft/sec Therefore, to get good cuttings transport (better hole cleaning), the annular velocity must be enough to prevent settling of cuttings.

The Most of injected cuttings were recovered by highest velocity of the drilling fluid, with more viscous mud and smaller cutting size. This fact also supports previous discussion about mud yield point in which increasing yield point.

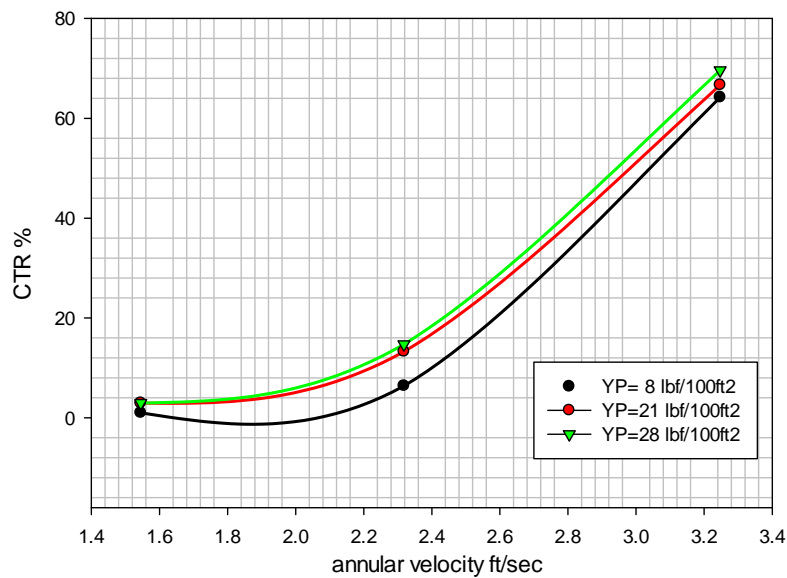


Figure 3a. Cutting size 3.35 mm with RPM=0

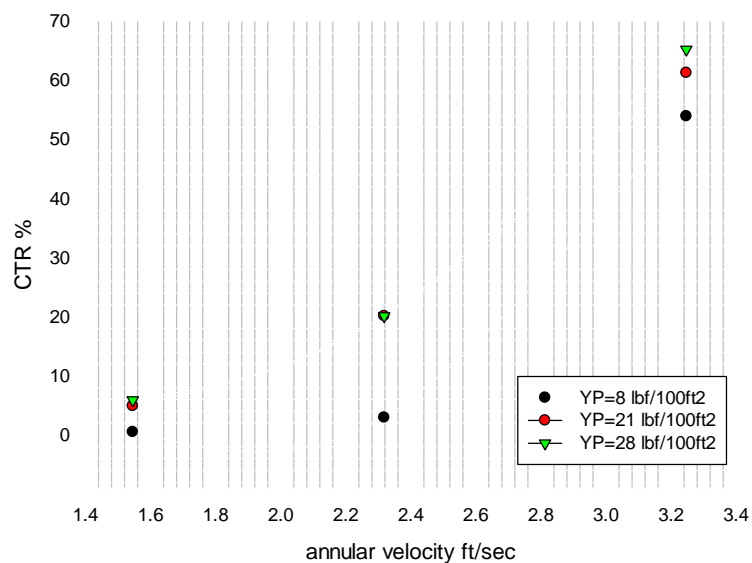


Figure 3b. Cutting size 1.7 mm with RPM=0

3.3 Effect rotation of drill pipe

Drill pipe rotation (RPM) observingly has an important role in the removal of cuttings especially in laminar and transition flow as seen in figures (4 a – b). In figures (4a) for 3.35 mm cuttings size and (4b) for 1.7 mm cutting size, the CTR is drew with multiple annular velocities, three value of yield point (YP) and two rotation of drill pipe (RPM). From figures, the drilling cutting is become faster with rotation of drill pipe. Attributed the effect of drill pipe rotation to several reasons as follows:

- 1- Rotation of drill pipe drives the drilling cuttings to the stream of fluid flow.
- 2- Rotation of drill pipe assist to improve the flatting of flow regime.
- 3- Rotation of drill pipe irritate of bed cuttings.

Therefore, the effect of drill pipe rotation is slight in turbulent flow and decreased with increasing in fluid yield point. In low yield point (8 lbf/100ft²) and turbulent flow (3.247 ft/sec), the effect of drill pipe rotation is very slight for both cutting size 3.35 mm and 1.7 mm. The rotation of drill pipe effect on cuttings 1.7 mm more than on cutting 3.35 mm.

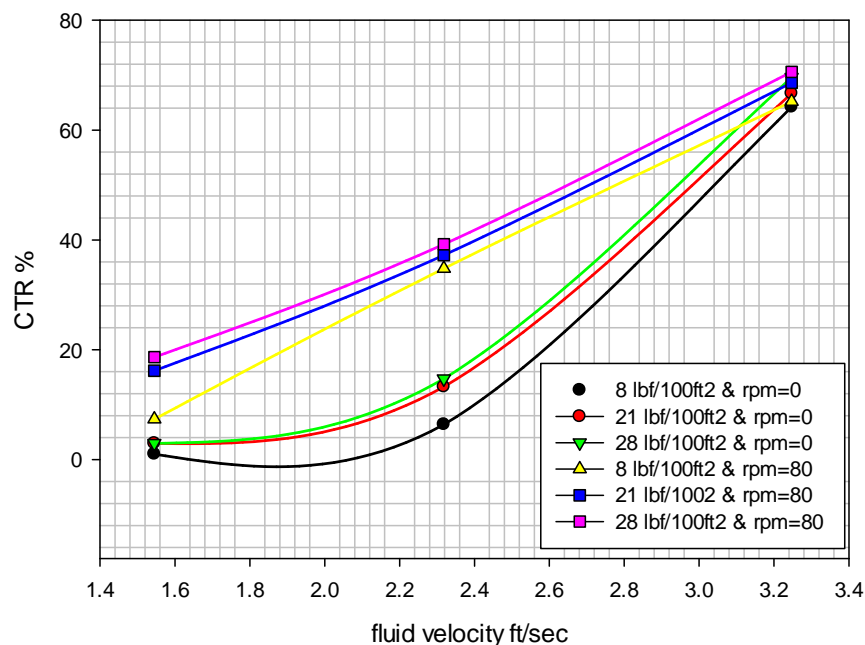


Figure 4a. Cutting size 3.35mm

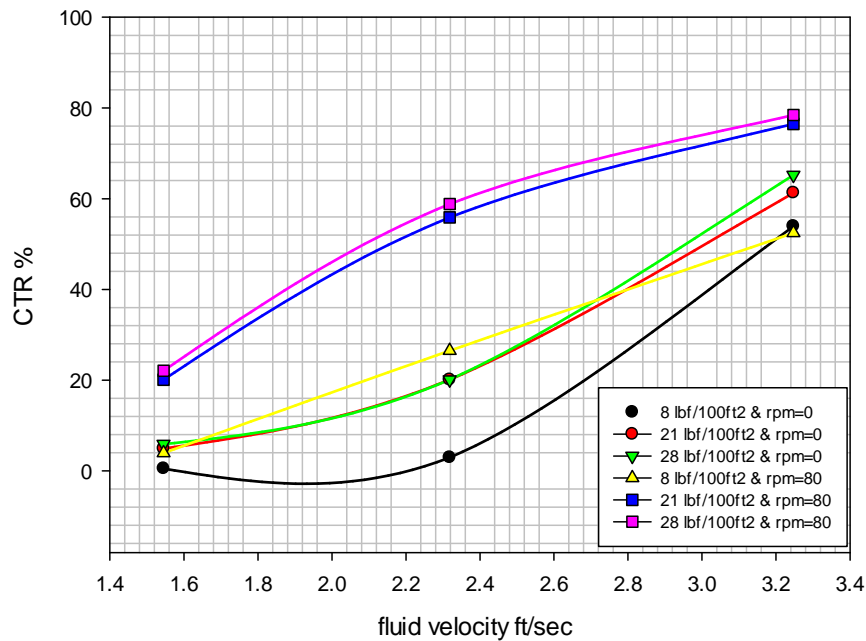


Figure 4b. Cutting size 1.7mm

3.4 The Effect size of cutting

The size of cuttings is one of the parameter that has an influences on the hole cleaning. For this study the small and medium sized cuttings have been considered for the analysis as showing in figures (5 a – d).

Figure 5a for cuttings size 3.35 mm and 1.7 mm, the CTR is drew with multiple annular velocities for three mud viscosities (YP) with RPM=0. Also figure 5b for cuttings size 3.35 mm and 1.7 mm, the CTR is drew with multiple mud viscosities (YP) for three annular velocities with RPM=0.

From figures noticed that the cuttings with 1.7 mm transported faster than cutting with 3.35 mm but in low yield point the effect became inversely phenomena. As shown in figures, the drilling cutting become slowly with decres in annular velocity for the same size.

The effect of drill pipe rotation is big on small cutting size 1.7 mm because of slip velocity as show:

$$V = \frac{(\mu_c - \mu_m)^{0.6} * 1 * d}{M^{0.3} * \mu^{0.3}} \quad (2)$$

Therefore, in laminar flow with rotation of drill pipe and high yield point, the cuttings 1.7 mm are transported faster than 3.35 mm comparison with laminar flow without rotation of drill pipe as mentioned previously. Also in this case, in low yield point the cuttings 1.7 mm transport less than cuttings 3.35 mm. In general, altering cutting size alone does not have significant role in enhancing hole-cleaning actually because of drilling operation that cannot control the cuttings size diameter.

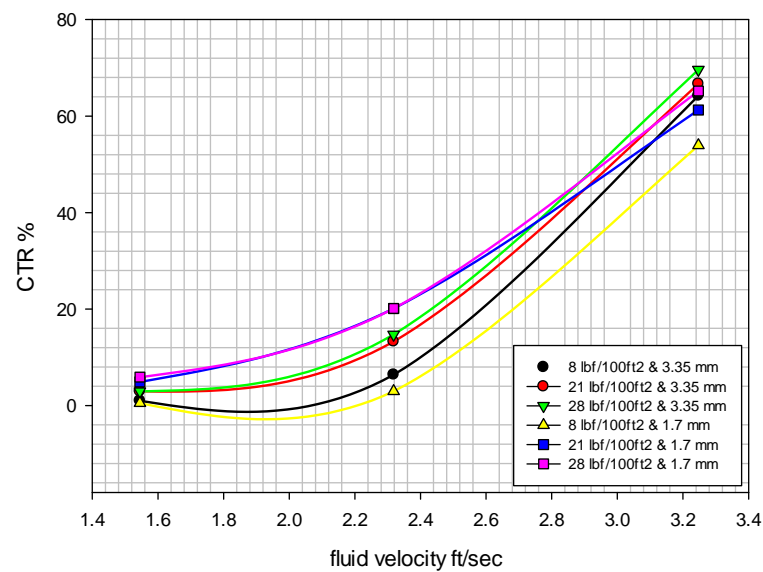


Figure 5a. Cutting size 3.35mm and 1.7 mm with RPM=0

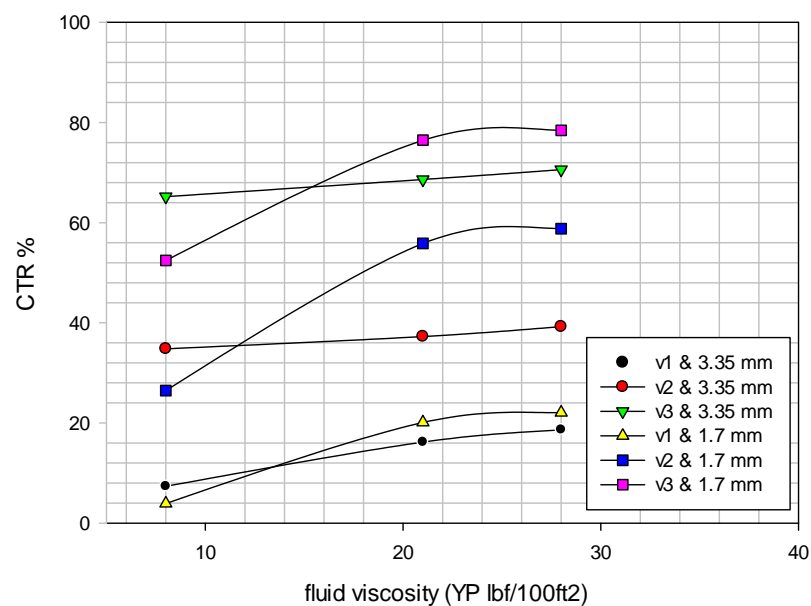


Figure 5b. Cutting size 3.35mm and 1.7 mm with RPM=0

4 Conclusions

Only four effective factors were chosen to the rotation of drill pipe, fluid yield point and velocity as the topical of this research. The most points noticed summered as:

- 1- when mud yield point (YP) increase, the CTR is increased. The increase in YP is the main reason

for the increase in the amount of removed cutting. Increasing of fluid yield point at the same flow rate,

the turbulent flow tends to shift to laminar flow. However, it should be observed that converting a turbulent flow to laminar flow requires crossing through a large range of Reynolds number including transition zone. If velocity and hole inclination are kept constant, the CTR has been greater by upper fluid yield point until the flow is still turbulent. However, when muds yield point are increased that the CTR has been slightly increased gradually until the end of transition zone. Also the CTP has been more increased after transition zone. Finally, for better hole cleaning must use high mud yield point yield point with laminar flow and low yield point with turbulent flow.

- 2- Fluid velocity has a significant impact and more contribution in removal of drilling cutting. Any small increase in annular velocity well be creates a great increase in cuttings transport.
- 3- Rotation of drill pipe was noticed an impact part in the removal of cuttings especially in laminar and transition flow. Its effect leads to increase the ability of cutting removal and the maximum effect was in transition flow. Also this effect was slightly in turbulent flow. Through the previous point, increase impact of drill pipe rotation with increase fluid yield point.
- 4- In high yield point 1.7 mm cuttings are transport better than 3.35 mm cuttings but in low yield point going on the contrary. Moreover, actually in drilling can't control the cuttings size while drilling.

Nomenclatures:

CTR: Cutting transport ratio

YP: Yield point

RPM: Rotation of drill pipe

V: Annular velocity

Vs is slip velocity in ft/min.

ρ_c is cutting density in ppg

dc is cutting diameter in inch

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