Improving accuracy and technology for manufacturing tricone roller bits

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Abstract. As a result, the control of the process of basing a roller bit in a chuck was experimentally tested and introduced into production by measuring the gap between the working surface of the restrictive ring and the calibrating surface of the cone in order to increase the accuracy of drill bit manufacturing. Bits with a diameter close to the lower limit value can be machined in a chuck with a restrictive ring of reduced diameter. Height differences of the cones are reduced by introducing into the production the method of group interchangeability of sections in height, measured in a direction parallel to the axis of the bit.

1. Introduction

During drilling wells, tricone roller bits suffer from enormous loads: abrasion, wear and loss of carbide elements, runout in roller bearings (since roller bits move with two degrees of freedom). The reduction of the last effect (runout) requires increased attention to the quality of the manufacture of the bits at the stage of welding of the roller bit pins with the body.

2. Results and discussion

The main indicators of the accuracy of roller cone bits (Figure 1), such as tolerances for diameter, height differences \((HD)\) of the cones relative to the thrust ledge and radial runout \((RR)\) of cones relative to the thread, are regulated by GOST 20692-75. However, the tricone sectional bit refers to low-tech engineering products, since its sections are interconnected by welding; it does not contain a basic part and is characterized by the presence of complex combined spatial dimension chains [1].

The accuracy of a tricone bit in diameter depends on the errors in the machining of its main parts, on the displacement of the sections during the assembly of the bit, on the errors caused by deformations during welding operations [2]. The listed factors to varying degrees affect the other two indicators: \(HD\) and \(RR\). However, there are considerable caveats in the composition of the accuracy of a tricone bit in terms of said indicators. First, it is impossible to control and regulate \(HD\) and \(RR\) at the stage of assembly of the product, since the measuring base of the bit is formed only at the final stage of its manufacture—processing a threaded nipple. Second, the influence of bit basing errors when processing the nipple on \(HD\) and \(RR\) is so great that correctly assembled from right parts, but installed in the chuck with a significant error, turns out to be substandard, and in this case, it requires additional time-consuming and energy-intensive processing [3].
Figure 1. Tricone roller bit: 1 – cone bit; 2 – leg; 3 – welding seam; 4 – joint thread; O – thread axis; K – plane of the thrust ledge; D – diameter of the bit; C – displacement of the axis of the cone relative to the axis O

Figure 2 shows two schemes for three-cone bit mounting in chucks that are most widely used. Scheme I provides for the mounting of each of the cones in the chuck along the teeth of the peripheral row by means of a support 1 with a concave surface close to the surface enveloping the tops of the teeth, two of the three supports can move along an circular arc to compensate for the displacement of the cones in the processed bit relative to their nominal position. In the radial direction, the bit is based on the sections of the calibrating cones of the roller bits by centering mechanism 2 made in the form of a rotary ring with three centering surfaces or in the form of a collet, cams, etc. The cones of the bit are first set on the supports 1 and slightly pressed axially. At the same time, it is centered in the radial direction, and then fixed with a floating ring 3. To increase the rigidity of the fastening, an inner chamfer is made on the nipple; on its surface, the bit is fixed with center 4. Basing is carried out on the tooth crowns, according to which P bits are subsequently controlled, while the concave shape of the support allows avoiding the component of the basing error Δ due to the nature of the contact of the tops of the bit teeth with the support.

Figure 2. Schemes for basing a tricone bit during processing of a threaded nipple: 1 - support; 2 - centering mechanism; 3 - floating ring; 4 - rotating center; 5 - cams; 6 - restrictive ring
3. Experimental

Consider the consequences of processing a bit assembled with an offset of one section in the axial direction by a certain value $A$. Regardless of the specified offset of the tooth section, the tops of the peripheral crowns of each of the tricone cones come into contact with the corresponding supports. As a result, after processing the nipple, the peripheral crowns of the cones are more likely to be located at the same level relative to the plane of the thrust ledge. In this case, assembly defects are manifested in the form of a bit inclination by an angle $\alpha$ relative to its nominal position, as a result of which, in particular, a change in the angles of inclination of the axles of the pins to the axis of rotation of the bit occurs.

The angle $\alpha$ can be approximately determined by the formula [4, 5]:

$$\tan \alpha \approx \frac{A}{R (1 + \sin 30^\circ)}, \quad (1)$$

where $R$ is the distance between the axis of the bit and the tooth, the distance is being used for basing.

For example, if the section of the bit with a diameter of 215.9 mm is displaced in the axial direction by 0.5 mm, the angle $\alpha$ will be no more than $10–12^\circ$. Therefore, the processing in the considered chuck of the bit with a relative displacement of the sections by a significant amount is accompanied by only a slight change in the angles of inclination of the pins relative to their nominal position.

Consider the option of processing a bit with a significant radial runout $RR_{assy}$ formed during the assembly process, for example, due to the different sizes of its sections in height, measured relative to the edge of the dihedral angle.

Since the bit is centered in the radial direction along the sections of the calibrating surfaces of the roller bits and these sections are equally distanced from the axis of the thread formed during the processing of the nipple, the radial runout $RR_{assy}$ that occurs during the assembly can be corrected. It should only be borne in mind that such a correction affects the displacement of the axes of the cone bit relative to the axis of the edge of the bit. The error of displacement of the axis of the cone can be determined by the formulas

$$\Delta_{c1} = K \sin \omega; \quad (2)$$
$$\Delta_{c2} = -K (\omega + 60^\circ); \quad (3)$$
$$\Delta_{c3} = K \cos (\omega + 30^\circ), \quad (4)$$

where $\Delta_{c1}$ is the error of the shift of the cone axis of the corresponding section of the bit (see Figure 3); $\omega$ is the angular coordinate of the direction of displacement of the axis of the bit relative to the plane of symmetry of the nearest section ($0 \leq \omega \leq 60^\circ$); $K$ is the offset of the axis of the bit, calculated for known values of $RR_{assy}$ and $\omega$ from the ratio $RR_{assy}/K$ determined according to the plot (Figure 4) [6].

**Figure 3.** Error of the displacement of the axes of the cones due to a change in the position of the axis of the bit: $O$, $O_1$ are the nominal and actual position of the axis of the bit, respectively.
From the point of view of ensuring the required accuracy of the bit in $HD$ and $RR$, Scheme I can be considered optimal. The error $\Delta C$ is relatively small. In addition, it can be taken into account when assigning the nominal value of the displacement of the axes of the cones eliminating the possibility of a negative displacement.

![Graph](image)

**Figure 4.** Dependence of the ratio $RR/K$ on the direction of displacement $\omega^0$ of the tricone bit

According to the basing Scheme II (see Figure 2), along with the cam mechanism 5, a rigid restrictive ring 6 is used the inner diameter of which is slightly larger than the diameter of the bit. The advantages of Scheme II include the possibility of processing bits of different types in one cartridge, ease of installation of the bit, and providing a higher rigidity for securing the product. The calculations and practice of the operation of the cartridge showed that the bit made with a minimum diameter can shift in the radial direction by an unacceptable amount, despite the presence of a restrictive ring 6, and the bit assembled with a significant relative displacement of the sections in the axial direction has a correspondingly severe cone height difference.

In order to improve the accuracy of bits in terms of $RR$, the control of the process of basing the bit in the chuck was experimentally tested and introduced into production by measuring the clearance $S$ between the working surface of the restrictive ring 6 and the calibrating surface of the cone. The possible value of the bit $RR$ is judged by the difference of the gaps $S$ in the three sections. Bits with a diameter close to the lower limit value can be machined in a chuck with a restrictive ring of reduced diameter. The cone height difference is reduced as a result of introducing into the production the method of group interchangeability of sections in height, measured in a direction parallel to the axis of the bit [7].

Factors such as backlash in the support, runout of the working surfaces of the cone teeth when the latter rotate on the trunnions significantly affect the accuracy of the base of the bit during the processing of the threaded nipple, especially using Scheme I, and the accuracy of the measurement of $HD$ and $RR$. Base errors due to these factors were determined experimentally by the following procedure.

Rotating the cone Sh215 and 9TZ-GH bits on the trunnions, we found a position of three cones in which $HD$ and $RR$ had the minimum values, then turned the cones half a turn and repeated the measurements, fixing now the maximum values of $HD$ and $RR$. Since these measurements were carried out using the same tooth crowns, on which the bit was based when processing the nipple. The maximum value of the axial basing error $\Delta_a$ was estimated by the half-difference of the $HD$ measurement results. Similarly, based on the results of measurements of the $RR$, the error of basing in the radial direction $\Delta_r$ was estimated. The values $\Delta_a$ and $\Delta_r$ characterize the possible displacement of
the bit relative to its nominal position in the chuck due to runout of cones. The maximum values of the indicated errors can reach 1/4 - 1/3 of the tolerances on HD and RR (see Table).

Table 1. Maximum measurement errors

| Accuracy indicators                                                                 | Number of studied bits | Grouping center value $x$ [mm] | Standard deviation [mm] |
|------------------------------------------------------------------------------------|------------------------|--------------------------------|-------------------------|
| Radial runout* bits with a diameter of 215.9 mm                                      | 145/150                | 0.603/0.847                    | 0.313/0.373             |
| Different heights* of cones of the same bits                                        | 145/150                | 0.555/0.7                      | 0.324/0.394             |
| Radial runout** of bits                                                            | 67; 4061/295           | 1.02; 0.699/0.727              | 0.655; 0.324/0.365      |
| Basing errors*** of Sh215TZ-GN bit due to the rolling fastening of the cones       | 22/22                  | 0.205/1.195                    | 0.105/0.079             |

* In the numerator, for TKZ bits; in the denominator, for MZ bits.

** In the numerator, for basing according to Scheme II (the first digit is before the introduction of control of the basing process, the second one is after the introduction of control); in the denominator, according to Scheme I.

*** In the numerator is $\Delta_\alpha$; the denominator is $\Delta_\rho$.

As practice has shown, the accuracy of manufacturing bits of the same diameter, but of different types, in the conditions of the same production can be different. To a large extent, it depends on the displacement of the axes of the cones due to the displacement and uncertainty of the position of the calibration point in a particular bit, as well as on the presence of backlash in the bearings and on the tooth pitch in the peripheral crowns of the cones.

Figure 5 and Table show the distribution of HD and RR indicators in batches of 145 bits of type Sh215, 9TKZ and 150 bits of type Sh215, 9MZ [8]. These bits, significantly differing in terms of displacement of cone cutters (respectively 1 and 8 mm) and the maximum amount of play in the support (0.55 and 0.8 mm), were processed in serial production using the same equipment, using the same technological process. Both considered accuracy parameters of TKZ bits, having smaller displacements of the cones and backlash axes in the bearings, are significantly higher [9, 10].
Figure 5. Distribution of accuracy indicators $HD$ and $RR$ in batches of two types of bits: 1 – TKZ bits; 2 – MZ bits

4. Conclusion

As a result, the control of the process of basing a bit in a chuck was experimentally tested and introduced into production by measuring the clearance $S$ between the working surface of the restrictive ring 6 and the calibrating surface of the cone in order to increase the accuracy of the bits in $RR$. Bits with a diameter close to the lower limit value can be machined in a chuck with a restrictive ring of reduced diameter. The cone different heights are reduced as a result of introducing into the production the method of group interchangeability of sections in height, measured in a direction parallel to the axis of the bit.

The results also allow concluding that it is necessary to assign accuracy standards differentially, depending not only on the diameter of the bit, but also on its type. Due to this, its runout decreases during the well drilling process, and thereby increasing their durability.

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