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Improvement and Application of Directional Reaming While Willing Bit in Tahe Oilfield

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Abstract: Unlike conventional sidetracking technology, the technology of reaming while directional drilling makes it possible for us to conduct directional drilling and reaming simultaneously using dual core bit, which simplifies the construction steps and can greatly shorten the drilling cycle and reduce drilling costs. With the increasing of the tasks of sidetrack horizontal well in the old wells of Tahe Oilfield, the technology of reaming while directional drilling has become an important means for sidetrack of old wells in Tahe Oilfield. However the substratum of Bachu formation has high content of gravel with large diameter and strong consolidation, which cause severe abrasion of dual core bit, short drill life and low ROP. With the problems in the substratum of Bachu Formation, Tahe Oilfield continuously improves dual core bit based on its effect of reaming while drilling, and breaks the national records of the maxim setting depth, inclination and continuous expansion length during the operations of well TH12124CH. This paper shows the improvements of dual core bit and its application effect both in well TH10233CH and well TH12124CH, and put forward a further scheme to improve the dual core bit for the substratum of Bachu Formation of Tahe Oilfield.

Keywords: Tahe Oilfield; Reaming While Drilling; Dual Core Bit; Bachu Formation.

1. Introduction

Due to the restrictions of wellbore structure and formation conditions, the sidetrack horizontal wells in the Ordovician reservoirs of Tahe Oilfield must drill through complex formations such as upper mudstone members, abnormal pressure members, or water layers, which are prone to complications like wellbore collapse, lost circulation, and kicks. To ensure the safety of the lower horizontal member construction, it is necessary to perform reaming operations to cement and seal the upper complex well members with expandable casing. The technology of reaming while directional drilling, using a dual core bit, allows for simultaneous directional drilling and reaming, simplifying the construction steps and reducing the drilling cycle and costs [1,2,3].

The well TH12115CH in Tahe Oilfield utilized the CK306B type reaming while drilling bit to achieve great reaming results, setting two national records: the deepest single operation with a 140mm expandable casing at 5965.86m and the maximum well inclination at 63.1° [4]. However, during the drilling process in the gravel-containing substratum of the Bachu Formation, this bit experienced loss of the guide block composite piece and severe abrasion of the blades, leading to a short service life and low rate of penetration (ROP). To extend the service life of the drill bit and improve the ROP in the gravel-containing substratum of the Bachu Formation, the guide block of the CK306B type drill bit was redesigned. This paper will introduce the improvement process of the CK306B type dual core bit and its enhanced versions, CK306BD and CK306BDKG dual core bits, in the drilling performance in the Bachu Formation substrata of wells TH10233CH and TH12124CH, and propose a further improvement plan for the drill bits in the gravel-containing substratum of the Bachu Formation in the 12th block of Tahe Oilfield.

2. Tahe Oilfield Well TH10233CH

2.1. Drill Bit Improvement Plan

The sidetrack point of well TH10233CH is at a depth of 5585m, located in the middle member of the Bachu Formation of the Lower Carboniferous system. The formation rocks are gray and grayish fine sandy mudstone and brownish-brown fine sandy mudstone interbedded with light gray fine sandstone, known as the lower mudstone member. The lower member of the Bachu Formation consists of brownish mudstone, grayish mudstone, and light gray gravelly fine-grained sandstone, gray fine sandstone, and grayish fine sandy mudstone in roughly equal thickness layers, known as the sand-mud interlayered member. The reaming while drilling operation successively encountered the Upper Devonian Donghetang, the Upper Ordovician Qrebake, and the Middle Yijianfang Formations.

Since the CK306B type reaming while drilling bit achieved commendable results in well TH12115CH, it was still used for drilling the mudstone formation layers in the middle and upper parts of the Bachu Formation in well TH10233CH. In response to the guide block composite piece falling off and severe blade wear of the CK306B bit during the drilling process in the high-gravel content substratum of the Bachu Formation in well TH12115CH, the CK306B bit was improved as shown in Figure 1: (1) The crown profile and tooth arrangement of the bit were modified to minimize the imbalance of cutting tooth forces during composite drilling, improving the working conditions of the cutting teeth of the guide block bit to prevent PDC loss and uneven wear due to overload; (2) The tooth arrangement of the guide block bit was optimized to set the main blade positions reasonably and strengthen the core part teeth arrangement; (3) Longitudinal backup teeth were arranged on some blades on the neighbor block bit to improve the service life of the guide block bit.

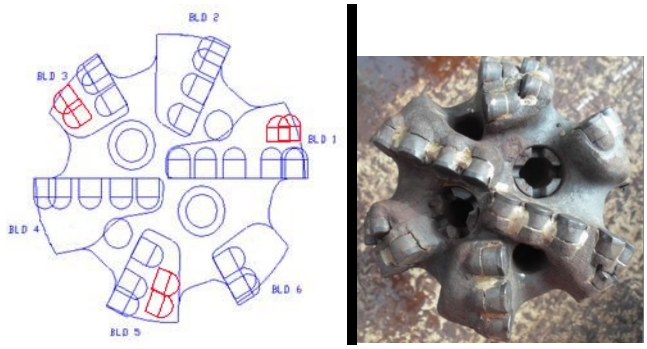


Figure 1. Guide Block Design of CK306BD Type Reaming While Drilling Bit

2.2. Application Results

In the drilling process through the gravel-containing substrata of the Bachu Formation of well TH10233CH in Tahe Oilfield, the CK306BD bit was used and achieved commendable results, with an improvement in bit life. The usage of the dual core reaming while drilling bit in well TH10233CH is shown in Table 1. Due to the addition of partial teeth to the guide block blades of the bit, compared to the CK306B type reaming while drilling bit used in well TH12115CH, the wear level of the neighboring block bit after extraction is lower, and both the build rate and wellbore enlargement rate meet the design requirements.

Table 1. Usage Effectiveness of Dual Core Reaming Bit in Well TH10233CH

NO.	Model	Borehole section (m)	excavation footage(m)	ROP(m/h)	drilling formation
1	CK306B	5583.33~5610.1	26.77	0.74	C_1b^2
1-1	CK306B	5610.1~5636.46	26.36	1.1	C_1b^2
2	CK306BD	5636.46~5645.87	9.41	1.13	C_1b^2
2-1	CK306BD	5645.87~5713	67.13	0.98	C_1b^2,C_1b^1
3	CK306BD	5713~5734.5	21.5	0.70	C_1b^1
1-2	CK306B	5734.5~5807	72.5	1.08	C_1b^1,D_3d
4	CK306BD	5807~5884	77	1.78	D_3d ,O_3q

As shown in Table 1, during the sidetracking process of well TH10233CH, a total of four dual core reaming bits were used, three of which were utilized in the Bachu Formation. The CK306B and CK306BD bits showed relatively ideal drilling performance. The first CK306B bit was used three times, achieving a total footage of 126.13 meters. The second CK306BD bit was used twice, achieving a total footage of 77.5 meters. During its second entry, in the lower member of the Bachu Formation (well depth of 5648.46 meters), it achieved a footage of 64.5 meters through gravelly fine sandstone, and after wear, the rate of penetration (ROP) significantly decreased, with an average mechanical ROP of only 0.98 m/h. The third CK306BD bit showed poor drilling performance, achieving only 21.5 meters footage in the lower member of the Bachu Formation, with a mechanical ROP of only 0.7 m/h. After pulling out of the hole, it was found that the gap between the bit and the drill pipe shaft reached 11mm, the guide block part of the bit was severely worn, and several teeth were broken off (as shown in Figure 2). This was due to the radial movement of the screw shaft and the lateral imbalance forces on the bit causing the cutting teeth to fail by fracturing. Since the Dongtang and Qrebake Formation layers do not contain gravel, the fourth CK306BD bit had a high mechanical ROP of 1.78 m/h, achieving 77 meters of footage with very low wear on the bit. The logging well diameter curve shows that the enlargement effect was good, and the expanded wellbore met the requirements, as shown in Figure 3.



Figure 2. Wear Condition of the Second and Third CK306BD Drill Bits in Well TH10233CH

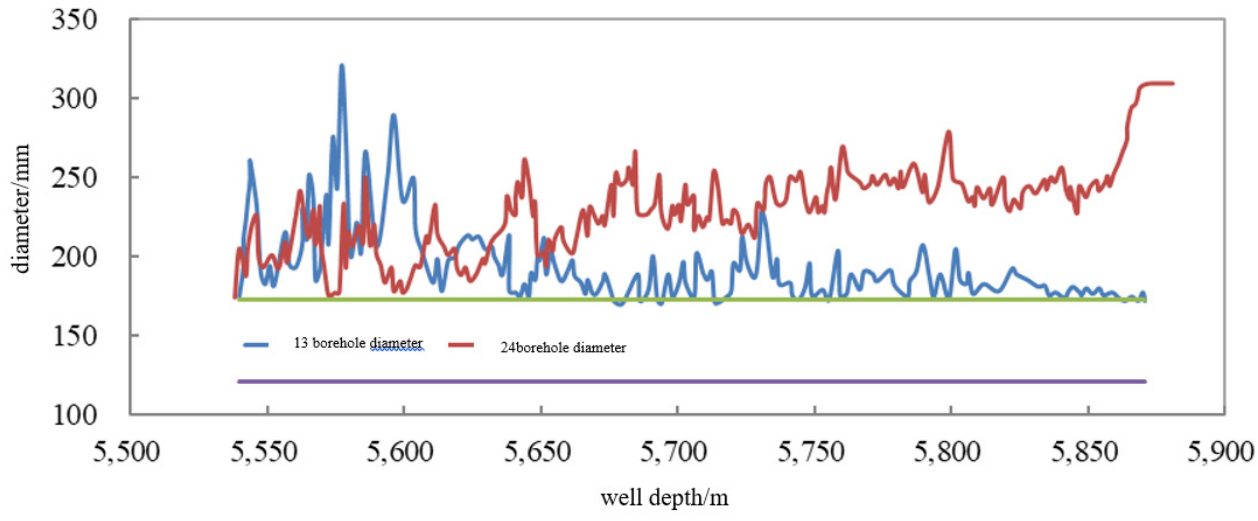


Figure 3. Wellbore Diameter Curve for the Reamed Members in Well TH10233CH

3. Tahe Oilfield Well TH12124CH

3.1. Drill Bit Improvement Plan

Well TH12124CH is the third sidetrack horizontal well with expandable casing completed successfully in Tahe Oilfield by the Drilling Engineering Technology Research Institute of China National Petroleum Corporation in collaboration with Huading Petroleum. The sidetrack kickoff point for well TH12124CH is at 5607m, sequentially drilling through the middle and lower members of the Karashayi Formation of the Lower Carboniferous system, the Bachu Formation, and the middle-lower Ordovician Yingshan Formation. The middle and lower members of the Bachu Formation have a high gravel content, large gravel size, strong consolidation, and the sandstone has a high quartz content which makes it highly abrasive. This well and TH12115CH are both located in the 12th block, sector 1, where the CK306B drill bit in well TH12115CH suffered severe guide block wear in the gravel-containing lower members of the Bachu Formation. Although the drilling performance with the CK306BD bit in well TH10233CH showed some improvement, significant bit wear still led to a decrease in mechanical rate of penetration (ROP). Therefore, given that well TH12124CH may encounter large members of gravel-containing strata, the dual core reaming approach used in well TH12124CH needs further improvement:

(1) The upper mudstone member of the Bachu Formation has good drillability, and the CK306B bit was effective in both wells TH12115CH and TH10233CH. Therefore, the six-blade guide block CK306B single-row tooth matrix body design continues to be used to improve the mechanical rate of penetration (ROP).

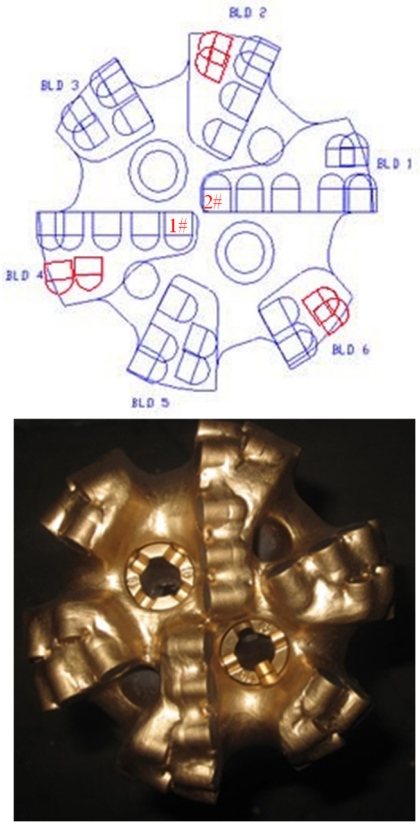


Figure 4. CK306BD Drill Bit with Double-Row Tooth Matrix Body Design

(2) The middle and lower members of the Bachu Formation consist of interbedded gravel sandstone and mudstone, where the gravel content is relatively less and the consolidation is relatively weaker. The six-blade guide block CK306BD matrix body design is still used. Considering the wear of the CK306BD bit used in well TH10233CH which caused a decrease in mechanical ROP, this bit is further improved by slightly increasing the back rake angle of the cutting teeth. The guide block's six blades all add a row of backup teeth to improve the ability to penetrate interlayers and resistance to abrasion, as shown in Figure 4.

(3) For the middle and lower members of the Bachu Formation consisting of interbedded gravel sandstone and mudstone, with high gravel content, strong consolidation, and high quartz content in sandstone contributing to strong abrasiveness, the six-blade guide block CK306BDKG matrix body design is adopted. Not only does this drill bit's guide block add a row of backup teeth to improve the ability to penetrate interlayers and resistance to abrasion, but also, in response to the rapid wear rate of the guide block segment, the guide block blades are equipped with embedded secondary teeth technology. As shown in Figure 5, when the primary cutting teeth are completely worn or fractured, the secondary teeth can take over the rock-breaking work. The embedded secondary teeth technology can significantly increase the lifespan of the PDC bit in difficult-to-drill formations [5].

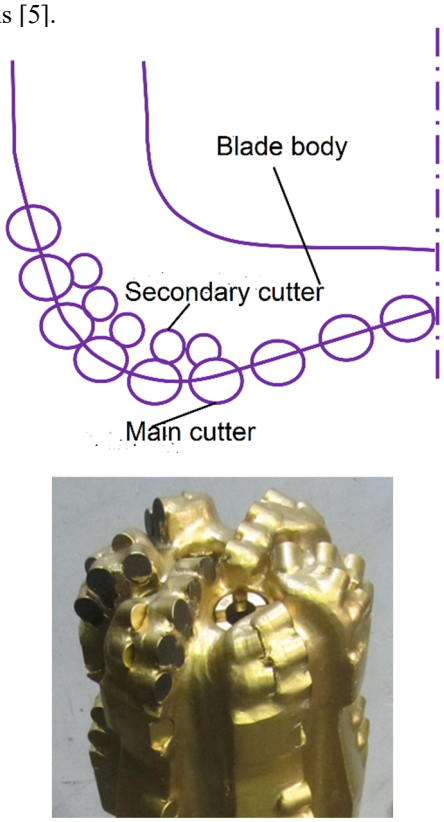


Figure 5. Embedded Secondary Teeth Technology and CK306BDKG Drill Bit

3.2. Application Results

With the improved dual core reaming bits, the reaming while drilling operation in Tahe Oilfield Well TH12124CH met the requirements. The expandable casing was set to a length of 526.88 m, at a well depth of 6065 m, with a maximum well inclination of 65.8°, setting new national records for setting depth, well inclination, and continuous expansion length [6]. The usage and results of the dual core reaming bits in this well are shown in Table 2:

Table 2. Usage Effectiveness of Dual Core Reaming Bits in Well TH12124CH

NO.	Model	Borehole section(m)	excavation footage(m)	ROP(m/h)	drilling formation
1	CK306B	5650~5827	177	1.20	C_1kl^l C_1b^3 C_1b^2 C_1b^1
2	CK306BD	5827~5839	12	1.33	C_1b^1
3	CK306BDKG	5839~5909	70	1.32	C_1b^1
4	CK306BDKG	5909~5946	37	1.39	C_1b^1
5	CK306B	5946~6003	57	1.29	C_1b^1
6	CK306BDKG	6003~6066	63	1.69	C_1b^1

Due to drill string failure, the improved CK306BD bit only made a 12m penetration in the lower member of the Bachu Formation, but the mechanical rate of penetration (ROP) reached 1.33 m/h, while the second CK306BD bit in Well TH10233CH only achieved an ROP of 0.98 m/h. In the gravel-containing lower member of the Bachu Formation, the third CK306BDKG bit not only achieved 70m of footage but also had a high ROP of 1.32 m/h, compared to the highest ROP of 1.13 m/h for the CK306BD bit in Well TH10233CH. This third bit drilled through brownish mudstone, light grey fine-grained quartz sandstone, and light grey gravelly fine-grained quartz sandstone with 10% gravel for 5m, and light grey gravelly fine-grained quartz sandstone with 30% gravel for 29m, showing a noticeable slowdown in drilling speed. After being pulled out, the guide block teeth of the bit were almost completely worn into a groove, nearly losing all rock-breaking capabilities. The fourth CK306BDKG bit drilled through formations with 30-40% gravel content; although it only achieved 37m of penetration, the average mechanical ROP was as high as 1.39 m/h. After extraction, the guide block core teeth were completely worn and fractured, forming a groove. The sixth CK306BDKG bit encountered formations with up to 65% gravel content but still achieved a long footage and the highest mechanical ROP of 1.69 m/h, while the bit showed lower wear levels, with the guide block's 1# and 2# teeth severely worn and three other teeth normally worn, the rest of the cutting teeth remained intact, as shown in Figure 6.



Figure 6. Wear Condition of the Third, Fourth, and Sixth CK306BDKG Drill Bits in Well TH12124CH

Comparing the third and fourth CK306BDKG drill bits, it is evident that the core teeth of the bits are prone to fracturing and forming a groove. Relative to the highly abrasive gravel in the lower members of the Bachu Formation, the improved CK306BDKG drill bits still lack sufficient abrasion resistance. Although the drilling performance of the third, fourth, and sixth CK306BDKG bits in the gravel-containing lower members of the Bachu Formation varied significantly, compared to the earlier CK306BD bits, the CK306BDKG bits achieved a substantial increase in mechanical rate of penetration (ROP) and footage. Overall, six dual-core bits were used in this well, and the CK306B, the improved CK306BD, and CK306BDKG bits all showed relatively ideal drilling performance in this well.

Well TH12124CH, following well TH12115CH, is the second directional reaming while drilling well located in block 12, sector 1 of Tahe Oilfield, and they are closely located to each other. The bit usage in both wells is shown in Table 3:

It can be seen from Table 3 that the directional reaming while drilling member of well TH12124CH is longer than that of well TH12115CH by 173.86m, and the gravel layer is also longer by 23.14m. Despite the significantly increased difficulty of drilling, the average mechanical ROP for the entire member increased to 1.31m/h. If it were not for the premature failure of the screw shaft of the second CK306BD bit leading to less footage, perhaps only five dual-core bits would have been required to complete the entire member.

Table 3. Comparison of Bit Usage Effectiveness between Wells TH12124CH and TH12115CH

Well NO.	TH12124CH	TH12115CH
Directional reaming length (m)	416	242.14
Number of bits used (Pcs)	6	4
Footage per bit(m)	69.3	60.54
Average penetration rate(m/min)	1.31	1.14
Gravel length(m)	121	97.86

4. Conclusion and Recommendations

Using the CK306B type directional reaming while drilling bits and related improved versions, CK306BD and CK306BDKG, both TH10233CH and TH12124CH wells in Tahe Oilfield have seen improvements in bit footage and bit life within the Bachu Formation strata. However, due to the high gravel content, strong consolidation, and abrasive nature of the rocks in the large gravel-containing members of the lower Bachu Formation, the CK306BDKG bits with embedded secondary teeth technology still suffer from severe

wear. Further improvements to the CK306BDKG type dual core bits are recommended:

(1) Considering the severe wear encountered by the third bit in the gravel-containing strata of the Bachu Formation in well TH12124CH, leading to a decrease in mechanical drilling speed, it is recommended to add natural diamonds to the core part of the CK306BDKG bit.

(2) Given that the guide block core teeth of the fourth CK306BDKG bit in well TH12124CH fractured prematurely and formed a groove, it is recommended to increase the tooth density in the core area. As shown in Figure 4, place two cutting teeth behind the 1# and 2# teeth respectively, so that when these 1# and 2# teeth are worn or broken, the teeth positioned behind can continue the rock-breaking work, thereby increasing the lifespan of the drill bit.

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