

Analytical research and classification of mechanism of diamond drilling-bits contact with rocks during well sinking

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Abstract. Calculating the correct number of the diamonds and making practical recommendations during the diamond bit applications are of great importance. The recommendations are usually made based on the assumption that the diamond matrix and the bottomhole are flat bodies. However, this assumption may lead to significant errors in the calculation of the number of diamonds in contact with the rock and projections during the diamond bit applications. In this work, the calculations are made based on the assumption that the contact between the diamonds and the rock surface has a curved structure. The results show that the diamonds located along several cutting circumferences may be in contact with the rock surface. In this case, the number of diamonds of one cutting line in contact with the hole will not depend on the size of the diamond matrix of the other cutting line and is determined by the degree of bottomhole roughness and the amount of diamond protrusion from the matrix along each cutting circumference.

1. Introduction

Prior to drilling, a new diamond bit must be run-in. The necessity of this operation is explained by several reasons, the main ones being the difference in diamond heights, the discrepancy between the diameter of the bit and the diameter of the well in the bottomhole zone, among others. Ignoring the bit running-in operation can lead to the chippage of the diamonds, the formation of bevel edge on the cutting face of the bits, the polishing of diamonds [1, 2].

From the known methods of diamond bits applications, it has been established that at the initial moment of contact with the bottomhole, about 20% of the total number of diamonds are in contact. Then, as the running-in period increases, the number of diamonds in contact increases and reaches 80%. According to this, it is recommended to gradually increase the load on the bit and the rotary speed of the drilling string before reaching the working or optimal mode.

The proposed recommendations are based on theoretical and empirical studies of the mechanism of diamonds in contact with bottomhole.

2. Materials and methods



In table 1, existing methods for determining the number of diamonds involved in contact and destruction of rocks are classified to some extent [3].

The classification is based on two main principles, according to which two groups of theoretical (estimation) and empirical (practical) methods are distinguished. In the group of estimation methods, some subgroups are highlighted, in the base of which the both deterministic and probabilistic methods are used. Typically, in the theoretical methods, using the calculation methods the number of diamonds are determined, which are hypothetically involved in the rock destruction. [4-9].

Table 1. An approximate classification of the methods of determining the number of diamonds, in contact with the bottomhole

Name of method		Area of application
Group	Subgroup	
Theoretical (calculation)	Deterministic	Impregnated bit
	Probabilistic	
Empirical (practical)	Laboratory	Surface-set bit
	Bench	

Using the empirical method, the number of diamonds in contact with the bottomhole surface is determined. Among the empirical methods, the laboratory and bench methods are highlighted. In the laboratory methods, the number of diamonds in contact with the plane, simulating the bottomhole, is determined. In the bench methods the investigation of the number of diamonds in contact is carried out directly during the drilling of the blocks (e.g., glass blocks), simulating rock.

The laboratory method is based on the method of indentation [1]. An organic glass plate with bit indents is used as a simulating rock. On the plate, within the borders of the contour, there was a diamond bit, on which the load was set at 5 and 20 daN. Then, the bit was displaced by 0.5-1.0 mm by rotating it. In conclusion, the bit was removed from plexiglass, the obtained prints of diamonds on the plexiglass were filled with ink and counted their number (Table 2).

Table 2. The results of experiment for determining the number of diamond indentations

Bit type	The number of diamond indentations in the load on the bit, daN.	
	5	20
O1AZ-59 (unrun)	13	20
A4DP-59 (run-in)	42	53

The table shows that, for an unrun-in bit at a load of 5 daN, 12% of the total number of diamonds are in contact (on average, for O1AZ-59 bits, the total number of bulky diamonds is 102 pieces); with an increase in the load to 20 daN, the number of diamond in contact increases to 20% of the total number (Figure 1). For the A4DP-59 run-bit with 128 pieces of diamonds, at a load of 5 daN, 32% of the total number of diamonds in contact with the counterbody: an increase in load up to 20 daN yields an increase in the number of diamonds in contact. The second stage of the study included experiments in the process of well drilling. For the A4DP bit type, based on the heights of protrusion of diamonds from the cutting

face, the average number of diamonds in contact with the borehole was calculated, which depended on the depth of penetration of diamonds. The bottomhole surface was considered to be smooth and the bit - rough. Analysis of the results shows that at the initial time there was a limited number of diamonds in contact with the bottomhole surface, not exceeding 20% of all bulky diamonds (Table. 2). With increasing depth of penetration into the rock, the number of the contact diamonds can reach 80-100%.

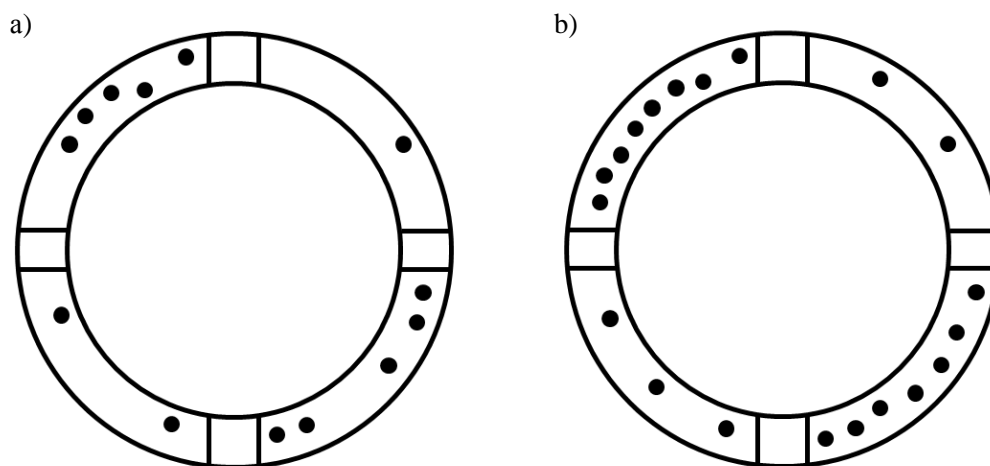


Figure 1. The number of prints diamond in contact with counterbody (non-run bit). P = 5 daN; b) P = 20 daN

3. Results and discussion

To verify the calculated data, studies were conducted while drilling production wells. Using a portable profiler, the diameters of the diamond protrusion from the cutting face along the midline of cutting of the same sector of the bit (during and after drilling) were measured. It was established that at the initial stages of work, the number of diamonds in contact with other cutting lines of this same cutting face increases to 16-20 pieces, and in the final stage of diamond bit wealth, up to 70% of the diamonds were in contact. According to the results of the study, the character of the distribution of diamond protrusion from the cutting face was established, corresponding with the normal law. Verification of the distribution law in production conditions showed that the preservation of height of protrusion of diamonds from cutting edges decreases with wear and the normal distribution law remains constant.

In reference [10], studies were carried out on a special bench with horizontal drilling on the block of optical glass. The study was carried out in two stages:

1) drilling by the principle of "boring", when the length of the drill string was 2 m; 2) when drilling a flexible drill string 50 m was used. Surface set bit and impregnated bits of types O1AZ, K-O1, O2IZ, BS-O1 were used.

Filming was conducted at a speed of 500-4000 frames per second at the bottom hole. The analysis of footage (at the first stage) made it possible to establish the following:

- the rock is destroyed by the same diamonds located on one or two sectors of the bits;
- the bit is not loaded symmetrically, which is determined by the bending of the core barrel and the nature of its rotation around the axis of the well;
- the number of diamonds that disintegrates the rock is 5-20% of all bulky diamonds: the remaining diamonds are in elastic contact with the rock

- with increasing axial load, the number of diamonds that disintegrates the rock increases.

When the drill string is turned on (stage 2), the kinematics of the diamond bit movement is much more complicated and is associated with the rotation mode of the drill string.

Based on the performed analysis, the following should be noted:

1. When investigating the mechanism of diamonds in contact with a bottomhole, the bottom hole should be regarded as a flat body.
2. In existing experimental studies, the profile of the cutting face is also considered as flat. The number of contacting diamonds is determined based on the maximum amount of diamond protrusion from the cutting face.
3. The noted shortcomings introduce a significant error in the calculation of the number of diamonds in contact with the bottomhole, which in turn leads to an increase in the error in calculating the volume of the contact of the pair between the diamond bit and rock.

Based on the above-mentioned, the mechanism of diamonds in contact with rock was studied, taking into account the curvature of the bottomhole. In this case, because of the curvature of the bottomhole, diamonds located along several cutting circumferences may be in contact. For example, diamonds located along two cutting lines can be in contact with the bottomhole. In this case, the number of diamonds of one cutting line in contact with the bottomhole will not depend on the size of the diamond cutting face of the other cutting line. The number of diamonds will be determined by the degree of roughness of the cutting face and the magnitude of their performance from the matrix for each circumference of the cutting. For surface-set bits, the number of diamonds in contact will be determined by the formula (1):

$$N = K \cdot N_1 \quad (1)$$

where N is the number of diamonds in contact for the entire bit; N_1 is the average number of diamonds in contact with the bottomhole along the circumference of cutting; K is the number of cutting circumferences.

When using formula (1), let us use the data from [4], which shows that for unrun-in OIAZ bits, 20% of the total diamonds of the bit are in contact with the flat object. Since the end face of the cutting face of such bits has a rounded profile shape, it can be proved that the data refers to diamonds of one, at most - two cutting circumferences running along the most protruding part of the end face of the cutting face. Then for bits of this type, 20% of 100-104 pieces of diamond (an average of 20 diamonds) refer only to diamonds of one or two cutting circumferences.

When a bit is in contact with the bottomhole via one cutting circumference, the number of diamonds will be about 10% of all diamonds located on it, and with two cutting circumferences, about 50% on each line. Consequently, if the bit is in contact with a bottomhole which profile corresponds to the profile of the cutting edge, then the contact will have diamonds lying on all the cutting circumferences. Taking into account formula (1), the number of contacting diamonds will be about 50-100% of the total number of them on the bit.

Table 3. Number of diamond dents (marks) on simulated bottomhole (according to laboratory data)

Experiment number	Coring weight, daN	Number of diamond dents(marks) in bit sectors				Total number of cutting lines	Percentage of total number of diamonds in bits
		1st	2nd	3rd	4th		

1	4	9	9	10	12	2	32
2	4	27	27	21	22	5	70
3	8	32	32	32	32	5	100

The proposed experimental studies of the mechanism of contact of a diamond bit with a bottomhole were carried out under laboratory conditions. An easily formed material (paraffin) was used in modeling the bottomhole. In the first experiment, paraffin was poured into a special metal mold in which a worn-out bit of type A4DP-59 (cutting face, close to the flat form) formed the bottomhole.

After this, a new bit of the same type was installed and with a load (4 daN) a number of diamond indents was made on the artificial bottomhole. In the consecutive two experiments, the bottomhole was formed based on the cutting face profile of a run-in bit. Each experiment was repeated 3 times; The average values of the results of the experiments are given in Table 3.

Conclusion

Analysis of the obtained data showed that: when the bottomhole's profile is close to being flat, diamonds with two cutting lines were in contact, which explains the existing differences in the shapes of the worn-out and new (run-in) diamond bits. When the bottomhole's profile is close to the profile of the cutting face of a run-in bit, up to 70% of diamonds with 5 cutting lines were in contact, and when the load was doubled, virtually all 100% of the diamonds came into contact.

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