EXPERIMENTAL STUDY OF DRILLING CUTTING REMOVAL IN INCLINED ANNULI

Abu Azam Md. Yassin, Ph.D
Mohd. Zaidi Yaakob
and
Mohd. Ariffin Daud
Universiti Teknologi Malaysia

Introduction

Drilling muds were introduced with the introduction of rotary drilling in 1900. Initially, the primary purpose of the drilling fluid was to remove formation solids continuously. No time was spent on a scientific evaluation of the carrying capacity of the fluid, and very little effort was made to control the fluid properties. Even with the advancement of science in mud treating, operators ignored the lifting capacity of drilling muds.

As oil exploration and development moved into the deeper water, the cost to drill a well increases tremendously and coupled with the trend of drilling deviated hole from offshore locations together with the increases in power requirements for circulating of the drilling fluid, has emphasized the need for critical examination of the factors affecting the removal of bit cuttings from the hole by the drilling fluid.

Failure of the mud to promptly remove bit cuttings from the wellbore causes redrilling and excessive wear on bit teeth, slows drilling rate thereby increasing well costs, and greatly increases possibilities for stuck drill pipe when circulation is stopped for any length of time.

Problem of Hole Cleaning

In highly deviated wells, there are several problems in ensuring efficient hole cleaning. Circulation in high angle well is similar to the movement of sediments in a stream bed. The bit cuttings are made up of rocks with a wide range of diameters. The heavier cuttings tend to drop down to the lower side of the hole due to gravity and hence resulting in the heavier cuttings and mud in the lower side, and clean mud in the upper side. The heavier cuttings and mud along the lower side of the hole moved at a lower rate than the clean mud on the upper side as shown in Figure 1.

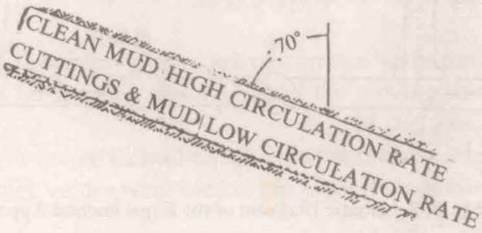

Figure 1: Hole Cleaning Problem in Deviated Holes

To overcome this problem it is necessary to establish the pump requirement to produce adequate pressure to circulate the cuttings to the surface. And also the criteria for the selection of the correct mud properties so that the mud can carry and keep the bit cuttings in suspension. Various techniques such as centralizing the drill pipe and rotation of the drill pipe help in ensuring efficient hole cleaning.

The transport of cuttings through vertical pipes and vertical annuli (1-5) has been investigated both in the laboratory and in the field. And the most important factors affecting the carrying capacity of the drilling muds are (1) annular fluid velocity; (2) drilling mud properties; (3) drill cuttings size, shape, density and concentration; (4) drillpipe rotary speed; and (5) annular size (drillpipe/hole diameter ratio).

Since little work has been done on the study of deviated hole cleaning so the objective of this study was to develop field-oriented cuttings transport model that account for the most significant factors affecting particle and fluid dynamics in deviated wells.

Test Apparatus

The test apparatus was designed and constructed in accordance with the following requirements: annular-flow steady state conditions must prevail in every test case, and the apparatus must allow the selection of various drilling variables (flow rate, drilling mud properties, well inclination, annular geometry configuration, etc.) that must be representative of average field conditions.

To meet the above requirements, a test apparatus as shown in Figure 2 was designed and constructed. It consisted of the following major components: (1) an independent means of circulating the transport fluid and of injecting the solid particles; (2) a section of annulus long enough to ensure steady-state solid/liquid flow; (3) an efficient means of separating the two phases before recirculation; (4) a reliable means of controlling and of measuring liquid flowrate and particle injection rate; (5) a reliable means of estimating the average transport velocity; (6) a means of varying the angle of inclination of the test section; (7) a means of simulating pipe/hole eccentricities; and (8) an efficient mud mixing system.

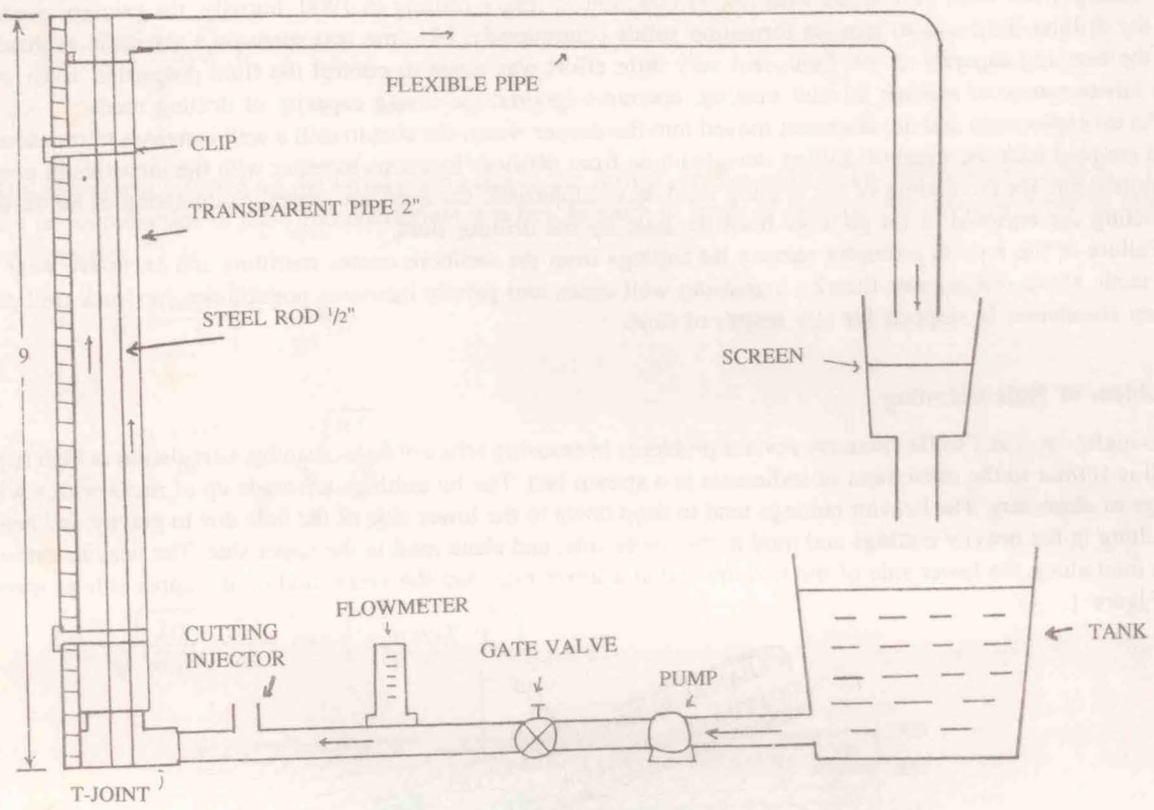

Fig. 2: Schematic Diagram of the Experimental Apparatus

Test Procedure

Before any test, the fluid to be used was mixed well and the rheological properties were measured carefully. The ranges of parameter values used in the tests are summarized in Table 1. Average rheological properties of the fluids used are shown in Table 2. The cuttings used for the study are summarized in Table 3.

Table 1 Summary of Parameters and Experimental Variables

Variable or Parameter	Range or Value
Annulus length, ft	10
Annulus dimensions, in x in	2 x 0.5
Annulus inclination, degrees from vertical	0, 20, 40, 60, 80
Liquid flowrate, ft/sec	1.4, 1.7, 2.0, 2.25, 2.5
Pipe/hole eccentricity, %	+ 50, 0

Table 2 Rheological Properties of Fluids Studied

Fluid	F V G		Apparent	Yield Point
	600	300	Viscosity	(lbs/100 sq.ft)
Water	2	1	1	0
Glycerine, low viscosity	11	7	4	3
Glycerine, high viscosity	28	17	11	6

Table 3 Summary of Cuttings Used

CUTTING NO	MATERIALS	S.G.	SIZE, in	CLASS'N	SHAPE
1.	Perspex	1.25	3/8 x 3/8 x 3/8	Large	Rectangular
2.	Perspex	1.25	3/16 x 3/16 x 1/8	Medium	Rectangular
3.	Perspex	1.25	-	Large	Irregular
4.	Perspex	1.25	-	Medium	Irregular
5.	Granite	2.6	-	Small	Irregular
6.	Aluminium	2.5	0.500	Large	Disc
7.	Aluminium	2.5	0.312	Medium	Disc

With everything in place, the pump was started and mud was allowed to circulate through the system. The cuttings rise time was recorder by observation of the time required for a cluster of coloured cuttings to travel between a predetermined ntervals.

For those inclination angles and flowrates where slug of cuttings were formed at the lower side of the pipe, the cuttings rise time was recorded for the slug and the rest of the moving particles - an average value was then calculated.

Then the fluid rheological properties were rechecked with the Fann viscometer, and the readings compared with those obtained before the test. Average values were used to calculate Reynolds number to establish the flow regine.

Test and Observations

Summary of Tests

Altogether, 100 test were performed. The various test run and observvations made are classified and discussed in this section in terms of fluid viscosity and flow regimes, pipe/hole eccentricities, and angle of inclination.

The efficiency of the fluid to remove the cuttings is measured by the cutting transport ratio

$$CTR = \frac{Va - Vs}{Va}$$

where Va is average fluid velocity,
Vs is slip velocity.

Effect of fluid visosity and flow regime

Effects of liquid viscosity on cuttings behaviour depended on the flow regime. In laminar flow, bed formation in high viscosity fluids was slower compared to the low viscocity fluid. In turbulent flow, slightly smaller bed of cutting is formed in higher viscosity fluid but bed formation was equally fast for both cases.

Figure 3 show the combined effects of viscosity and flow regime on cutting transport ratio.

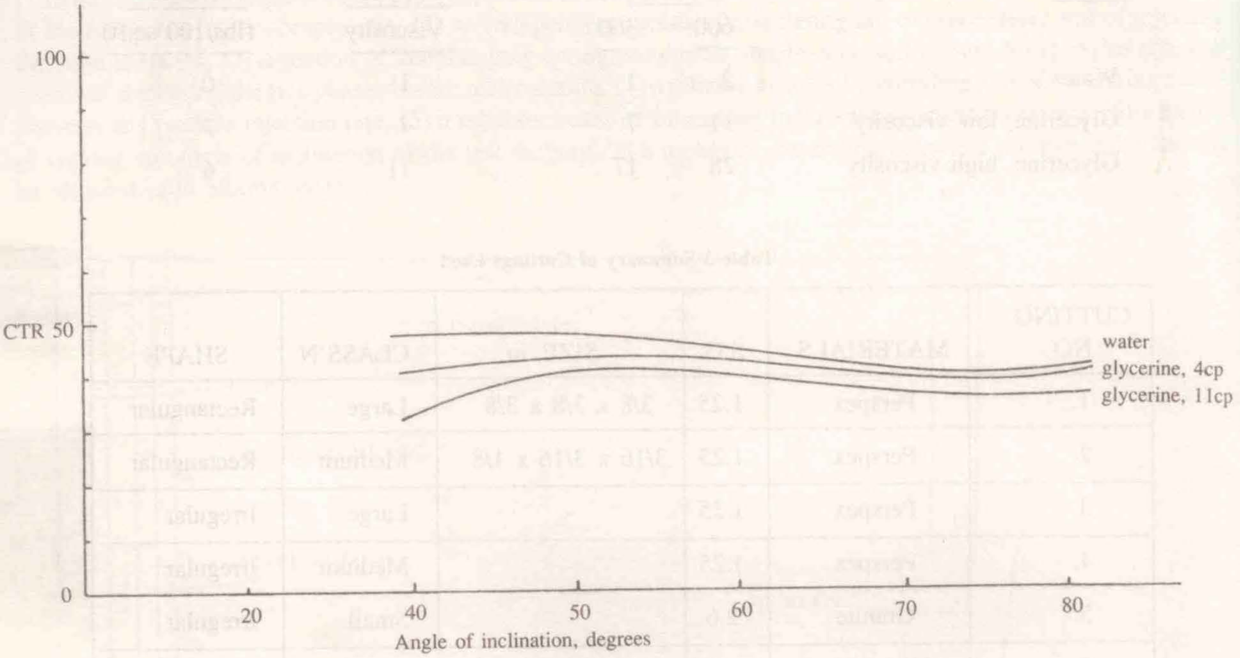

Fig. 3: Effects of Viscosity and Inclination on Cutting Transport Ratio

Effect of angle of inclination

The behaviour of cuttings in the annulus changed gradually as the angle of inclination was increased beyond 0°.

For low angle of inclination (20° - 30°), a small bed of cuttings was formed at low liquid velocities (< 1 ft/sec) and this bed of cuttings become unstable resulting inheterogeneous flow at higher liquid velocities (>1 ft/sec).

For intermediate angle of inclination (40° - 60°), bed formation was occured at all range of velocities and the bed usually slided downward against the flow because of gravity forces. When the pump was stopped, the entire contents of the annulus dropped and blocked the lower part of the annulus.

For high angle of inclination (60° - 80°), bed formation was instantaneous and the bed did not slide downward even when circulation was stopped. Particles above the bed consisted of two zones; the first zone was a narrow layer of closely grouped particles moving axially just above the bed and the second zone, just above this narrow layer, consisted of sparsely populated particles travelling smoothy with very little slugging.

Figure 4 and 5 shows the effect of the angle of inclination on cutting transportation.

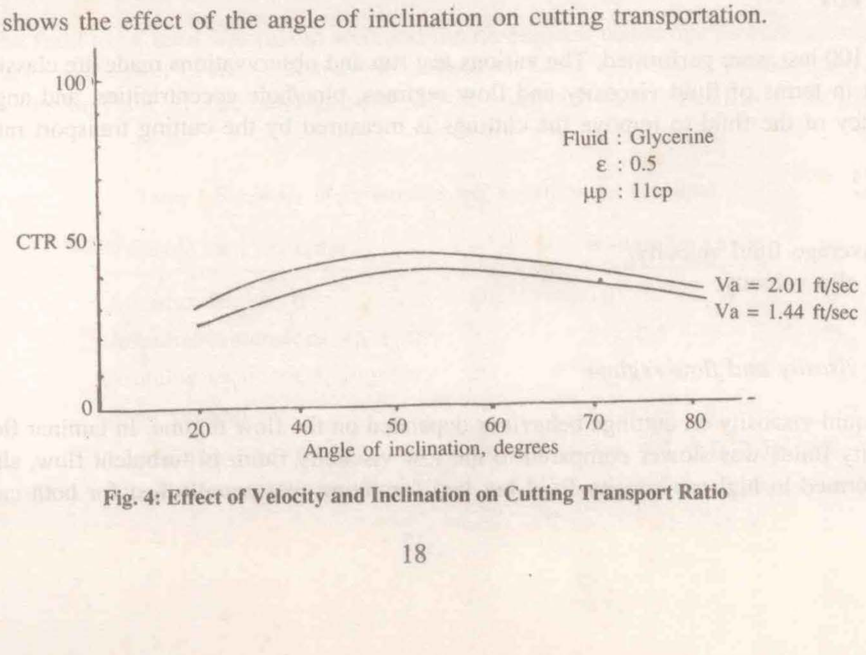

Fig. 4: Effect of Velocity and Inclination on Cutting Transport Ratio

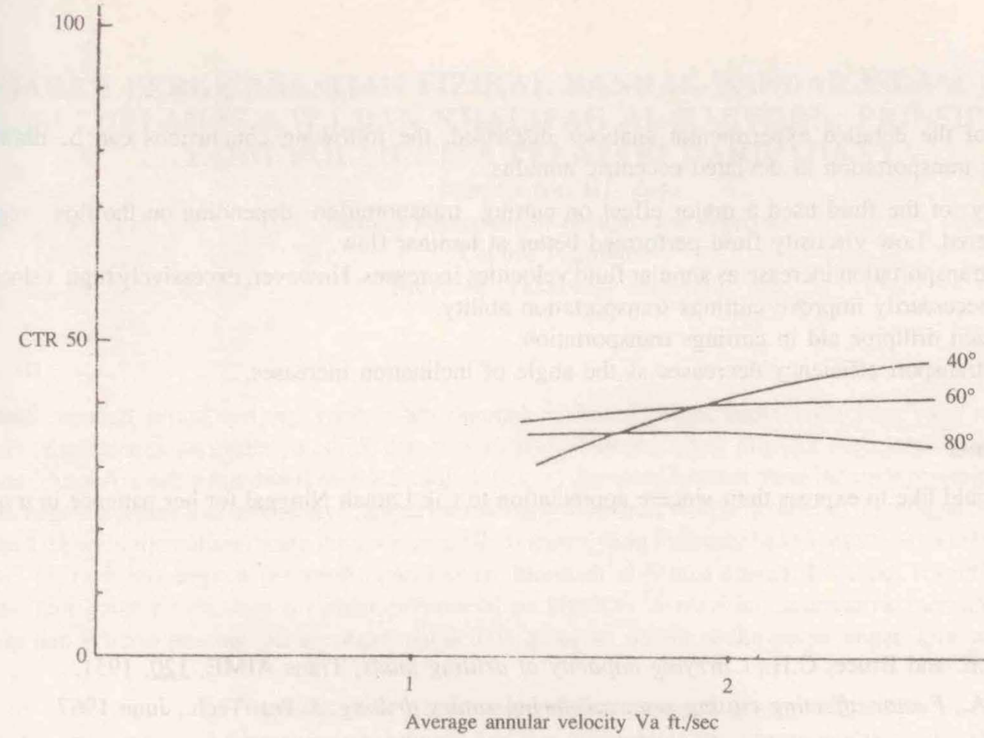

Fig. 5: Variation of Cutting Transport Ratio With Velocity

Effect of Pipe/Hole Eccentricity

The cutting build up was lowest when the inner pipe was concentric with the outer pipe. The rate of bed buildup appeared to be lightly faster with the inner pipe lying on the outer pipe. Figure 6 shows the performance of centralised and eccentric drillpipe on cutting transportation.

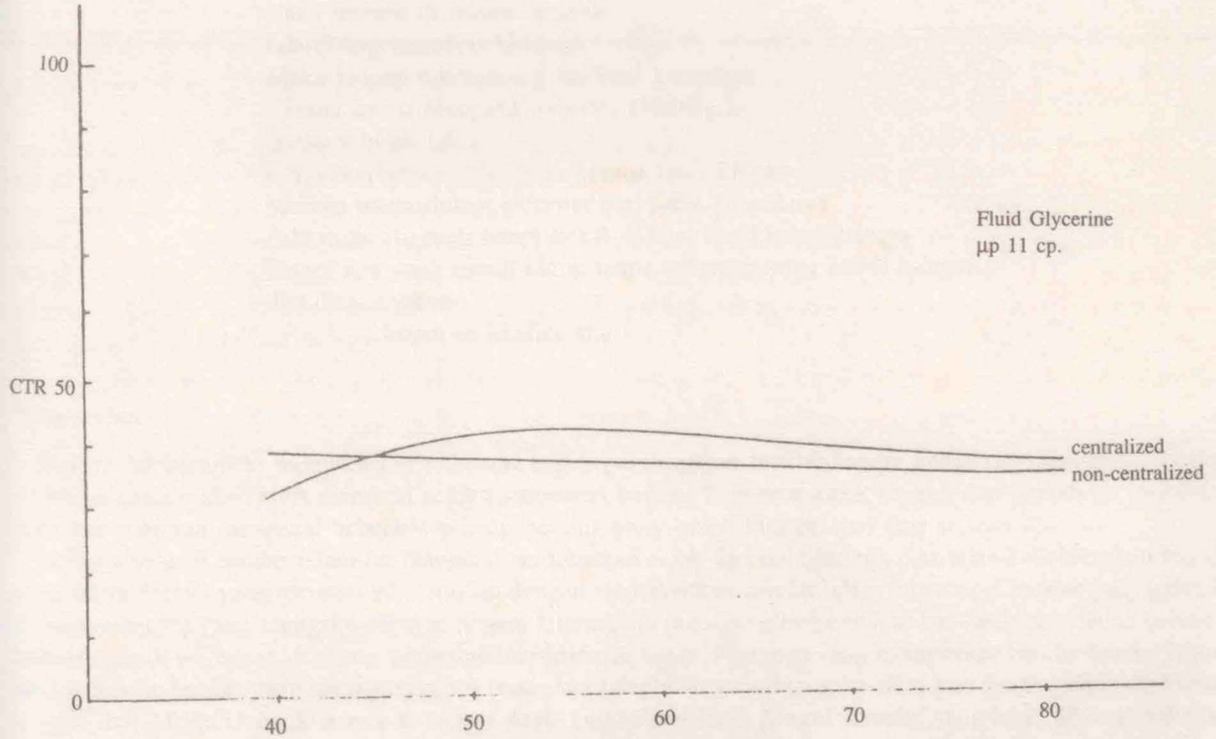

Fig. 6: Effect of Eccentricity on Cutting Transport Ratio

Conclusions

On the basis of the detailed experimental analyses discussed, the following conclusions can be drawnup regarding cutting transportation in deviated eccentric annulus.

1. Viscosity of the fluid used a major effect on cutting transportation depending on the flow regime encountered. Low viscosity fluid performed better at laminar flow.
2. Cutting transportation increase as annular fluid velocities increases. However, excessively high velocities do not necessarily improve cuttings transportation ability.
3. Centralized drillpipe aid in cuttings transportation.
4. Cutting transport efficiency decreases as the angle of inclination increases.

Acknowledgements

The authors would like to express their sincere appreciation to Cik Latnah Ninggal for her patience in tryping this manuscript.

References

1. William, C.E. and Bruce, G.H., *Carrying capacity of drilling muds*, Trans AIME, 120, 1951.
2. Hopkin, E.A., *Factor affecting cutting removal during rotary drilling*, J. Pet. Tech., June 1967.
3. Zeidler, H.U., *An experimental analysis of the transport of drilling particles*, Society of Pet. Eng. J. Feb. 1972.
4. Sifferman, T.R. Myers, G.M. Haden, E.L. and Wahl, H.A., *Drill cutting transport in full-scale vertical annuli*, J. Pet. Tech. Nov. 1974.
5. Anderson, G.W. and Hutchinson, S.O., *How to efficiently wash sand from deviated wellbores*, World Oil, Dec. 1978.