

Effect of fluid additives on rock drilling

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Abstract— Drilling is a very dominant operation in all rock cutting industries, namely, mining, petroleum, natural gas and civil engineering. The objective of this study is to understand the behaviour of rock drillability by mean of penetration rate of bit, with concentration of 10 ppm of carboxymethyl cellulose, guar gum, polyacrylamide polymer additives to drilling fluid. A total of four different type of drilling fluids were used to compare and identify the best drilling fluid for chunar sandstone.

For this research work, a laboratory drill setup was fabricated to study the effect of various rotary drilling machine parameters on overall drilling performance. Outcome of the experiment is discussed in terms of rate of penetration. It was found that at 10 ppm concentration, the performance of guar gum and carboxymethyl cellulose is almost same and much better than that of polyacrylamide.

Keywords—Drilling fluids; drillability; penetration rate; water soluble polymer

I. INTRODUCTION

Drilling is the first unit operation of mining engineering that provides knowledge about sub-surface strata. Further, this comprises as a major activity in mining engineering, petroleum engineering, CO₂ storage, natural gas extraction, tunneling and many other engineering activities. Due to improper flushing, the debris generated may not be removed properly from hole, which may cause regrinding of debris and jamming of drill bit. This leads to loss of time and energy.

Proper selection of flushing media may help in plugging the fractures, provide better bit rock interaction and lead to better drilling performance. Water soluble polymer possesses many good qualities for improving drilling performance, namely reducing friction, cooling of drill bits, hence causing uniform wear of the drill bit etc.

In this research, commonly available polymers such as guar gum (GG), carboxymethyl cellulose (CMC), and polyacrylamide (PAM) were used [1, 3, 11, 6, 9].

II. MATERIALS AND METHODOLOGY

Various materials and measurement procedure that were used during this study are discussed as follows.

A. Rock sample

Fine grain chunar sandstone samples were used to find out the effect of various drilling fluid on drillability of rock.

B. Drilling Fluid

In this work four types of drilling fluids were used to measure the drillability. Water alone was used as a drilling fluid and three other fluids were prepared as 10 ppm solution of three water soluble polymers, namely, guar gum (GG), carboxymethyl cellulose (CMC) and polyacrylamide (PAM) in distilled water individually.

C. Laboratory Rock Drilling Setup

Drilling setup was fabricated for laboratory examination of various machine and rock parameters of rock drillability. Rock drillability is defined as “the penetration rate of a drill bit into the rock” [8]. It depends on combined effect of rock and machine parameters. Machine parameters includes load on bit, torque, rotational speed of bit and flushing media [2].

The fabricated setup is capable of providing variation in bit type, bit rotational speed, weight on bit, flushing media, rock sample size with flexibility. This setup also allows us to measure values of depth and diameter of hole, drilling time and power consumption. Each test has been repeated three times to minimize and checkout the error. The holes were drilled with diamond impregnated core bit.

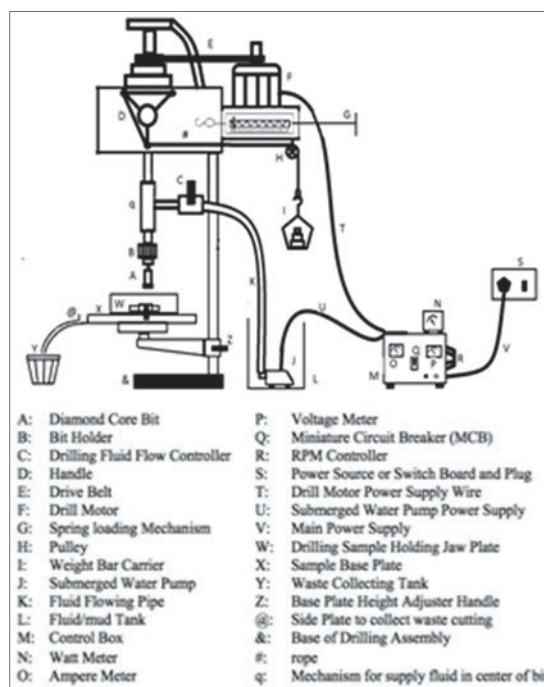


Fig.1. Fabricated setup and description of tagged parts

Line diagram of fabricated setup and description of tagged parts are shown in Figure 1.

D. Operating Parameters

Table-1 gives the operating parameters used during the experimentation.

TABLE I OPERATING PARAMETER

| Bit Rotational Speed (RPM) | Weight on Bit (Kg) | Rock Type | Flushing Media | Polymer Additives (10 ppm) |
|----------------------------|--------------------|----------------------|-------------------------------|----------------------------|
| 450 | 1 | Fine Grain Sandstone | Tap Water Alone | Guar Gum |
| 600 | 3 | | Tap Water + Polymer Additives | Carboxymethyl Cellulose |
| 750 | 5 | | | Polyacrylamide |

This value is produced by calculating ratio of “Depth covered by drill bit by cutting rock mass and the time required to drill that mass” as shown in eq. (1). It is expressed in the unit of “mm/min”.

$$\text{Penetration Rate} = \text{Depth of hole(mm)} / \text{Time(min)} \quad (1)$$

III. RESULT AND DISCUSSION

Final calculated values of penetration rate for all four types of drilling fluid were analyzed and the percentage increment in ROP was calculated by considering tap water as base drilling fluid.

A. Penetration Rate (ROP)

All the experimental data along with calculated values of penetration rates for all drilling fluids individually were collected in format of table 2.

TABLE II: EXPERIMENTAL DATA FOR PENETRATION RATE

| Bit Rotation Speed (RPM) | Weight on Bit (Kg) | Time Taken in Drilling (min) | Hole Depth (mm) | | Penetration Rate = Depth/Time (mm/min) | Avg. Penetration Rate (mm/min) |
|--------------------------|--------------------|------------------------------|--------------------------|---------------|--|--------------------------------|
| | | | Measured At Three Points | Average Depth | | |
| 450 | 1 | 1 | 4.4, 4.3, 4.2 | 4.3 | 4.3 | 4.7 |
| | | | 4.4, 4.7, 4.5 | 4.53 | 4.53 | |
| | | | 5.2, 5.3, 5.2 | 5.23 | 5.23 | |
| | 3 | | 5.6, 5.8, 5.6 | 5.66 | 5.66 | 6.0 |
| | | | 6.1, 5.2, 6.2 | 6.16 | 6.16 | |
| | | | 5.9, 5.9 | 5.96 | 5.96 | |

| | | | | |
|---|---------------|------|------|-----|
| 5 | 5.9, 6.1 | 3.03 | 3.03 | 3.0 |
| | 2.9, 3.1, 3.1 | | | |
| | 3.0, 3.1, 3.1 | 3.06 | 3.06 | |
| | 2.9, 3.0, 3.1 | 3.0 | 3.0 | |

B. Penetration Rate for All Drilling Fluid

Calculated values of penetration rate for all drilling fluids are tabulated as shown in table 3. This tabulation helps in comparative study of penetration rate. Salient findings have been presented graphically. For best operating condition (maximum penetration rate), each drilling fluid were taken into consideration.

TABLE III: PENETRATION RATE WITH ALL DRILLING FLUIDS

| Bit Rotational speed (rpm) | Weight on Bit (Kg) | Time Taken in Drilling (min) | Avg. Penetration rate (mm/min) | | | |
|----------------------------|--------------------|------------------------------|--------------------------------|------------------------|-------------------------|---------------------|
| | | | Tap Water | GG with water (10 ppm) | CMC with water (10 ppm) | PAM with water (10) |
| 450 | 1 | 1 | 4.7 | 10.1 | 7.0 | 6.6 |
| | 3 | | 6.0 | 12.1 | 8.7 | 8.9 |
| | 5 | | 3.0 | 12.5 | 9.2 | 6.6 |
| 600 | 1 | 1 | 6.3 | 12.7 | 8.9 | 7.6 |
| | 3 | | 8.1 | 14.3 | 9.4 | 9.6 |
| | 5 | | 10.0 | 15.9 | 11.9 | 13.4 |
| 750 | 1 | 1 | 7.5 | 10.9 | 11.4 | 8.5 |
| | 3 | | 8.4 | 14.9 | 16.7 | 12.2 |
| | 5 | | 6.9 | 19.9 | 19.4 | 14.9 |

IV. PARAMETERS AND CALCULATION

Outcome of this study was calculated in terms of rate of penetration (ROP).

A. Penetration Rate Measurement

Rate of drilling is “rate at which bit penetrates the rock”. All these best operating values of penetration rates are used to calculate percentage increment in penetration rate, considering the tap water as base drilling fluid. The percentage variation in penetration rate due to 10 ppm concentrations of different fluid polymeric additives are presented through Table 4 and Figure 2.

TABLE 4: PERCENTAGE INCREMENT IN PENETRATION RATE ON THE BASIS OF TAP WATER AS BASE DRILLING FLUID

| Drilling Fluids (10 ppm con ⁿ solution with water) | Guar Gum | Carboxymethyl Cellulose | Polyacrylamide |
|---|----------|-------------------------|----------------|
| Percentage Increment in penetration Rate | 49.7 | 48.4 | 32.9 |

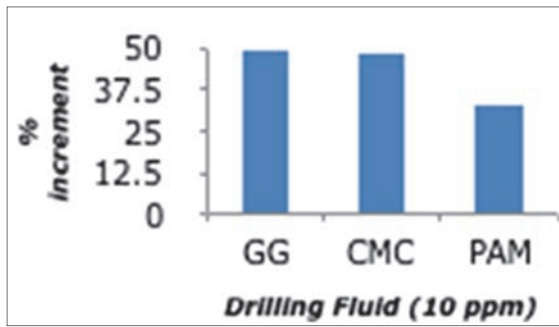


Fig. 2 Percentage increment in Rate of Penetration on the Basis of Tap Water as Base Drilling Fluid

V. DISCUSSION

The friction in drilling process (intra-machine friction and drill rod to rock friction) resists the motion of bit, which reduces the drilling performance. All these additives work as a lubricating agent for the annulus space between the drilling rod and the hole.

The viscosity of a lubricant is related to its ability to reduce friction. Viscosity can be defined as fluids internal resistance to flow at specific temperature. The percentage variation in penetration rate due to 10 ppm concentrations of different fluid polymeric additives are presented through Table 4 and Figure 2.

In general, if the lubricant is highly viscous, it will consume a large amount of energy to flow; if it is very low viscous, the moving surfaces will come in contact and friction will increase. So, the moderate viscous lubricant is suitable for forcing the moving surfaces apart [4]. Intrinsic viscosity of polymeric additives is in order of GG > CMC > PAM, which is the cause of reduction in friction and so on increase in penetration rate.

Percentage improvement with GG, CMC and PAM additives to drilling fluid, considering the tap water alone as base fluid, are 49.7%, 48.4% and 32.9% increase in rate of penetration (ROP).

VI. CONCLUSION

From the result of this study we found that the GG and CMC additives with water are better performers in penetration rate improvement compare to polyacrylamide. Guar Gum (GG) is best additive among all drilling fluid used in this study. Use of water soluble polymer additives

enhances the drilling performance. For drilling Chunar Sandstone rock GG is better fluid additive.

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