Optimized design of new composite drill

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Abstract. In drilling engineering, the timeliness of the drill bit is very important, which affects the drilling speed and drilling cost. This paper starts from the rock breaking mechanism of the drill bit and the feedback of on-site construction, and analyzes the relative position of the composite drill bit PDC blade-roller. For the impact of mechanical drilling speed and load distribution, a new type of composite drill bit was optimized and designed to form a two-level cutting composite drill bit. The new composite drill is designed for two-stage cutting mode. The stepped wellbore after two-stage cutting produces an equivalent steering angle, which can effectively reduce local head loss. The new composite drill bit can increase the mechanical drilling speed, reduce the cost of oil and gas extraction, and adapt to the future drilling dynamic needs.

1. Introduction
Compound drills (also known as hybrid drills) have a 90-year history since the design concept was put forward, but at the construction site, compound drills have not shown large-scale applications because the actual exploration of compound drills has mainly focused on the last decade. Within, at the same time, its basic theoretical research is not deep enough. This article aims at the research and construction status of new composite drill bits at home and abroad, starting with basic theoretical research and problems in the construction process, to optimize the design of composite drill bits.

2. Design theory of composite drill

2.1. Rock breaking mechanism of composite drill
The rock-breaking effect of the new composite drill is mainly due to the superposition of the two sets of rock-breaking mechanisms of PDC and roller cones, that is, the plow rock breaking process of PDC cutting teeth and the intrusive crushing rock breaking process of the roller cone part. The rock breaking process of the composite drill bit is the interaction between the PDC cutting blade and the cone; in different formations, there are different performances. In the hard formation, the cone teeth first contact with the rock, which acts as a buffer structure. It bears on the teeth of the roller cone to protect the PDC cutting teeth; it effectively prevents the rapid wear or chipping of PDC cutting teeth[1]. When the roller bearing or roller tooth wears, the load will shift, increasing the load on the PDC cutting teeth, so that the load is effectively distributed, which is beneficial to prevent the failure of the bearing.

The ploughing and rock breaking process of PDC cutting teeth is essentially an extrusion process. As shown in Figure 1, when the rock begins to contact the cutting edge of the cutting teeth at the initial instant, the pressure at the contact point causes elastic stress and strain inside the rock; when cutting When the blade approaches the rock, the elastic stress inside the rock gradually increases. At a certain
position in the rock, the shear stress reaches the yield strength of the rock, so the rock begins to slip along the "initial slip surface" with the same shear force (as shown in the figure 1 OA surface), when the cutting edge moves through the OA surface, the slip deformation becomes larger and larger. When the rock moves to the OE, the rock layers 1 and 2 will no longer slide along the OE, but Together, it flows out along the rake face of the cutting tooth[2]. When the rock flows out along the rake face, due to the pressure and friction of the rake face of the cutting tooth, the bottom layer of the cutting (the layer close to the rake face) produces greater compression and shear As a result of the shear deformation, the lower layer expands, and the cutting flows out in the opposite direction of the rake face, leaving the rake face as chips.

The longitudinal vibration of the roller cone and the impact crushing effect on the formation are mainly manifested as: the longitudinal vibration of the drill bit at the bottom of the well causes the drill string to continuously compress and expand [3]. The lower drill string can pass this periodically changing elastic deformation through the drill teeth It is converted into an impact on the stratum to break the rock. This action is the main way for roller cones to break the rock.

2.2. Problems in site construction
Because the compound drill bit is composed of PDC and cone part, the cone is too small, the outer row teeth are small, and the scratch effect is not obvious; the rock breaking mechanism of the compound drill is that the cone is pre-broken, and the PDC is repeatedly sheared, and the use effect is very good. However, the teeth are small, the abrasiveness of sandstone is strong, and the speed of tooth wear is fast; the design of the water eye runner needs to be optimized to reduce the erosion of the PDC blades [4]; there is currently no radius-preserving teeth on the compound drill cone, once the cone is discharged when the tooth is worn, it will wear the back of the roller cone and the oil cup, shortening the service life of the bit [5]. As shown in figure 2, the composite drill bit from the scene has serious wear on the back of the roller cone, and the wear reaches 6mm.
3. **Optimized design of composite drill**

The mechanical drilling speed and service life of the composite drill bit are affected by many factors. As shown in Figure 3, as the relative position of the PDC-cone increases, the torque that the drill bit bears gradually decreases. According to the feedback of experimental data, the relative position of PDC-roller will also affect the distribution of weight on the bit. Within a certain range, the relative position of PDC-roller gradually increases, the greater the weight-on-bit ratio of the cone part of the compound drill, as shown in Figure 4. Through the investigation of domestic and foreign literature and on-site construction feedback, this paper will optimize the design from the crown of the drill bit, the relative position of the PDC blade-roller, cutting teeth, and oil storage lubrication sealing system, as shown in Figure 5.

![Figure 2. Abrasive composite drill bit](image1)

![Figure 3. The effect of the relative position of PDC blade-cone on torque](image2)
3.1. Crown structure design

The crown geometry of the drill bit includes B-type, flat-bottom type, double-cone type and other types. The main differences are the concave degree of the center of the carcass and the inner cone angle. Its geometry affects the stability of the drill bit and the bottom of the hole cleaning, abrasion of the drill bit and load distribution of various parts of the drill bit. This drill bit adopts B-type structure, so that the stress on each part of the drill bit can be as uniform as possible to prevent local early damage, and a larger cone angle is designed on the outside of the crown to facilitate drilling. As shown in Figure 6, the middle of the crown is in the shape of an inner cone, which is very helpful for preventing slant. The side on which the stratum is cut on the crown blade is flush, which is good for cutting the bottom of the well; and the PDC cutting teeth are inlaid on the side where the blade cuts the stratum. One of the cutting teeth of the blade is arranged through the center axis of the cone. This allows the crown blades to make full contact with the working surface, and the other two blades are designed with water holes to cool the cutting teeth and remove cuttings. The diamond particles are added to the tail of the PDC blade and arranged regularly, which can well protect the diameter and prevent premature wear of the spine.
3.2. PDC blade wing relative position

The crown of the drill bit adopts a two-level cutting mode, that is, the PDC blade first cuts the formation to form a small-diameter wellbore, and then the roller cone performs second-level cutting, that is, the borehole is expanded, and the diameter-preserving part is subjected to micro-cutting to prevent well deviation and increase the smoothness of the well wall reduces the effect of the lateral vibration of the drill bit.

The whole bit adopts the composite structure of PDC bit and roller cone bit. The whole cone and the PDC blade are arranged in a staggered pattern. They are all three. The cone is biased towards the back of the PDC blade, and its maximum cutting diameter is the same as that of the drill gauge. On the other side of the roller cone there is a drilling fluid circulation space, the purpose is to facilitate the backflow of drilling fluid and cuttings.

The cutting diameter of the cone is larger than the cutting diameter of the PDC, and the top of the PDC blade is higher than the working surface of the cone. Therefore, in the actual drilling of the drill bit, the PDC cutting tooth cuts the formation first, this is the first-level cutting, followed by the tooth wheel rotates to cut the remaining part, that is, to cut the rock of the well wall and expand the borehole.

PDC cutting tooth cutting cooperates with the rotary cutting of the cone to achieve layer-by-layer cutting, so as to play their respective cutting functions and play the role of a composite drill. The shape of the bottom of the hole after cutting is a stepped cylinder with rounded corners. It can reduce the hydraulic loss in the process of drilling fluid circulation in the well, and indirectly reduce the consumption cost of ground power equipment.

3.3. Design of cutting teeth

There are three types of cutting teeth for the new composite drill, which are PDC cutting teeth (polycrystalline diamond composite discs), cemented carbide teeth, and square diamond particles. They are used for the crown PDC blade, cone, and gauge. Since the drill body is sintered using a mold, after the sintering is completed, the turning process is performed, and the PDC blades are turned out in the crown, and the groove containing the PDC cutting teeth is placed in the groove for welding. Then form the crown blade. The crown is designed with three blades, which are 1200 symmetrically distributed. One of the cutting teeth passes through the center and can cut the center rock. This structure has a large tooth area and low density, which can prevent mud packs. In addition, water eyes are designed on the blades at the bottom, and nozzles are added to make it have better ability to clean, cool and discharge cuttings, as shown in Figure 7.

The new composite drill is equipped with three cones on the side. The teeth of the cone are designed with inlaid cemented carbide and high-strength cemented carbide teeth. The tooth shape is divided into spherical and conical. The strength and abrasiveness of spherical teeth are more High, the top is a hemisphere, crushing and grinding high abrasive hard formation by crushing and impact. According to the cone angle, conical teeth can be divided into medium hard formations and hard formations. As shown in Figure 7, different tooth shapes can be selected according to the formation hardness in actual production to improve its practical applicability[2].

![Figure 7. Carbide tooth profile](image-url)
4. Conclusions and suggestions

1) The effect of the relative height of the composite structure of the composite drill bit on rock breaking: When the relative height of the PDC blade-roller in the composite drill bit increases, the weight of drilling shared by the cutting structure of the roller cone increases, which can more easily crush the rock and form an effective fracture pit. In order to give full play to its auxiliary rock breaking function, and at the same time will reduce the torque that the drill bit bears;

2) When the newly designed new composite drill bit works, the two-level cutting structure will form a stepped bottom after breaking the rock, which will produce an equivalent steering angle, which can effectively reduce the local head loss.

3) The design of the composite drill is a complex problem. At present, there is insufficient experimental research, and related experimental verification is required. The experiment and simulation are combined to further quantitatively analyze the rock breaking mechanism. It is recommended to further expand the field application conditions of the composite drill bit to provide a basis for later optimization.

References

[1] Gao Yuan. Kymera hybrid drill bit of Baker Hughes [J]. Oil Drilling Technology, 2012, 0(2):40.
[2] Chen Tinggen, Guan Zhichuan. Theory and technology of drilling engineering [M]. Dongying: The Press of the University of Petroleum, China, 2000:142-164.
[3] Gao Xiang. Research on rock breaking mechanism and design of composite drill [D]. Master thesis of Southwest Petroleum University, 2013, 5:1-23
[4] Hu Daliang, Yan Yancheng, Li Qunsheng, etc. Application of mixed bit in high-abrasive formation of Xujiahe Formation in Yuanba [J]. Drilling and mining technology, 2013, 36: 8-12.
[5] Dong Bo. Experimental study on rock breaking mechanism of PDC-roller hybrid bit [D]. Master Thesis of Southwest Petroleum University, 2013: 1-43.
[6] Yang Yao. Research and field application of directional well composite bit technology [D]. Master Thesis of Southwest Petroleum University, 2016.
[7] Ma De un. Working mechanics of roller cone bit [M]. second edition. Beijing: Petroleum Industry Press, 2009.