New generation drilling bits

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Abstract. The article describes innovative approach to designing new generation drilling bits with diamond hard-metal-alloy plates coring in accordance with established regularities. Based on the results of theoretical and experimental investigations the authors have stated the offers on the important aspects of drilling bits with diamond hard-metal-alloy plates coring design optimization. The authors have determined the features of influence of geometry, arrangement and dynamic of diamond hard-metal-alloy plates cutters on rock failure when drilling wells. The description of the stabilizing drilling bit is presented along with reasons for optimum angles of the diamond hard-metal-alloy plates mounting onto the casing.

1. Introduction

For drilling rocks of various hardness, alternate types of drilling bits are designed which differ both in design parameters and materials characteristics. Such variety of drilling bits is caused by the intention to increase their operational durability, drilling speed and to lower production costs.

A number of innovative approach to drilling bits designing are based on the relationships determined and methods developed for determination of geometrical, design and regime parameters of the rock destruction tools (RDT) of the cutting type with a poly-crystalline diamond cutter bit (PDC).

It is proved that by drilling exploratory and operational wells with rock destruction tools of the cutting type the mechanical speed of drilling within the whole range of operational frequencies does not practically depend on the rotation speed, but exclusively depends on axial weight value in case of sufficient flushing.

Unlike the traditional bits of the cutting type with tungsten-cobalt alloys (TC) coring, new generation bits are reinforced with diamond and poly-crystalline diamond cutter bit (PDC), the wear resistance of which exceeds 95 and more times the wear resistance of tungsten-cobalt alloys (TC) [1, 2].

2. Design solution

For several latest decades SRSPU (NPI) employees have been developing drilling bits with PDC coring. Within this period, more than 10 types of various bits designs were developed, manufactured and tested.
The continuous process of drilling bits improvement demonstrated that there are no bits so far, capable of drilling I to X drilling capacity category rocks with equal success.

For the purpose of solving the above-mentioned tasks the authors developed, manufactured and industrially tested the stabilizing drilling bit intended for drilling rocks of VI to VIII drilling capacity category [3, 4]. The stabilizing drilling bit (fig. 1), contains a case 1 with a connecting carving 2, divided by the main flushing channels 3 into sectors 4 supplied on the face surface with the diamond hard-metal-alloy plates 5 mounted in different directions at a negative angle of 10°-15° to the cutting direction.

![Figure 1. A general view of the stabilizing drilling bit.](image)

The main flushing channels 3 and additional flushing channels 6 are designed opposite at an angle. The main 3 and additional 6 flushing channels are designed along full height of the bit case 1 in a screw following the bit rotation to the right.

The height of the bit casing 1 depends on a screw stage length of the main 3 and additional 6 flushing channels. Inside additional flushing channels 6 two and more diamond hard-metal-alloy calibrating plates 7 are placed, each of which represents an element of the separate screw line and is fixed on the casing by means of brazing or mechanically at a negative angle βc from minus 5 degrees to minus 15 degrees to the cutting surface. γc is the angle of mounting the cutting element which works upon the core sidewall. When drilling very abrasive ores not two, but three rows of calibrators are mounted on the bit, that is 9 PDC of Ø10 mm.

The bit described works as follows. The flush liquid intended for the bit cooling and delivery of drill cuttings to the well surface moves from the flushing pump through boring pipes string rotating to the right and the bit casing gets to the borehole bottom.

Passing from under the bit end plane 1 the flush liquid captures the drill cuttings and transports them to the surface through main 3 and additional 6 flushing channels in the highest turbulence regime owing to the fact that the main and additional channels are located opposite at an angle along the screw to the right.

At the same time, the calibrating PDC 7 are fixed in additional flushing channel 6 and calibrate the well walls reducing bore hole deviation. The main diamond hard-metal-alloy plates work in a multidirectional cutting regime. All in all, this gives the opportunity to improve drill cuttings removing from the bore hole bottom, reduce vibration, decrease the number of chippings and breakdowns, smooth the drilling path and as a result, increase mechanical speed of drilling and endurance or bit sinking.

Unlike traditional bits of the cutting type with tungsten-cobalt alloys coring, new generation bits have the poly-crystalline diamond cutter bit (PDC) coring the wear resistance of which exceeds 95 and more times the wear resistance of TC alloys.
Hard-metal-alloy bits have operating front and back cutting angles which are not interconnected since reinforcing plates can be of various shapes while the PDC are most often round cylinders. The cutting angle $\delta$ of such plates is $90^\circ$, and front $\beta$ and back $\alpha$ are interconnected. The cutter load $F_{\text{cut}}$ and rock chipping (fig. 2) depend on the front angle $\beta$ [5; 6].

- $R=0.24$ P for cutters with positive front corner $\beta$;
- $R=0.06$ P for cutters with zero front corner $\beta$;
- $R=0.08$ P for cutters with negative front corner $\beta$.

Then the cutter load determined by the formula (1) will increase by $R$ growth and chipping angle $\tau$ reduction:

$$F_{\text{cut}} = \mu_c \cdot R \cdot F_{dul} \cdot \frac{R \cdot h \cdot R \cdot (\sin \delta + \mu_c \cos \delta)}{2 \sin \tau \cdot \sin(\tau + \delta)}$$

Where $F_{dul}$ - dulling area, mm$^2$;
- $h$ - thickness of the cut-off rock layer, mm;
- $R$ - radius of mounting the cutting element, mm;
- $\delta$ - cutting angle, degrees;
- $\tau$ - chipping angle, degrees;
- $\mu_c$ - friction coefficient of the cutting elements against the rock.

**Figure 2.** a) shift with compression $\tau = 15^\circ$; b) shift $\tau = 20^\circ$; c) shift with stretching $\tau = 25^\circ$. 
Fig. 3 shows a fragment of the bit with cutting calibrating elements 7 of the 8 mm diameter fixed in the additional channel 6 through which drill cuttings are removed from the bore hole bottom, and number 5 illustrates PDC forming the wall of the well [7-8].

3. Conclusion
1. The designed stabilizing drilling bit will allow one to reduce bore hole deviation, to improve flushing quality, to reduce vibration rate and consequently to achieve significant increase in core drilling mechanical speed.

2. The given bits are manufactured in a classical way. Their geometry and the scheme of the PDC mounting allow the tool to work in more stable regime. The PDC plate is mounted on the bit case both by brazing and mechanically which supposes fast replacing in case of failure.

3. Hydrodynamic analysis of the PDC bits operation has allowed to modify their design and consequently improve cleaning a bottom hole from cuttings, chilling of cutters and to increase flush flow turbulence [9-10].

4. The PDC advantage is the ability to self-sharpen and have up to 30% diamond layer run in the course of operation without changing the cutting element (cutter) contact area with a well bottom.

5. The designs developed provide increasing the PDC bits maintainability and can ultimately raise the drilling commercial speed. The bits are of substantial interest for the branch and require further research.

The general overview of drilling bits design in the nearest future describes the latter as being multifunctional concerning mostly the cutting section equipment in accordance with ore drilling capacity categories. The bits will be necessarily affected by outer physical factors which accounts for increasing their endurance. Simultaneously the bits will have design modifications, all cutting elements will be easy to remove, interchangeable, and the hydraulic system will be improved towards optimization. Such approach will provide an increase in well boring mechanical speed, reduce bottom hole vibration, improve bore hole cleaning, achieve smoother drilling path, decrease emergency, and
as a result reduce one meter of ore boring cost.

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