IOP Conf. Series: Earth and Environmental Science **43** (2016) 012073 doi:10.1088/1755-1315/43/1/012073

Methods to ensure optimal off-bottom and drill bit distance under pellet impact drilling

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Abstract. The paper describes pellet impact drilling which could be used to increase the drilling speed and the rate of penetration when drilling hard rock for various purposes. Pellet impact drilling implies rock destruction by metal pellets with high kinetic energy in the immediate vicinity of the earth formation encountered. The pellets are circulated in the bottom hole by a high velocity fluid jet, which is the principle component of the ejector pellet impact drill bit. The paper presents the survey of methods ensuring an optimal off-bottom and a drill bit distance. The analysis of methods shows that the issue is topical and requires further research.

1. Introduction

Recently the trend to drill hard rocks has intensified; therefore, new drilling methods are urgent to increase the drilling speed, as well as the rate of penetration. One of the most promising drilling methods is pellet impact drilling currently investigated by the Department of Well Drilling, Tomsk Polytechnic University.

Pellet impact drilling implies rock destruction by metal pellets in the immediate vicinity of the bottom hole encountered. The pellets are circulated in the bottom hole by a high velocity fluid jet, which is the principle component of the ejector pellet impact drill bit. According to the previous experiments and studies [1, 2, 3], the method ensures higher drilling speed, the rate of penetration, and speed per run.

As in the case with conventional drilling methods of drilling, the efficiency of pellet impact drilling depends on many important parameters; one of them is an off-bottom and a drill bit distance. Ensuring an optimal off-bottom and drill bit distance is a complicated issue, which was first studied in the middle of the previous century. Since then different ways to solve this task have been suggested.

2. Review and analysis of the methods ensuring an optimal off-bottom and a drill bit distance

The first method suggested by A.B. Uvakov [1, 2] is based on calculating the average rate of penetration. If it is known, the ejector pellet impact drill bit is run to bottom hole at estimated distance per equal period of time. However, the lack of well logging data may significantly restrict the use of the method. Also, it is difficult to apply it for drilling deep wells.

The second method to ensure an optimal off-bottom and a drill bit distance is the jostle of a drill bit, when it is run to a bottom hole and then lifted up at the distance required and lifted then at specific time [3]. It should be noted that a drill bit is subjected to deformation under the influence of axial load when it contacts with bottom hole. Besides, hydraulic standoff is possible due to shutoff of drill bit's inner valves.

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In 1952 L. W. Ledgerwood suggested a new version of the above-mentioned construction [4]. It is based on application of a mechanical feeler 7 with an enlargement 8 (fig. 1). When a critical distance to the bottom hole controlled by the length of a mechanical feeler 7 is exceed, an enlargement 8 partially blocks a primary nozzle 2 enhancing the pressure in a mud system that is a signal for the ejector pellet impact drill bit to be run. However, there are some disadvantages of this version, firstly, it is unreliable due to the high risk to break the feeler, and secondly, it fails to destroy the rock immediately under the feeler of the drill bit. In addition, it is required to use the pellets of smaller diameter, which decreases efficiency of pellet impact drilling.

There is a method to ensure an optimal off-bottom and a drill bit distance via a pellet meter [5]. It is based on the principle of pellets circulation (fig.2), when circulating in a mixing chamber 2 each pellet 8 changes either inductance or capacity of a sensor 5 that is registered by a meter 6. In this case, an optimal off-bottom and a drill bit distance is set by a maximum pellet supply. This version involves some disadvantages too. Firstly, it is necessary to design an additional source to supply and power the pellets that complicates a flow chart of pellet impact drilling. Secondly, making the construction more complicated in general, the version decreased durability and wear-resistance of a drill bit due to wall thickness reduction reducing of walls thickness.

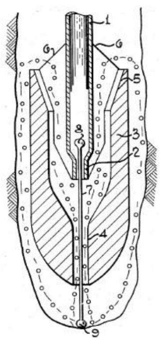


Figure 1.
A device with a mechanical feeler:
1 – a tubular support member ;
2 – a primary nozzle;
3 – a sleeve;
4 – a secondary nozzle;
5 – a hopper;
6 – a web plate element; 7 – a mechanical feeler;
8 – an enlargement;
9 – a spherical enlargement.

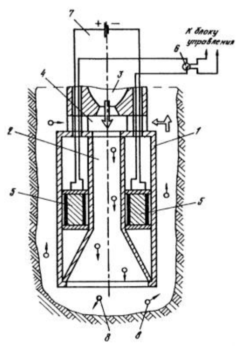


Figure 2.
A device with a pellet meter:
1 – a bit;
2 – a mixing chamber;
3 – a nozzle;
4 – process windows;
5 – a sensor;
6 –a meter;
7 – power source;
8 –pellets.

Other versions have been designed to ensure an optimal off-bottom and a drill bit distance via supports. These designs imply to maintain a fluid jet rigidly in some distance from drill bits destroying a peripheral part (fig. 3) or a central part (fig. 4) of bottom hole via rotary drilling.

However, the first version has its limitations. Firstly, it is difficult to synchronize drill bit operations performed via both rotary drilling and pellet impact drilling [6]. If a central part of the bottom hole is destroyed faster or slower than a peripheral part, it is difficult to control off-bottom and a drill bit distance. Secondly, it is necessary for a drill bit to rotate, which is in contrast to pellet impact drilling, where there is no need for rotation. In addition to above-mentioned limitations, a serious disadvantage of the second version is low wear-resistance because of pellet impact upon the supports.

The third design comprises a tubular support member (fig. 6). The disadvantages are as follows: the ejector pellet impact drill bit should be rotated; it is difficult to synchronize drill bit operations; and pellets of small diameter are to be used.

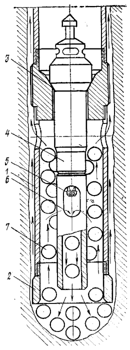


Figure 3.
A pellet impact drill (A B Uvakov and V V Shtrasser design):
1 – a body; 2 – rock-breaking foot; 3 – a cradle; 4 – a fluid jet; 5 – a nozzle; 6 – a mixing chamber; 7 – pellets; 8 – end.

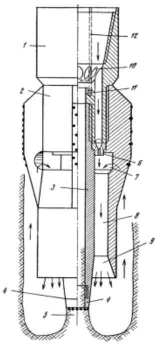
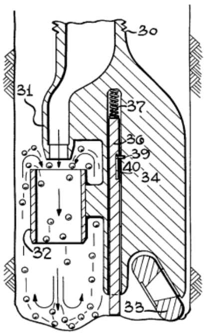


Figure 4.
A pellet impact drill (M M Maylibaev design):
1 – a body; 2 – a ribbed checker; 3 – an inner core tube; 4 – a bore bit; 5 – core; 6 – a nozzle; 7 – ; suction ports 8 – suction port ; 9 – a cone; 10 – canals; 11 – a cradle; 12 – a tube with a core-cutter.



Fiqure 5.
A pellet impact drill (P Williams design):
30 – a tread; 31 – a primary jet nozzle; 32 – a secondary jet nozzle; 33 – a wheel ; 34 – a frame; 36 – a guard deflector; 37 – a spring; 39 – a pin; 40 – a slot.

Other method to ensure required off-bottom distance is based on changing the hydrodynamic conditions in the bottom hole. Figure 6 illustrates a modification of the device. In a position I the pressure at A is less than at B, at point II pressure A equals pressure B, and in a position III the fluid pressure at A is greater than at B. This principle of pressure variation was implemented in McNatt's embodiment (fig.7). [9]. The limitations are complicated design of the ej.p.im.d.b. and costs for adjustment.

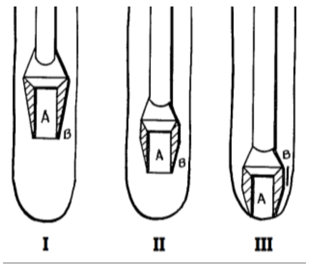


Figure 6.
The principle of the hydrodynamic conditions in the bottom hole

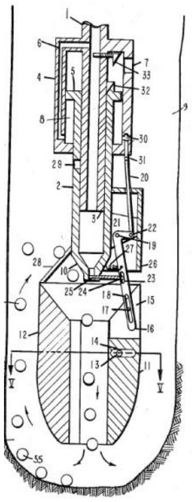


Figure 7. A pellet impact drill (McNatt's design):
1 – a drill string; 2 – a primary nozzle barrel; 3 – a tubular support member; 4 – a cylinder; 5 – a piston; 6 – a channel; 7 – ports; 8 – an annular chamber; 9 – bore hole annulus; 10 – a primary nozzle; 11, 12 – pieces of the secondary nozzle assembly; 13 – pins; 14 – slots; 15 – a slot; 16 – a bell crank; 17 – a pin; 18 – a slot; 19 – a pin; 20 – a connecting link; 21 – web; 22 – a nozzle barrel; 23 – a slot; 24 – a pin; 25 – a member; 26 – a body; 27 – a spring; 28 – web members; 29 – a port; 30 – a bleed port; 31 – a slide valve; 32 – a cam; 33 – a cam; 34 – a slide valve; 35 – a port; 36, 37 – ports; 39 – a controlling port; 40 – a spring; 41 – a plate; 50 – a controlling port; 51 – catalytic fines.

3. Conclusion

The review has revealed a number of limitations in the methods for an optimal off-bottom position. Therefore, the issue is still topical and requires further research.

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