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Truth-Preserving Coring Tool for Broken and Soft Mineral Stratum

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Abstract

It is very important for evaluating mineral resources to get representative original rock and mineral core sample accurately and reliably, however, it is difficult to get high-quality core samples which were representative with existing core drill tool in soft and broken mineral stratum. This paper introduces a truth-preserving coring tool which used for improving the quality of coring in soft and broken mineral stratum, and the structure and work principle of coring tool were elaborated. Meanwhile, we have analyzed and calculated coring movement and force of the tool. Finally, there is an effect of the field test which was introduced briefly. Study indicates: the new truth-preserving coring tool owned many advantages that were innovative design ideas, simple structure, easy operation, and can improve core quality in soft and broken mineral stratum significantly.

Key words: Soft and broken stratum, coring tool, work principle, core effect;

1. Introduction

The quality of the coring during the drill is directly affected with judging of geological structure, assessing the mineral resources, and submitting the accuracy and reliability of mineral reserve. At last, it will affect the rationality of mining and designing ore mine. Therefore, in the process of the drilling, we did not only improve the drill efficiency, but also more importantly, we obtained the original core samples [1] [2].

It is not difficult to get the core samples which is meet the requirement of the quality for hard and

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complete rock and mineral layer. But, it is very difficult to get rock and mineral core samples which is representative by using conventional core drill, especially in complex stratums which develops joints, is soft, is broken, fears wash off, fears of dissolution and fears of contamination. Even, we can not get the rock and mineral core at all from some complex stratums. To improve the rate of coring and the quality from soft and broken rock and mineral core, being combination with the scientific drilling project in WenChuan, the project team developed a new dual tube forced truth-preserving coring tool [3][4].

2. The structure and work principle of truth-preserving coring tool

The traditional coring tools used snap rings to snap the core. However, because of the limited scope of the shrinking diameter of the snap ring, it is available in the rock and mineral stratums which were complete, medium hard or hard. But it is very poor for the core quality and effect in the soft and broken stratums.

The structure of truth-preserving dual tube forced coring tool that was designed by the project team is shown in figure 1: The core drill includes the inner tube assembly, the outer tube assembly and the steel ball 22. The inner tube assembly mainly includes: slug valve 2, elastic clip holder 3, elastic clip

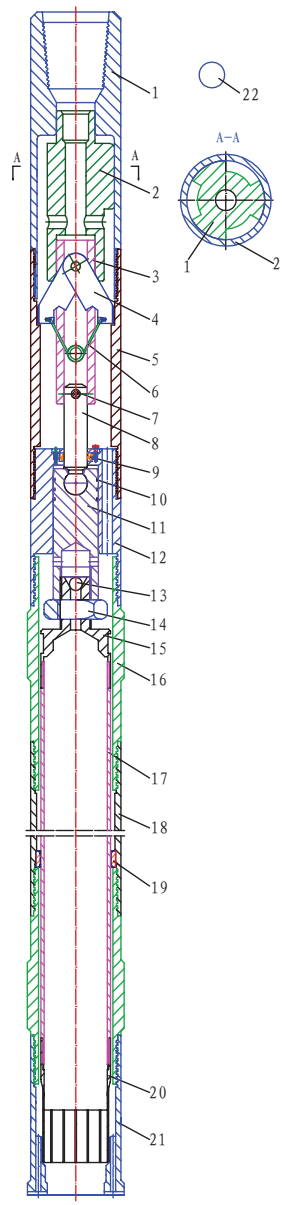

Figure. 1 the structure of truth-preserving sampler

1- drill rod conjunction，2- slug valve，3- elastic clip holder，4- elastic clip plier，5- elastic clip tube，6- cylindrical helical torsion spring，7- pin shaft，8- connecting rod，9-Y-style airproof ring，10-O-style airproof ring，11- core column，12- perforated conjunction，13- steel ball，14- adjusting screw nut，15- adjusting adapter，16- reamer，17- core tube，18- outer tube，19- centralizer-ring，20- core claw，21- face discharge bit，22- steel ball

plier 4, cylindrical helical torsion spring 6, pin shaft 7, connecting rod 8, core column 11, steel ball 13, adjusting screw nut 14, adjusting adapter 15, core tube 17and core claw 20.The outer tube assembly mainly includes: drill rod conjunction 1, elastic clip tube 5, perforated conjunction 12, reamer 16, outer tube 18 and face discharge bit 21.

The structure of the slug valve 2 is shown as figure 2. It is consisted of three sections, both ends are cylindrical, and the middle section is spline model. There are holes in the middle of the slug valve, and no screw thread in the slug valve. It covered over the elastic clip holder 3 directly. Meanwhile it is easy slide fit with the inner of the drill rod conjunction 1.The elastic clip plier 4 fixed on the elastic clip holder 3 by the pin shaft. The cylindrical helical torsion spring 6 made the elastic clip plier 4 keep open. The elastic clip holder 3 linked with the connecting rod 8 by the pin shaft 7. The connecting rod 8 linked with the core column 11 by the spherical hinge.The core column 11 linked with the adjusting adapter 15 by the screw thread.

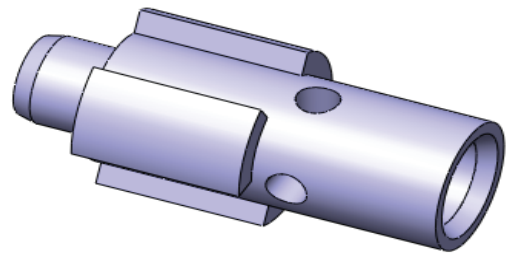

Figure. 2 the 3-D view of the slug valve

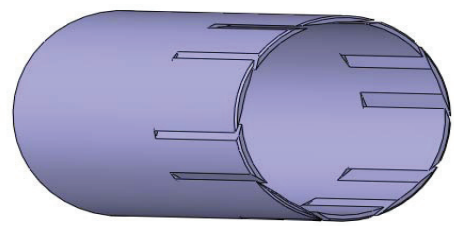

Figure. 3 the 3-D view of the core claw

The length of the whole inner tube assembly can be regulated slightly by changing the length of the adjusting adapter 15 which is screwed in the core column 11. The adjusting adapter 15 linked with the core tube 17 by the screw thread. The core tube 17 linked with the core claw 20 by the screw thread. The core claw 20 is an important accessory to the whole coring tool. The structure is shown as the figure 3.It is made by a thin-walled cylinder. One end is the connecting screw thread. The other end is ten equal- width slits which are made by wire-electrode cutting. Their length is 20mm, and their width is 0.3~0.8mm.The cylinder is divided into 10 claws by the ten slits. When we carried on the wire-electrode cutting, the tangent line did not pass throw the center. First, the inside diameter of the cylinder were divided into 10 equal parts, and cylinder divided into 10 claws by the 5 jointcuttings, the ten claws are the 5 inner claws and the 5 outer claws.

Each part of the outer tube assembly connected by screw threads. The elastic clip tube 5 has a step. The perforated conjunction 12 has six passing water holes. There is step and face discharge holes in the face discharge bit 21. The centralizer-ring 19 lied in between the inner tube assembly and the outer tube assembly. The whole inner tube assembly hung on the step of the elastic clip tube 5 with the elastic clip plier 4.

The truth-preserving coring tool worked as follows: First, we connected the drill as shown in figure 1, and make the inner tube assembly hang on the step of the elastic clip tube 5 by the elastic clip plier 4. Meanwhile, adjusting the length of the inner tube assembly by adjusting the part 15 and part 14 made the distance which the core claw is away from the step of the face discharge bit of 2~4mm. Turn on the ground mud pump and the rig to make normal drilling. The mud passed the drill string inner chamber, then in turn, flowed into the drill rod adapter 1, and flowed into the inner chamber of the elastic clip tube 5 through the water holes in the slug valve 2, and flowed into the annular gap between the core tube 17 and the outer tube 18 through the water holes in the perforated conjunction 12, till flowed into the bottom of the bit. Then the mud flowed back to the ground surface through the annular gap between the outer tub

of the core drill and the drilling hole. Meanwhile the rock core entered into the core tube 17 gradually, and forced the mud in the core tube 17 washing off the steel ball 13 and flowed into the annular gap between the inner tube and the outer tube. Due to using the face discharge bit, avoid the mud wash directly the rock and mineral core sample entered, thus it will be good to keep original state for the core samples.

When the core tube is filled with the core, turn off the rig and the mud pump, turn on the hose connector which is at the outlet of the mud pump, put the steel ball 22 in the hose and connect the hose connector, turn off the mud pump after turning on shortly. Under hydraulic action, the steel ball 22 move to the slug valve 2 through inner chamber of drill string and block the central channel of the slug valve 2. After being forced the hydraulic action of the slug valve 2, the elastic clip plier 4 was forced to gather up and departed away from the step of the elastic clip tube 5. Comparing with the outer tube assembly, the whole inner tube assembly moved downward. The core claw 20 was forced to gather up when it met the step of the face discharge bit 21. The scope of the diameter of which the core claw can gather up was wide. After gathering up, the core claw was in the state of closed. Thus the core claw can hold the soft and broken rock and mineral core. With the analyzing the structure and the work principle of the core drill, the truth-preserving coring tool can not only keep the rock and mineral core original , but also can it obtain high core rate in the soft and broken stratum.

3. Core action and stress analysis

It is known by the structure and the work principle of the truth-preserving coring tool, to make sure that the drill tool can get the rock and mineral core, the key is that the core claw can gather up after the steel ball being put. Then, we will do some calculating and analyzing about the movement and the mechanical after the ball being put.

The movement after the steel ball being put can be divided into two stages.

The first stage: the elastic clip plier separated from the suspension step.

The steel ball blocked the central channel of the slug valve 2 after being put. This moment the pump pressure continue rise. The force that the slug valve 2 acted on the elastic clip plier 4 will enhance until the elastic clip plier 4 did not separate from the step of the elastic clip tube 5 after the plier gathering up. Now we take the φ140 core drill tool for an example to calculate whether the elastic clip plier can gather up. The forced figure of the elastic clip plier is shown as the figure 4.

The force that the elastic clip plier is acted included:

G_1——pin shaft force, the value was the half of the inner tube assembly, designed value is 200N.

F——the stress that the slug valve 2 acted on the elastic clip plier, the value is calculated by the following formula.

$$F\cos 60° = \frac{P}{2} = \frac{pA}{2} \tag{1}$$

In the formula: P is representative of the stress that the mud acted on the slug valve 2 after the ball being put (N).

p is representative of the stress of the mud(MPa).

A is representative of the Cross-sectional area of the upper part of the slug valve 2, the designed value is $2.826\times10^{-3}m^2$.

After arranging:

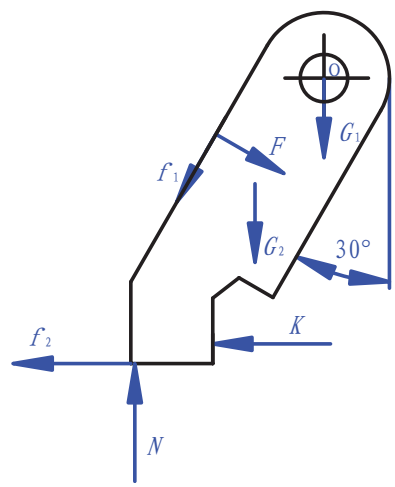

Figure. 4 the force diagram of the elastic clip plier

$$F=2.826\times10^{-3}p \tag{2}$$

f_1——friction that the slug valve 2 acted on the elastic clip plier, the value can be calculated by the following formula.

$$f_1=\mu F=0.15F \tag{3}$$

In the formula: μ is coefficient of friction of the steel 45. The value is 0.15.

G_2——weight of the elastic clip plier, designed value was 10N.

K——force that the cylindrical helical torsion spring acted on the elastic clip plier, designed value was 10N.

N—— force that the step acted on the elastic clip plier. The value can be calculated by the following formula.

$$N=G_1+F\cos 60^\circ+G_2=210+0.5F \tag{4}$$

F_2——friction force that the step acted on the elastic clip plier. The value can be calculated by the following formula.

$$F_2=\mu N=0.15(210+0.5F)=31.5+0.075F \tag{5}$$

In the formula: μ is coefficient of friction of the steel 45. The value is 0.15.

The force that acted on the elastic clip plier all calculated the torque to the point "O". If the rotation is counter-clockwise the value is positive. If the rotation is clockwise direction the value is negative. When the sum torque is greater than zero, the elastic clip plier gathered up.

It is known by the above calculating and designing to that all acting force and the torque to the point "O" were shown as the chart 1.

Table 1: The force and the torque on the elastic clip plier

Force code	G_1	F	f_1	G_2	K	N	f_2
Force value	200N	$2.826\times10^{-3}p$	$0.15F$	10N	10N	$210+0.5F$	$31.5+0.075F$
Torque to "O"	0	0.0325m	0.02m	0.02m	0.08m	0.056m	0.086m

The torque equation of all force to the point "O":

$$\begin{aligned}\sum M&=F\times0.032+f_1\times0.02+G_2\times0.02-K\times0.08-N\times0.056-f_2\times0.086\\&=F\times0.0325+0.15F\times0.02+10\times0.02-10\times0.08-(210+0.5F)\times0.056-(31.5+0.075F)\times0.086\\&=1.05\times10^{-3}F-15.069\\&=1.05\times10^{-3}\times2.826\times10^{-3}p-15.069\end{aligned}$$

It is derived by the sum torque equation $\sum M=0$ to that the minimum value of the mud pressure is pmin=5MPa. That was to say when the mud pressure (bump pressure) was grater than 5MPa, the elastic clip plier will gather up.

The second stage: the core claw gathered up. The elastic clip plier gathered up causes the inner tube assembly moved down relatively to the outer tube assembly. And the inner tub assembly was in the state of the mud pressure and the own weight. Meanwhile it overcame the friction drag of the Y-style airproof ring 9 and the O-style airproof ring 10. The core claw was forced to gather up and stuck and got the rock and mineral core.

The laboratory experiments show that only about 15~20KN vertical pressure can achieve the purpose that the core claw was in the state of gathering up. The value of the friction drag is very small and is assumed to be 1KN. The sum of the mud pressure and the inner tube assembly weight is far greater than the sum of the friction drag and the core claw gathering up force. Thus, when the elastic clip plier

gathered up, then the inner tube assembly will move downward relative to the outer tube assembly, and force the core claw gathering up, at last make the action of sticking the core come true.

4. The preliminary field experiment of the fidelity core drill

To test and verify the actual coring results of truth-preserving tool, we did some preliminary experiments in soft and broken stratum.

The experiment in the soft stratum

To test and verify the coring results of the truth-preserving tool in soft stratum, the project team took the tool do experiments in an exploratory hole in the field. The drilling stratum was soft clay layer. The figure 5 was the core photo of the φ89 truth-preserving core drill. The core rate was 100%, core result was perfect.

Figure. 5 the core photo in the soft stratum

The experiment in broken stratum

November 2010, the project team did some initial field experiments to the core drill tool in henan luanchuan gold mine ZK121 drilling hole. The test-hole depth was 180m, and the diameter was φ89, and the drilling rig was the spindle-type core drill, the pump was BW-320.

To make sure the reliability of the core drill in the bottom of the hole, firstly we do the experiment of the drill to the sticking core action. At first connect the drill with the swivel. Open the bump after the steel ball being put down. The pump pressure raise quickly to 6MPa, this time the condition of the core claw spring gathering up was good and is shown as the figure 6.

Figure. 6 the core claw gathering up photo in the ground

As the stratum that we drilled in the experiment was complete, in order to simulate the broken stratum we put some small gravel into the hole, and we did not drill the complete bedrock but put the core drill tool into the hole for cleaning bottom of the hole. And when the bit contacted the bedrock, close the pump. Then change to 3rd gear 230 L / min. open the pump. Immediately the pump pressure rise to 6MPa. Close the pump and pull out of hole. The gravels were removed by and large.

5. Conclusions

The core sample is the most perceptual and accurate information to evaluating the reserves and the geological structure of the mineral resources. It is very significant to get the representative core samples with adopting the reasonable drilling technology. But it is not very good for the core drill in hand to core in the soft and broken stratum.

The truth-preserving coring tool of the project team developed has many advantages. Such as the design idea is new and original, the structure is simple, it can significantly improve the core quality in soft and broken mineral stratum, and it can provide the reliable geological information on the physical to geologist.

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