International Journal of Management and Applied Science, ISSN: 2394-7926 Volume-4, Issue-5, May-2018
http://iraj.in

POLYETHYLENE POLYMER BEADS ON CUTTINGS TRANSPORTATIONIMPROVEMENT IN DEVIATED HOLES

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Abstract – The quest for petroleum exploration and production has been uprising in fulfilling the energy demand. As oil and gas wells are being drilled deeper and in various directions, hole cleaning efficiency is significantly affected. In order to overcome this problem, this study was conducted to investigate the effect of polyethylene beads on water-based mud to increase cuttings lifting efficiency. The experiments were carried out in an 11 ft test section fabricated rig using 10ppg water-based mud and 1% to 5% concentration by volume of low density polyethylene polymer beads. Cuttings transportation performances were studied in three angles of inclination, i.e., 0˚, 60˚ and 90˚. Mud with xanthan gum performed the best under turbulent flow regardless of hole angles. Both types of muds showed positive results on cuttings transportation when polyethylene beads were added. Cuttings transportation performance was thebest in vertical hole while the poorest performance was in 60˚ wellbore.

Keywords – Viscosity, low density polyethylene beads, wellbore inclination

I. INTRODUCTION

The use of water-based mud as drilling fluid increased due to its performance and economic valueas well as contamination control and easy disposal. These features enable water-based mud to be commercially used worldwide in drilling operations. The addition of different additives further enhances its performance and makes it possible to drill any type of formations when properly designed.

The efficiency of drilled cuttings lifting is affected by drilling fluids rheological properties, cuttings sizes and shapes as well as drillpipe rotation and its eccentricity [1]. The effect of hole inclination angle shows a significant negative influence with rise in well deviation from the vertical as reported by [2 – 4]. According to [5 – 6], in a deviated well, the forces acting on transporting cuttings upwards in the drilling fluid are portrayed in Fig. 1.

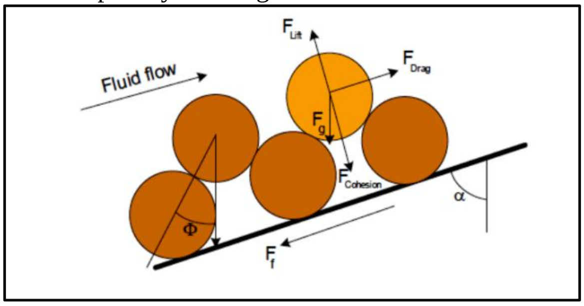

Fig. 1 Forces acting on particle at an active erosion site of a cuttings bed (Skalle, 2011)

High viscous mud has a higher cuttings carrying capacity and low tendency to erode stationary cutting beds in highly deviated well. In vertical well, high viscous mud performs better in both aspects. Reference [7] also stated that high viscous fluid has a higher cutting transport efficiency compared to low viscous fluid in the same flow regime. Reference [8] also stated that fluid with higher viscosity improves the transport of cutting transport significantly compared to low viscous fluid. This statement can be further supported by [9]. According to his research, thicker mud performs better than thinner mud when sufficient pump bottomhole pressure is supplied to enable a turbulent flow regime. Reference [10 – 11] stated that the thicker mud has a higher tendency to reduce cutting bed thickness and pressure gradient compared to low viscous mud under the same flow regime.

Hole inclination plays a significant role in cuttings bed formation. According to [12], hole inclination imposes obvious effect on cuttings transport. They propose that as inclination of the hole increases, larger cutting bed are formed as a result of cutting settlement at the lower side of the annulus. As a result, higher mud flow rate is required to ensure optimum cuttings transport and cuttings bed erosion. Reference [13] also stated that the critical hole angle for efficient cuttings removal ranges from 50 to 60 degrees. In this angled wellbore, the cuttings transport of mud is limited.

II. MATERIALS AND METHODOLOGY

A. Lab Scale Flow Loop

The experimental rig was built in the Heavy Duty Laboratory at Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia (UTM). The outer pipe demonstrated as a wellbore and casing with 1.80 in in internal diameter (ID). The test section has a length of 11 ft. A polyvinyl chloride (PVC) pipe was used as a drill string in the wellbore. The pipe has an outer diameter (OD) of 0.85 in. The PVC pipe is placed concentrically into the hollow transparent acrylic pipe to demonstrate the condition of the wellbore. The layout and schematics of flow loop are shown in Fig. 2.

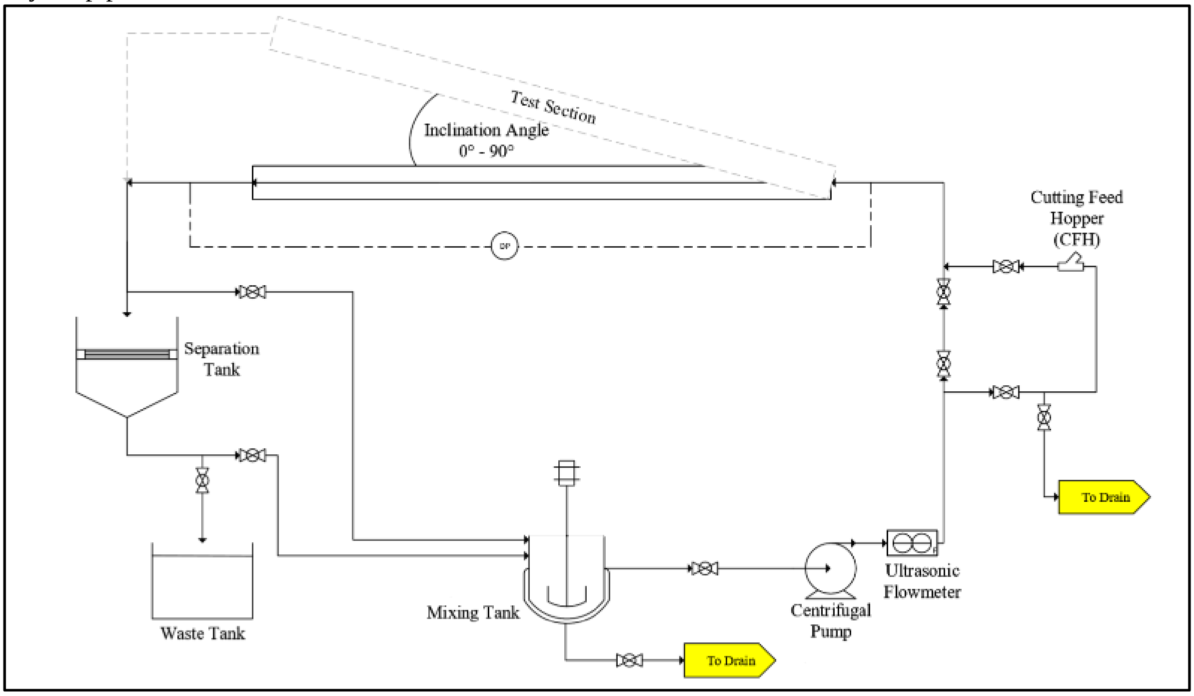

Fig. 2 Flow loop schematic diagram

B. Sand Preparation

The size of cuttings used in this experiment ranged from 1.2 mm to 2.0 mm with a density of 2.66 g/cc. The weights of each packet of cuttings were kept constant at 200 grams for each run.

C. Mud Preparation

In this experiment, two types of drilling mud were used. The first type was basic water-based mud that contained xanthan gum and the second type contained starch. These water-based mud (WBM) were prepared with and without pre-determined percentage of polyethylene beads by volume. The mud weight was kept constant at 10 ppg. The mud formulation used in this experiment is shown in Table I.

Table I: MUD FORMULATION

Mud	Mud composition	Mass of barite added (g)
1	316.34 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of starch	77.17
2	312.64 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of starch + 1% LDPE	77.55
3	308.93 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of starch + 2% LDPE	77.93
4	305.22 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of starch + 3% LDPE	78.31
5	301.52 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of starch + 4% LDPE	78.68
6	297.81 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of starch + 5% LDPE	79.06
7	316.34 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of xanthan gum	77.17
8	312.64 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of xanthan gum + 1% LDPE	77.55
9	308.93 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of xanthan gum + 2% LDPE	77.93
10	305.22 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of xanthan gum + 3% LDPE	78.31
11	301.52 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of xanthan gum + 4% LDPE	78.68
12	297.81 ml of water + 25.4 g of bentonite + 0.25 g of soda ash + 1 g of xanthan gum + 5% LDPE	79.06

D. Low Density Polyethylene Beads

The concentration of beads was gradually increased from 1% to 5% by volume and was added to the basic water-based mud containing starch and xanthan gum. Polyethylene beads are chemically inert and reusable. The properties of the low density polyethylene beads are listed in the Table II.

Table II: PROPERTIES OF LOW DENSITY POLYETHYLENE POLYMER BEADS

Properties	Titanlene LDi300yy	ASTM method
Melt index (g/10 min)	20	D1238
Melting point (°C)	450	D1238
Density (g/cm^3)	0.920	D1505

Vicat softening point (˚C)	87	D1525
Tensile strength at yield (kg/cm^2)	120	D638
Tensile strength at break (kg/cm^2)	100	D638
Elongation at break (%)	120	D638
1% Secant modulus (kg/cm^2)	1900	D638
Low temperature brittleness (°C)	-35	D746

E. Experimental Procedure

The basic water-based mud containing starch with a density of 10 ppg was prepared in the mud tank and circulated at ambient temperature in vertical annuli. Once a constant velocity under turbulent flow of mud was achieved, which was monitored using an ultrasonic flowmeter, the sieved sand particles were added to the flow system through the cuttings feed hopper. The transported sands were collected, washed, dried and weighed to obtain the mass of sand that were lifted across the test section which would indicate the cuttingstransportationefficiency of the mud.The cuttings transport efficiency (CTE) was calculated as follow:

$$CTE = \frac{\text{Mass of retrieved sand (g)}}{\text{Mass of Injected sand (g)}} \text{x } 100\%$$

III. RESULTS AND DISCUSSION

A. Effect of Viscosifiers on Cuttings Transportation Efficiency

Water-based mud with starch had a lower plastic viscosity of 7 cp and a yield point of 5 lb/100 sq ft. When xanthan gum was added to water-based mud, the plastic viscosity increased to 18 cp and had a yield point of 36 lb/100 sq ft. Further details of mud rheological properties are shown in Table III and Table IV.

Table III: RHEOLOGICAL PROPERTIES OF WBM WITH STARCH

Mud type	Density (ppg)	Plastic viscosity (cp)	Gel strength @10 sec (lb/100ft^2)	Gel strength @ 10 min (lb/100 ft^2)	Yield point (lb/100 ft^2)
Basic mud (BM)	10	7	3	8	5
BM +1% LDPE	10	7	3	8	5
BM+2% LDPE	10	7	3	8	5
BM+3% LDPE	10	7	3	8	5
BM+4% LDPE	10	7	3	8	5
BM+5% LDPE	10	7	3	8	5

Table IV: RHEOLOGICAL PROPERTIES OF WBM WITH XANTHAN GUM

Mud type	Density (ppg)	Plastic viscosity (cp)	Gel strength @ 10 sec (lb/100ft^2)	Gel strength @ 10 min (lb/100 ft^2)	Yield point (lb/100 ft^2)
Basic mud (BM)	10	18	29	39	36
BM +1% LDPE	10	18	29	39	36
BM +2% LDPE	10	18	29	39	36
BM +3% LDPE	10	18	29	39	36
BM +4% LDPE	10	18	29	39	36
BM +5% LDPE	10	18	29	39	36

Based on Fig. 3, water-based mud with xanthan gum which has a higher viscosity compared towater-based mud with starch performed better and was able to lift higher amounts of cuttings in all three hole angles. In vertical hole, high viscous mud was able to transport 10% more cuttings than the less viscous mud. The trend continued at critical angle (60˚) but the increment of cuttings transportation percentage is reduced compared to vertical wellbore. In this hole inclination, high viscous mud was only able to retrieve about 5% more cuttings compared to low viscous mud. In horizontal hole, the performance of high viscous mud was also higher compared to the performance of low viscous mud. At this angle, the cuttings transport efficiency of viscous mud was about 7 % higher compared to cuttings transport efficiency of low viscous mud. This phenomenon was associated to the hole angle. According to[12],this is the reason for cuttings bed formation in the lower side of the wellbore. In this study, the high viscous mud was able to suspend small cuttings from settling down in the test section. In fact, due to the lower density of sand used to resemble the cuttings and smaller annuli in the test section, the cuttings mixed well with the viscous mud and the viscous mud was able to suspend the cuttings temporarily. As a result, cuttings bed were not formed in the lower section of the wellbore.

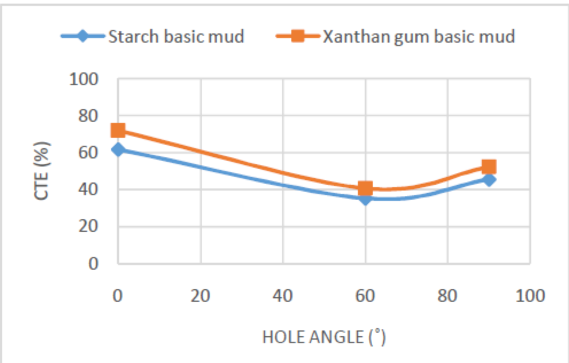

Fig. 3 The effect of viscosifiers on cutting transport efficiency

B. Cuttings Transport Improvement of Water-based mud with Low Density Polyethylene Beads

Fig. 4 shows the effect on cutting transportation efficiency of mud after low density polyethylene beads were added into both high and low viscous muds in vertical hole. The results clearly showed that the addition of polyethylene beads have a positive impact on the cutting carrying capacity of both types of mud in vertical hole. When the polyethylene beads concentration in the mud increases, the cutting transport efficiency also increases progressively. The cutting transport efficiency is at the peak value when 5% of polyethylene beads were present in the mud.

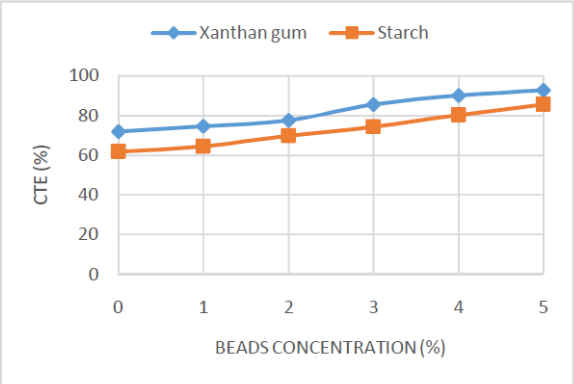

Fig. 4 CTE versus concentration of polyethylene beads in vertical hole

Fig. 5 shows the effect of polyethylene beads concentration on cuttings transportation efficiency of both types of mud. As observed, by increasing the concentration of polyethylene beads in both types of mud, the cuttings transportation efficiency of both muds increased. Since this hole inclination was at a critical angle, the cutting transportation ability of the muds were limited. The highest cuttings transportation efficiency for viscous mud was almost 50% while the highest cuttings transportation efficiencyfor low viscous mud was about 46%. Both types of muds showed maximum performance in cuttings carrying capacity when 5% of low density polyethylene beads were added.

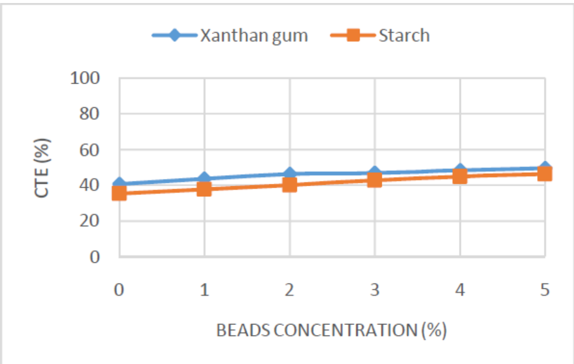

Fig. 5 CTE versus concentration of polyethylene beads in 60˚ inclination

Fig. 6 shows the effect of polyethylene concentration on cuttings transportation efficiency in horizontal hole. Based on the results, the addition of beads had no significant effect on enhancing the cuttings carrying capacity of low viscous mud. This was due to the buoyancy effect of low density polyethylene beads. In horizontal hole, the polyethylene beads had a higher tendency to float on the top of the low viscous mud while the cuttings sink in the mud. In this scenario, the low density polyethylene beads have no significant effect in assisting the cuttings transportation of low viscous mud. As a result, the cutting transport ratio remains unaffected or experience slight changes even though the concentrations of beads were gradually increased. In the contrary, there was a slight improvement for high viscous mud when low density polyethylene beads were added. The difference in cuttings transportation ratio between basic mud and basic mud with 1% low density polyethylene beads was about 6%. As the concentration of beads gradually increased, the cuttings transportation efficiency also increased but the increment was almost plateau. In high viscous mud, the polyethylene beads were mixed together with the cuttings. The beads and cuttings blended together within the mud. This reduced the free space for the cuttings to settle to the bottom. Since the beads were distributed within the mud, they acted as a net within the mud, supporting the weight of some of the cuttings and increased cuttings carrying capacity of the mud. However, the performance is restricted by wellbore inclination. The improvement of drilling mud with the presence of polyethylene beads was influenced by drag and gravitational forces. The slipping velocity of drilled cuttings was reduced due to the presence of polyethylene beads. This was because of the buoyancy effect in which the polyethylene beads increased the drag forces of the cuttings. Increased drag forces experienced by the cuttings, resulted in higher cuttings carrying capacity of mud in all hole angles.

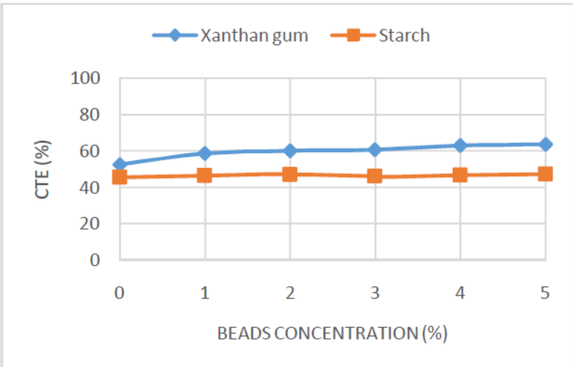

Fig. 6 CTE versus concentration of polyethylene beads in horizontal hole

C. Effect of Hole Inclination on Cuttings Transportation Efficiency for Both Types of Mud

Fig. 7 shows the effect of hole inclinations on cuttings transportation. As observed, the trend remained the same for every mud. The tested muds had the highest cuttings transportation efficiency in vertical holes followed by horizontal holes and the lowest cuttings transportation efficiencywas at 60˚ hole inclination. For vertical hole, about 92% of cuttingswere recovered by the higher viscosity mud containing 5% polyethylene beads. The cuttings transportation efficiency reduced as the amount of polyethylene beads in the mud reduced. Thelowest cuttings transportation efficiency for every mud was at a 60˚ angle. This angle is known as the critical angle for cuttings lifting performance. In horizontal well, the cuttings transportation efficiency of each mud slightly increased. The addition of polyethylene beads had a significant effect in high viscous mud raising the efficiency to a higher value. However, only 65% of the cuttings were successfully recovered. This was due to the effect of hole inclination which promotes the formation of cuttings bed at the lower side of the pipe. In order to efficiently remove cuttings in these wellbore inclinations, higher annular velocity is required [14]. Peak mud flow rate is required in hole angles ranging from 65˚ to 75˚, whiledecreasing slowly toward horizontal inclinations. Reference [12] shared the same idea. They stated that as the inclination of hole increases from vertical, the probability for the accumulation of drill cuttings in the hole also increases. Reference [7] concluded that the increase in hole angle imposed a negative effect on the performance of mud in drill cuttings transportation. Reference [15] observed that at inclinations greater than 40 degrees from vertical,the occurrence of a thick bed of cuttings accumulation was higher.

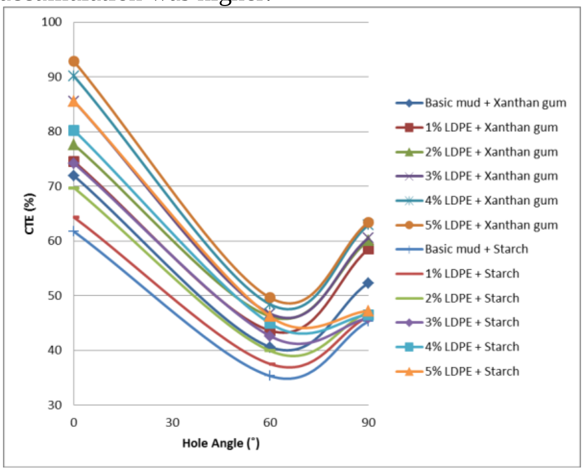

Fig. 7 Cutting transport efficiency (CTE) versus hole inclination

CONCLUSION

Based on the results obtained, the following conclusions were made:

1) Mud with higher viscosity was able to transport more cuttings compared to low viscous mud at all hole angles when the flow regime is kept constant.
2) As polyethylene concentration increased from 1% to 5% by volume, the CTE also increased regardless of the type of mud and hole inclination. However, the effects of polyethylene beads are more significant in mud with higher viscosity compared to its effect in low viscous mud. In terms of hole angle, the performance of polyethylene beads was the highest in vertical or near vertical well regardless of the type of mud.
3) The cuttings transportation efficiency was the highest in vertical well (90%)while the poorest cuttings transportationrecorded was in 60 degree inclination regardless of mud type and addition of low density polyethylene beads.

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