Evaluation of carry-out cuttings volume decrease as a result of well drilling with special bottom hole assembly unite

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Abstract. This paper describes the opportunity of drill-out cuttings volume decreasing. There are the big amounts of polluted cuttings at the rig-sites and landfills may be sources of ecological problem. Special bottom hole assembly unite permits using part of cuttings in drilling process. Simple mathematical approach was developed for process efficiency evaluation. This formula may be used in cuttings management calculations.

Keywords: Oil and gas Industry; Well drilling; Environment protection; Drill cuttings management

1. Introduction
Crushed rocks (cuttings) carried out from the well hole to the surface is an important part of drilling process. The trend toward deeper drilling has produced a large volume of drilling cuttings on the rig-site [1,2,3].

Drilling cuttings management is very important task. Cuttings has classified as waste of drilling. Cuttings may include pollution materials and components, as mud, filter cake, oil, formation fluids, etc. These materials have negative impacts on the natural environment. Therefore cuttings must be saved in lined pits at the rig-site.

After well completion cuttings must be transported to special plant and cleaned from pollutions using thermochemical technologies. At the final stage cuttings may be processed to construction materials or disposed to landfill / underground reservoir [4,5].

Of course, all these processes are costly and add further ecological hazards. Therefore cuttings volume decreasing during well drilling is real possibility to solve part of ecological and financial problems. Situation is especially actual in off-shore drilling and drilling in especially protected ecological areas. Using of special bottom hole assembly unit permits to immediately recycling / reusing part of cuttings volume in drilling operation without lift to a surface [6]. This drilling technology was successfully tested in various regions with sufficient effect [7]. But there is not any mathematical approach to calculate this volume decrease for cuttings management [8,9,10]. Such formula development permits to simplifying the well design work.
2. Function of the device for high permeable formation colmatage

The purpose of this chapter is to describe a function and opportunity of the device for high permeable formation colmatage, industrial named as “drilling cuttings calibrator” [6]. Device is a unit of bottom hole assembly. It is installed immediately over the drill bit. Unit design consist double box sub with three outside blades. Special shape of blade permits crushing and squeezing part of drilling cuttings in to the hole wall during drilling with mud circulation. Geometric characteristic of blade depends on drilling parameters. Working area of blade is reinforced. Upper part of blade counteracts a drill string stuck (figure 1).

Process of drilling cuttings crushing and squeezing on the wall hole leads to filling existing caves, fractures and open porous space (figures 2). Additionally hardening of unstable rock exists. As a result, the finite time seating of the hole is formed. The thickness of this seating has range from 5 mm to 20 mm in unstable high permeable formation (figure 3).

Main effect of drilling cuttings calibrator using consists in:
- protect the loss of fluid / mud into formation;
- decrease the depth of drilling mud filtration and the filtrate cake thickness in sand layers;
- protect the caving in clay layers;
- increase the quality of cement job;
- save the potential well productivity;

Figure 1. Drilling cuttings calibrator (computer animation fragment)

Figure 2. Drilling cuttings calibrator action – start stage (computer animation fragment)

Figure 3. Drilling cuttings calibrator action – final stage (computer animation fragment)
decrease the carry-out drilling cuttings volume to the surface in result of immediately recycling / reusing in well bore. This drilling technology was successfully tested in various regions (Russia and India) with sufficient effect. Main idea of present paper is to develop the mathematical approach to calculate the carry-out cuttings volume decrease as a result of drilling cuttings calibrator using for cuttings management.

3. Development of calculation approach

It means, one lay of drillings cuttings must be occurred on the hole wall for drillings cuttings calibrator successful job. It assumes that hole is cylinder and drilling cutting is sphere / ball. There is famous formula to calculate drilling cutting diameter \( d \) (m) in depending on drill bit diameter \( D \) (m):

\[
d = A + BD,
\]

(1)

where \( A \) and \( B \) are coefficients dependence from rock hardness.

| Rock hardness | \( A \)  | \( B \)  |
|---------------|---------|---------|
| Medium        | 0.0035  | 0.037   |
| Hard          | 0.002   | 0.035   |

The minimum drilling cuttings quantity occurred on hole wall perimeter may be calculated as:

\[
n_1 = \pi D/d.
\]

(2)

The minimum drilling cuttings quantity occurred along cylindrical generating line with length \( L \) (m) may be calculated as:

\[
n_2 = L/d.
\]

(3)

From (2)-(3) the total volume required drilling cuttings of sphere / ball shape \( V_1 \) (m\(^3\)) will comprise:

\[
V_1 = \frac{\pi^2 dDL}{6}.
\]

(4)

The total volume of drilled rock \( V_2 \) (m\(^3\)) may be calculated as:

\[
V_2 = \frac{\pi LDL^2}{4}.
\]

(5)

The dimensionless ratio \( V_1/V_2 \) will be indicated drilling cuttings volume decrease. Equations (1), (4), (5) combining gives the final formula:

\[
\frac{V_1}{V_2} = \frac{2\pi}{3} \left( \frac{A + B}{D} \right).
\]

(6)

4. Discussion of results

In this section, the numerical results of calculation are presented. Real case history dimensions of deep wells and both rock hardness were used.

| Drill bit diameter (m) | Rock hardness | Medium | Hard |
|-----------------------|---------------|--------|------|
| 0.1397                | 0.130         | 0.103  |
| 0.2159                | 0.111         | 0.093  |
| 0.2953                | 0.102         | 0.087  |
| 0.3937                | 0.096         | 0.084  |
As shown in table 2, well drilling with drilling cuttings calibrator using permit us to decrease carry-out drilling cuttings volume in range from 8.4 % to 13.0 %.

It is early to use volume unit (m$^3$) for practice cuttings management. These calculations per 100 m well length / depth are shown in table 3.

**Table 3.** Comparison of drilled and used cuttings volumes per 100 m well length

| Drill bit diameter (m) | $V_2$ (m$^3$) | $V_1$ (m$^3$) | Medium rock | Hard rock |
|------------------------|--------------|--------------|-------------|-----------|
| 0.1397                 | 1.53         | 0.20         | 0.16        |           |
| 0.2159                 | 3.66         | 0.41         | 0.34        |           |
| 0.2953                 | 6.84         | 0.69         | 0.60        |           |
| 0.3937                 | 12.17        | 1.17         | 1.02        |           |

For example, calculation result of drilling cutting volume decrease in real well 4640 m depth is shown in figure 4. Total drilling cuttings volume decrease is 39.16 m$^3$. At least, one 40 m$^3$ pit may be excluded from circulation system of on-shore drilling rig.

![Figure 4. Estimated value of drilling cuttings volume decrease in real well 4640 m depth](image)

5. **Conclusion**
A simple approximate solution was presented to calculate carry-out cuttings volume decrease as a result of well drilling with special bottom hole assembly unit such as drilling cuttings calibrator. Only well depth, drill bit diameter and rock hardness kind are necessary for calculation. The results indicate to 13 % carry-out cuttings volume decrease in well diameter range from 0.1397 m to 0.3937 m. Future research will focus on comparison of computational and field data.

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