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Development of rotary dislocation pressure holding sampling device in coal mine

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ABSTRACT: *The content of coalbed methane is an important parameter that characterizes the characteristics of coal seams, and is of great significance for the exploration and development of coalbed methane resources and the prevention of coal mine gas outbursts. The traditional coalbed methane sampling method requires stopping drilling, which not only affects production progress but also leads to the loss of coalbed methane samples. In order to solve the above problems, a closed sampling device for underground coal seams was developed by combining existing coal seam sampling devices with the geological characteristics of soft coal seams in China.This device can directly take samples during the drilling process, avoiding the limitation of traditional sampling methods that require stopping drilling. In addition, the device also has the advantages of sufficient sampling volume and fast sampling speed, which can reduce the loss of coalbed methane samples and improve the accuracy of coalbed methane content measurement underground in coal mines.*
KEY WORDS: *Coal Mine Underground, Closed Sampling, Coal Bed Methane Content, Accurate Measurement.*

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I. INTRODUCTION

Research background

Energy is the key factor to promote the rapid growth of social economy, as China's main energy source，coal has always played a central role in energy production and consumption[1]. Coal plays a crucial role in China's energy mix, and while its dominance is challenged by other energy sources， it will remain China's main source of energy for the foreseeable future[2]. With the development of clean energy technology and the guidance of national policies, the proportion of coal use may decline, but its role as a basic energy source will not change easily[3][4]. In addition to coal resources, coalbed methane, as a valuable fossil energy, is also rich in reserves in China. According to statistics, the amount of coalbed methane resources buried within 2000 meters is about 36.8 trillion cubic meters[5]. If we can effectively develop and utilize these resources, we can not only optimize the energy structure of our country, but also help to further ensure the energy security of the country. The accurate characterization of gas content is very important for the prevention and control of coal mine gas disasters and the development of coalbed gas resources[6][7]. However, the traditional open gas exploration technology can only measure the theoretical value which is lower than the actual gas content in the reservoir, which affects the scientific nature of the gas control scheme design to a great extent[8].

Research significance

Coal mine drilling equipment plays a vital role in ensuring the safe and efficient production of the mine. Through underground geological exploration, hydrogeological exploration, gas drainage, water exploration, coal exploration and other work, drilling equipment can obtain important information such as mine geological structure, hydrogeology, gas and so on. it provides a scientific basis for mine safety management and production decision-making. The equipment can effectively ensure the safety of mine production[9]. Through the exploration of underground geological structure and hydrogeology, the hidden dangers of geological disasters in the mine can be found and timely measures can be taken to avoid accidents. This type of equipment can also improve the production efficiency of the mine. Drilling equipment can carry out efficient prospecting, exploration and extraction, which provides accurate geological data and technical support for mine mining, thus improving the mining efficiency and resource utilization rate of the mine[10].

The technology of accurate measurement of coal seam gas content by fixed point closed sampling is of great significance for preventing and predicting the gas outburst phenomenon, improving the exploration and development of coal bed gas resources and the control level of coal mine gas disaster[11]. It is of great scientific significance and engineering application value to develop a method with short sampling time and accurate positioning, which can realize simultaneous drilling, sampling and monitoring, fixed point pressure and closed sampling of coal seam, and accurately measure the gas content of coal seam, which can prevent and predict the gas outburst phenomenon, improve the exploration and development of coal seam gas resources and control the level of coal mine gas disaster.

Scholars at home and abroad are constantly improving the fixed-point closed sampling and detection technology. Ren Haoyang et al proposed a low-temperature freezing core-taking method, which still has the problem of core exposure and cannot completely maintain in-situ gas content[12]. According to the characteristics of coal seam, Chongqing Research Institute of China Coal Science and Industry Group has developed a set of drilling and injection mining technology and special equipment[13][14]. The equipment can efficiently obtain undisturbed coal samples from deep boreholes. However, in deep drilling, the borehole injection method may face problems such as reduced suction rate and pipe blockage[15].

II.SCHEME DESIGN OF SAMPLING TECHNOLOGY

Design idea

The first step is to determine the overall structural size. The size of the whole structure actually restricts the selection of mechanical structures to achieve the corresponding functions. Because the device needs to carry out the pre-sampling experiment on the simulation testing machine, the simulation testing machine simulates a part of the underground situation of the coal mine, by carrying four simulated coal samples to test whether the designed coal sample sampling device can achieve the function of sampling.

The second step is to determine the function of the device. The basic functional requirements of the sampling device are as follows:

1. The device needs to meet the structural requirements of the basic drill pipe.
2. the device needs to have the ability of sampling while drilling.
3. The device needs to be able to take a certain amount of coal samples and keep the coal samples sealed.

The technical principle of the device is shown in the **Figure 1 Schematic diagram of the structure and function of the preliminary underground coal seam sampling device**Figure 1.

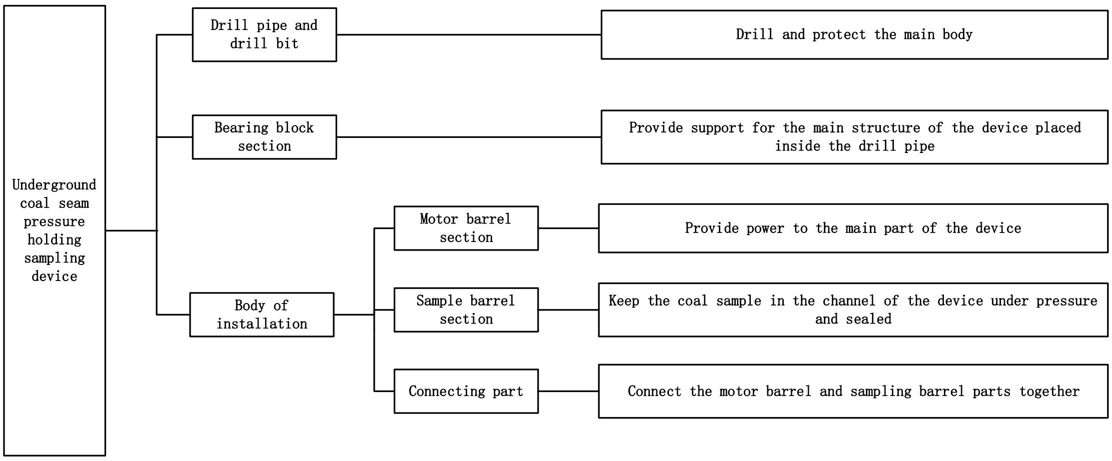


Figure 1 Schematic diagram of the structure and function of the preliminary underground coal seam sampling device

The structure of the underground coal seam sealing sampling device is shown in Figure 2. Compared to other existing pressure-retaining devices, this device has a higher degree of feasibility and stability, and subsequent experiments were based on this device.

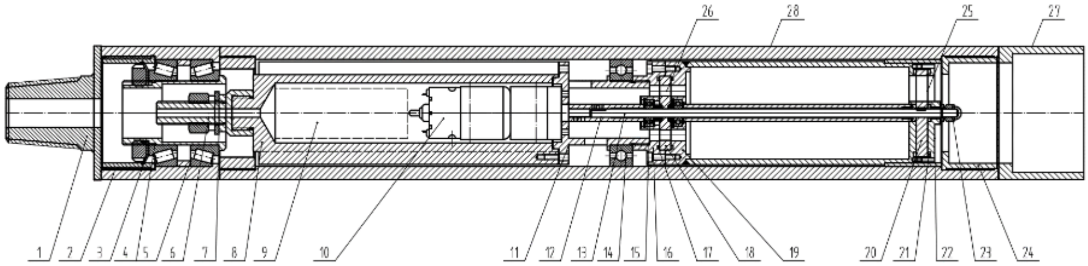


Figure 2 Mechanical design drawing of closed coring device

1 tail drill pipe joint, 2 ventilated bearing housing, 3 front nut retaining ring, 4 bearing bracket, 5 tapered roller bearing group, 6 hollow threading shaft, 7 support retaining ring, 8 motor barrel, 9 battery, 10 DC motor, 11 motor barrel cover, 12 sleeve coupling, 13 central shaft, 14 support bearing, 15 dustproof deep groove ball bearing, 16 tail cover plate, 17 tail sealing ring, 18 tail revolving door, 19 sampling barrel, 20 head revolving door, 21 head sealing ring, 22 head cover plate, 23 rear nut retaining ring, 24 drill bit mounts, 25 head sampling ports, 26 tail sampling ports,27 head drill pipe joints, 28 rib drill pipes

The structure of the tail bearing group is shown in Figure 3， which consists of a tapered roller bearing group, a locking nut and a ventilation bearing seat. During assembly， the bearing bracket is fixed through the washer and nut, the bearing group is placed on the bearing bracket jacket， and the locking nut is fixed. Protect the internal structure from rotation while drilling the rib pipe and ensure the stability of the sample barrel.

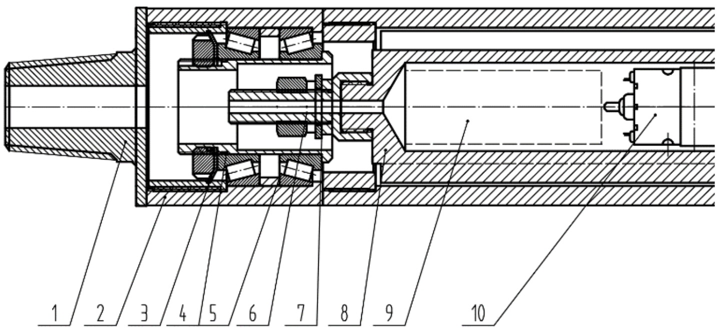


Figure 3 Tail bearing group structure

1 tail drill pipe joint, 2 ventilated bearing housing, 3 front nut retaining ring, 4 bearing bracket, 5tapered roller bearing group, 6 hollow threading shaft, 7 support retaining ring, 8 motor barrel, 9 battery, 10 DC motor

The motor barrel part includes the motor barrel body, the battery and DC motor mounted in the motor barrel body, and the internal adjustment circuit, and the sensor related circuit. When assembling the motor barrel part, the battery and the DC motor are first loaded into the barrel body of the motor barrel, and then the motor barrel cover plate is covered on the sampling barrel, so that a sealed space is formed inside the motor barrel, and the charging cable is pierced through the tail opening. The motor barrel cover plate is threaded with the tail cover plate, and the head is connected with the connecting mechanism through the bolt thread. The motor barrel part will be explosion-proof treatment during the installation process to prevent the sampling structure from working inside the coal seam drilling, and the gas combustion caused by the battery discharge in the coal seam will destroy the sampling device, so as to ensure the safety of the sampling process. The battery in the motor bucket needs to provide power support to the DC motor, which is also housed in the motor bucket, and the sensors required by the device. The DC motor in the motor bucket is the only power unit inside the structure, providing power support for the entire sampling process. The rotating power of the rotating doors at both sides of the sampling bucket is derived from the torque generated by the motor in the motor bucket.

The connecting assembly is shown in Figure 4 and includes a ventilation support rod, a connecting sleeve and a corner contact ball bearing. During assembly, the bearing is covered outside the ventilation support rod, and the connecting shaft sleeve is connected with the motor shaft and the central shaft of the sampling barrel through the pin. The tail of the ventilation support rod is also the head cover plate of the motor barrel, and the head is threaded with the tail cover plate of the sampling barrel. This part connects the two main structures of the motor barrel and the sampling barrel, which does not affect the ventilation performance of the structure and can improve the stability of the structure.

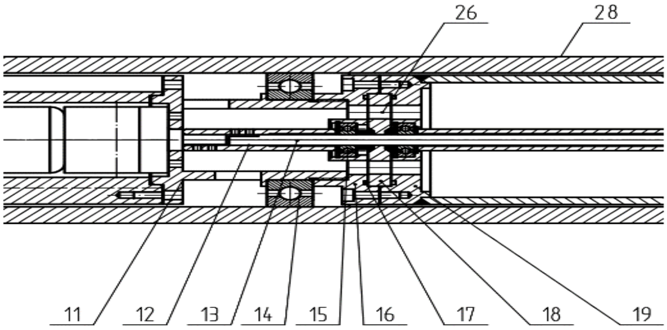


Figure 4 Connect components

11 motor barrel cover, 12 sleeve coupling, 13 central shaft, 14 support bearing, 15 dustproof deep groove ball bearing, 16 tail cover plate, 17 tail sealing ring, 18 tail revolving door, 19 sampling barrel, 25 head sampling ports, 26 tail sampling ports, 28 rib drill pipes

The sampling barrel part includes the sampling barrel tail cover plate, the tail revolving door and the center shaft welding assembly, the sampling barrel body, the copper sleeve, the center shaft, the sampling barrel head revolving door, the O-seal ring, the bearing assembly, the lock nut assembly, and the sampling barrel head cover plate. When assembling the sample barrel, put the deep groove ball bearing into the tail of the sample barrel and insert the O-ring seal, then insert the welding part of the tail revolving door and the center shaft into the hollow shaft of the sample barrel as a whole, and then assemble a deep groove ball bearing matching the tail of the sample barrel into the cover plate of the sample barrel tail. At the same time, an O-seal ring is also installed in the groove of the side of the cover plate in contact with the revolving door, and the tail cover plate of the sampling barrel is threaded to the sampling barrel by bolts, and the tail revolving door is tightly inserted between the sampling barrel and the tail cover plate; Insert a copper sleeve and O-type sealing ring into the head of the sampling barrel, insert a flat key into the exposed central shaft, set the head rotating door outside the key, and then bolt the head cover plate to the sampling barrel, and plug the head rotating door tightly between the sampling barrel and the head cover plate; Then cover the threaded part of the center shaft exposed outside the head cover with a cap nut and a gasket, and install a copper sleeve on the outside of the sampling barrel. This part is divided into the most important part of the whole structure, which is also the sampling bin, where the coal samples are stored, and the ventilation state and sealing state of the sampling barrel are changed by turning different angles through the revolving door. The physical objects of each part are shown in the Figure 5.

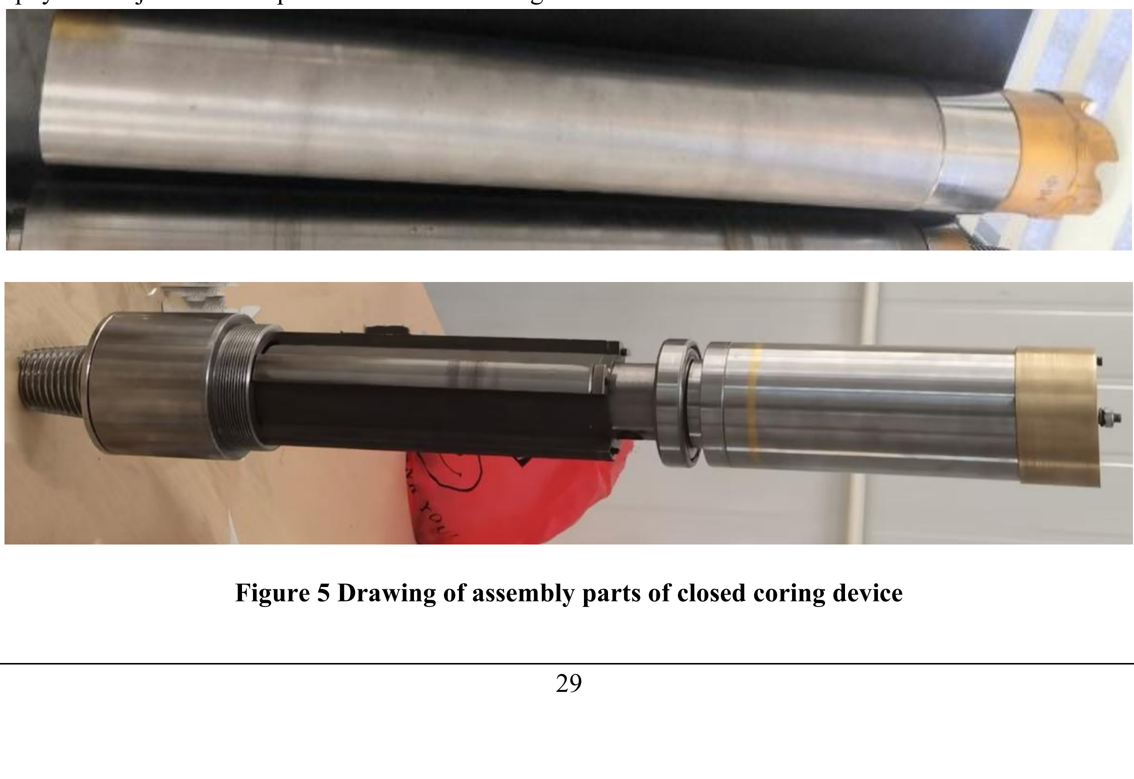
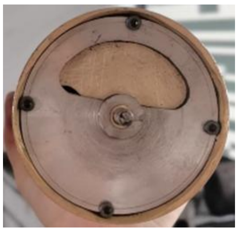


Figure 5 Drawing of assembly parts of closed coring device

Working principle

The DC motor is powered by the built-in battery, and the rotating doors on both sides of the head and tail of the sampling cylinder are opened and closed to realize the change of the ventilation state and sealing state of the sampling cylinder. The working state of the sampling cylinder at different periods is shown in Table **1**. The rotating doors on both sides need to be rotated at corresponding angles under three working states. The two doors that set the initial assembly position are at 0° position, the observation Angle is from the tail of the sampling cylinder to the head, and the positive direction of rotation is turned by counterclockwise rotation. In the initial position, the center of the single notch of the rotating door at the tail of the sampling cylinder is 90° and 135°, respectively, and the semicircular opening Angle of the sampling cylinder at the head is 45° to 225°. When starting sampling, control motor rotation 45°, so that the tail revolving door is closed, the head revolving door is fully open; When the sampling is finished, the control motor turns 180° again, with a difference of 225° from the initial Angle, so that the turnstiles of the two parts are sealed. The sealing of the revolving door is ensured by a labyrinth sealed revolving door machined from a self-lubricating graphite copper material with a rubber O-ring seal buried inside the revolving door card slot. Through the bearing group and copper sleeve, the whole structure can keep steady when the drill pipe rotates, and ensure the stability of the internal structure. The long distance and remote monitoring of coalbed methane is realized through the sensor in the sampling barrel and the transmission line attached to the outside of the drill pipe.

Table 1 Work status for different time periods

	Before sampling	Sampling	After sampling
Sampling tube tail			
Sampling tube head			

Technical characteristics

The long distance spot sampling of coal samples can be achieved, and the drilling sampling can be carried out simultaneously without replacing the drill rod of the drill bit, which greatly reduces the sampling time. When the sampling is completed, the drill pipe can be left in the drill hole, and the sampling barrel can be put out separately. When the next sampling is done, the new sampling barrel can be lowered into the drill pipe, so as to realize multiple collection and detection of coal samples at different depths, reducing the time for coal samples to parse gas in the drill hole, and making the sampling effect better. Through the sensor in the sampling barrel and the transmission line attached to the outside of the drill pipe, the long distance remote monitoring of coal bed methane can be realized to reduce the possibility of gas leakage from coal samples. The multi-layer sealing device and the bearing group maintain the function of the sampling body to ensure that the gas pressure in the sampling barrel is maintained in a constant state, ensure the air tightness of the device, and make the sampling result more accurate.

At the same time, through the sensor built in the sampling barrel and the transmission line attached to the outside of the drill pipe, the long distance remote monitoring of coal bed methane can be realized to reduce the possibility of gas leakage from the coal sample. The multi-layer sealing device and the bearing group maintain the function of the sampling body to ensure that the gas pressure in the sampling cylinder is maintained in a constant state, ensure the air tightness of the device, and make the sampling result more accurate. In addition, one part meets multiple design requirements, convenient assembly, simple disassembly, convenient follow-up debugging and maintenance.

III. DEVICE PARAMETERS CHECKING AND STRUCTURE SIMULATION

Main technical parameters of the device

External drill pipe, Φ94 mm×650 mm； The sampling space of the sampling tube is a cylindrical structure with a central axis, in which the outer diameter of the cylindrical cylinder $d1$ is 65.5mm, the outer diameter of the central shaft $d2$ is 10.5mm, and the internal length $l1$ is 157mm. In the experiment, an annular inflation port is added, the outer diameter of the air port $d3$ is 30mm, and the internal elongation of the air port $l2$ is 15mm, so it can be calculated that the internal capacity of the sampling space is about4.86$*$10-4m3， In the calculation, π is 3.14.

The main technical parameters of the device are shown in **Error! Reference source not found.**.

Error! Reference source not found. **The main technical parameters of the underground coal seam closed sampling device**

Outside diameter of drill pipe	Length of drill pipe	Barrel length	Sample barrel capacity
94mm	650mm	157mm	4.86×10^{-4} m^3

Force analysis and checking calculation of device structure

Strength check of the center axis of rotation inside the sampling cylinder:

It is known that the material of the sampling cylinder is Q235， The material of the central shaft is 45 steel ， The sealing ring is made of butadiene rubber. when the shaft is 45 steel, $[\tau_T] = 35Mpa$； Coefficient of friction between steels is $f_{\mathrm{steel}} = 0.32$, The contact area between the sealing ring of the left door and the metal parts is $S_{\mathrm{lr}} \approx 199mm^2$, The contact area between the sealing ring of the right door and the metal parts is $S_{rr} \approx 1419.8mm^2$.

The coefficient of friction between steel and rubber is $f_{\mathrm{m}} = 0.8$, Contact area between metal parts of left side door is $S_{\mathrm{ls}} \approx 2123.7mm^2$, Contact area between metal parts of right side door is $S_{\mathrm{rs}} \approx 3000mm^2$.

Pre-tightening force provided by screw thread fixing cover plate is

$$F_N = 1.6F_{\mathrm{p}} \tag{1}$$

Where F_p is the positive pressure exerted by the door panels on both sides when the sampling cylinder is full of air, In the experiment, it is limited by the actual testing equipment, $F_p = 0.8Mpa$. Calculate and analyze the friction and torque received by the left and right doors respectively.

Left door:

The pressure on the contact part of the left side door with the rubber ring F_{Nls} is

$$F_{N\mathrm{ls}} = F_{\mathrm{p}} \times S_{\mathrm{ls}} \approx 0.8Mpa \times 199mm^2 \approx 158.4N \tag{2}$$

The pressure between the pure metal of the left door F_{Nls} is

$$F_{N\mathrm{ls}} = F_N \times S_{\mathrm{lr}} = 1.6F_{\mathrm{p}} \times S_{\mathrm{ls}} \approx 1.6 \times 0.8Mpa \times 2123.7mm^2 \approx 2718.3N \tag{3}$$

The total friction force on the left door F_{fl} is

$$F_{fl} = F_{f\mathrm{lr}} + F_{f\mathrm{ls}} = F_{N\mathrm{lr}} \times f_{\mathrm{m}} + F_{f\mathrm{ls}} \times f_{\mathrm{steel}} \approx 996.9N \tag{4}$$

The total torque of the door on the left is

$$T_{\mathrm{l}} = r_{\mathrm{l}} \times F_{f\mathrm{l}} \approx 13N \cdot m \tag{5}$$

Right door:

The pressure on the contact part of the right side door with the rubber ring F_{Nrr} is

$$F_{N\mathrm{rr}} = F_{\mathrm{p}} \times S_{\mathrm{rr}} \approx 0.8Mpa \times 1419.8mm^2 \approx 1135.8N \tag{6}$$

The pressure between the pure metal of the right door F_{Nrs} is

$$F_{Nrs} = F_N \times S_{\mathrm{rr}} = 1.6F_{\mathrm{p}} \times S_{\mathrm{rs}} \approx 1.6 \times 0.8Mpa \times 3000mm^2 \approx 3840N \tag{7}$$

The total friction force on the right door F_{fr} is

$$F_{fr} = F_{f\mathrm{rr}} + F_{f\mathrm{rs}} = F_{N\mathrm{rr}} \times f_{\mathrm{m}} + F_{f\mathrm{rs}} \times f_{\mathrm{s}} \approx 2137.44N \tag{8}$$

The total torque of the door on the right T_l is

$$T_1 = r_1 \times F_{f1} \approx 32N \cdot m \tag{9}$$

From the above, it can be seen that the maximum torque caused by friction on the rotating shaft connecting the two doors occurs in right side door, with the of 33 $N \cdot m$. If the device uses the motor as the driving force, it can be seen from the table that the appropriate motor torque is 60 $N \cdot m$, so the maximum torque received on the center shaft is the motor torque, which is 60 $N \cdot m$.

The diameter of the central shaft $d_s = 6mm$， the torsion strength of the axis is calculated as follows:

For a solid circular shaft, the torsion modulus of the dangerous section of the shaft WT is

$$W_T = \frac{\pi d_{轴}{}^3}{16} \approx 42.4mm^3 \tag{10}$$

The constraint condition of torsion strength is

$$\tau_T = \frac{T_{max}}{W_T} = \frac{60N \cdot m}{42.4mm^3} \approx 1.4MPa \ll [\tau_T] = 35Mpa \tag{11}$$

Therefore, it can be seen that the axis satisfies the torsional strength.

Device structural stability calculation

First, the internal structure of the drill pipe was calculated separately, the internal structure components were drawn in solidworks, and the materials of each part were configured. The mass of the model was measured as 8709.83g by the software internal measurement tool. After the internal structure of the physical device was weighed, the weight of this part of the structure was found to be 8687g. The deviation from the software calculated quality is less than 0.2%, so subsequent calculations will be made using solidworks software based on the quality data provided by the software.

According to the original structural design, the stress situation of the internal components is simplified. The structural stress situation in the vertical direction is simplified as shown in the Figure 6 below.

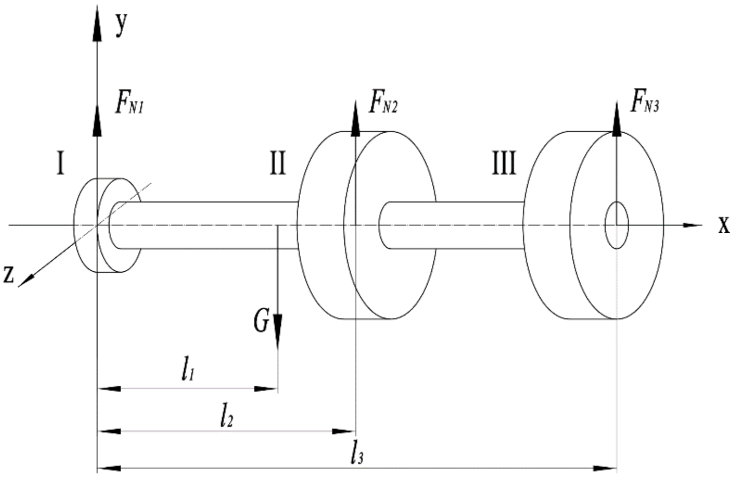


Figure 6 The force of the internal structure in the vertical direction

The mass of the device is m = 8.7kg and the acceleration of gravity is g = 9.8N/kg.

The friction coefficient of position I $\mu_1 = 0.4$ and radius $r_1 = 8mm$,The friction coefficient at position II $\mu_2 = 0.001$ and the radius $r_2 = 37.5mm$; The friction coefficient at position III is $\mu_3 = 0.3$， and the radius $r_3 = 37.5mm$.

The gravity force on the device is calculated as:

$$G = m \times g = 8.7 \times 9.8 = 85.3N \tag{12}$$

The sum of the friction forces at each position is:

$$f_N = f_{N1} + f_{N2} + f_{N3} = \mu_1 \times F_{N1} + \mu_2 \times F_{N2} + \mu_3 \times F_{N3} \tag{13}$$

$$f_N = 0.4 \times F_{N1} + 0.001 \times F_{N2} + 0.3 \times F_{N3} \tag{14}$$

The equilibrium equation is established according to the force balance respectively as follows:

$$F_{N1} + F_{N2} + F_{N3} = G = 85.3N \tag{15}$$

$$22F_{N1} + 9F_{N2} = 955.4N \tag{16}$$

$$0 \leq F_{N1} \leq 85.3N \tag{17}$$

$$0 \leq F_{N2} \leq 85.3N \quad (18)$$

$$0 \leq F_{N3} \leq 85.3N \quad (19)$$

Through the use of linprog function in Matlab for linear programming check calculation:

$$f_{Nmax} = 29.9N \quad (20)$$

Then

$$F_{N1} = 43.4273N \quad (21)$$

$$F_{N1} = 0N \quad (22)$$

$F_{N1} = 41.8727N$;

According to the formula:

$$F = ma = m \times 4 \times \pi^2 \times n^2 \times r \quad (23)$$

The maximum rotational speed of the internal structure can be obtained by calculation $n_{max} = 4.5r/min$; Comparing drill pipe speed $n_{\text{drill pipe}} = 60r/min$, drilling rate decreased by 92.5%.

IV. COAL SEAM CLOSED SAMPLING DEVICE SAMPLING

Sampling device sampling experiment

The sampling function of the closed sampling device is one of its important components, which directly affects the effect of CBM exploration and gas extraction. Therefore, it is necessary to test its sampling function to ensure its sampling accuracy and reliability.

Coal seam closed sampling device test bench

The underground coal seam closed sampling device conducts sampling experiments on the experimental platform shown in Figure , and intercepts a single sampling barrel after sampling to detect the internal air pressure of the sampling barrel to test whether the sampling barrel has the pressure holding performance required by the design. The experimental platform simulates the drilling rig through two motors, one of which provides the rotating power for the simulation rig, the other motor works together with the screw nut structure to make the simulation rig move in a straight line, and the two motors provide the original external power for the closed sampling device of coal seam underground, so that the device can have the ability to drill holes in the coal sample. Four simulated coal samples with a diameter of 100 mm×300 mm are loaded inside the tail of the device. At the same time, various sensors are loaded at various positions of the device, including torque measurement. The actual torque measurement sensor is shown in Figure . Pressure measurement and other sensor data as well as experimental time, temperature, rig rotation length and other data will be displayed on the display screen of the experimental console, as shown in Figure .

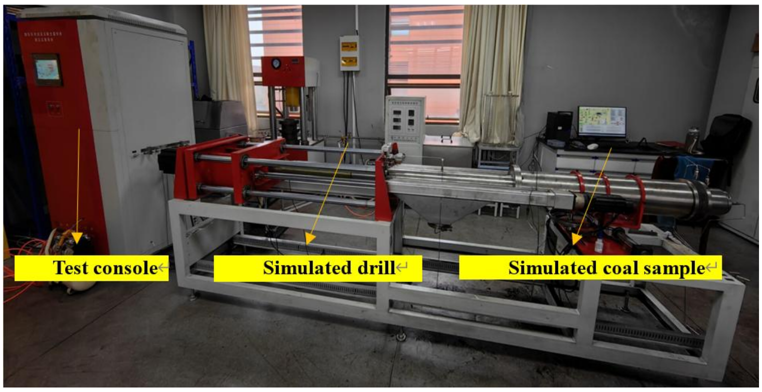


Figure 7 Experimental system for rapid determination of coal seam gas content sampled while drilling

Figure 8 A torque sensor on the device

Figure 9 Display of the experimental console

Experimental sample

The composition and preparation of simulated coal sample greatly affect the reliability of the sampling test results. Whether it can effectively reflect the real coal seam and coal sample condition is a problem that needs to be considered in the preparation of coal sample certification. In this experiment, the composition of the simulated coal sample is 3.5×760g crude coal, 3.5×240g fine coal, 3.5×100g water, 3.5×100g sodium humate and 3.5g lignin. The composition ratio of the simulated coal sample is shown in Figure 7. Sodium humate is used as the binder of the coal sample. Finally, the mixture density of the simulated coal sample is 1400kg/m3, and the physical diagram of the simulated coal sample is shown in Figure .

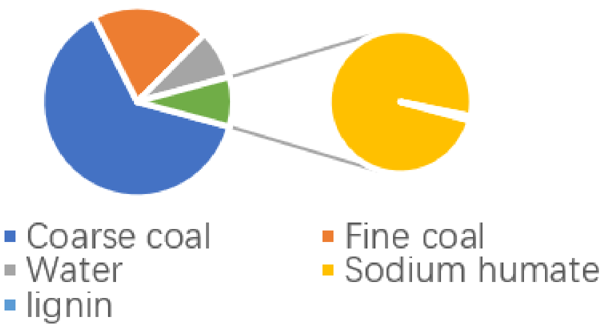


Figure 7 Composition ratio of simulated coal samples

Figure 11 Simulated coal sample (raw material)

The simulated coal sample greatly restores the coal condition of the soft medium layer, and well meets the experimental requirements of the device. The appearance of the simulated coal sample before the experiment is shown in Figure.

Figure12 Simulated coal sample before sampling experiment

Sample data

In the process of testing the coal seam closed sampling device in the underground mine, the actual drilling rate was referred to ensure that the experimental rig speed was a stable 60 r/min, and then the sampling experiment was carried out for a total of 6 times with different rig Settings. Three times with different drilling lengths as reference variables, three times with different drilling times as reference variables, recorded the load and torque changes of the whole device under different circumstances, as well as the change of sampling volume under different circumstances, among which sampling volume is the main object data tested in this experiment, the experimental results are shown in Table and

Table .

Table 3 Statistical table of coal seam sampling test data at different drilling lengths

Drilling length（mm）	Load（N）	Torque（N·M）	Sample volume（g）	sampling cylinder
30	135	0.9	23.5	closed
60	238	5.5	98.7	closed
120	516.7	42.1	189.6	closed

Table 4 Statistical table of coal seam sampling test data at different drilling times

Drilling time（min）	Load（N）	Torque（N·M）	Sample volume（g）	sampling cylinder
3	143.4	8.8	32.1	closed
6	410	15.1	92.3	closed
12	447.7	43.3	203.6	closed

As shown in Table and

Table of the experimental results, with the increase of drilling time and drilling length of the rig, the load on the device will be greater, and the torque will be greater, and it can be seen that the torque and load are more sensitive to the change of drilling time. At the same time, with the increase of drilling time and drilling length, the device samples more. Under other conditions, the coal sample obtained when the drilling length is 120 mm is 192 % of the drilling length of 60 mm. The coal sample obtained at the drilling time of 120 min is 220% of that at the drilling time of 60 min.

Conclusion of sampling experiment

According to the experimental situation obtained from the current preliminary experiment, the load and torque of the device are within the range that the device structure can bear within the value set by the experiment. Moreover, the underground coal seam closed sampling device can meet the measurement standard of coal seam gas content determination with the coal sample volume of at least 200 g, meeting the actual use needs. Due to the limitations of the weight on bit and the size of the experimental platform, the amount of coal sample in the sampling device is also limited. In the follow-up study, by improving the length and size of the sampling cylinder and increasing the coal sample capacity, the closed sampling experiment can be further realized in the actual underground coal mine.

Pressure keeping experiment of coal seam sealed sampling device

In this paper, a metal flat seal test device is designed as Figure 8, and the air pressure required for sealing is provided to the test device through an air pump. The pressure gauge is used to detect changes in the air pressure inside the test device. The test device is placed in water and soap is applied on its surface to observe whether there is gas leakage and the location of leakage. The actual diagram of the experiment is shown in Figure .

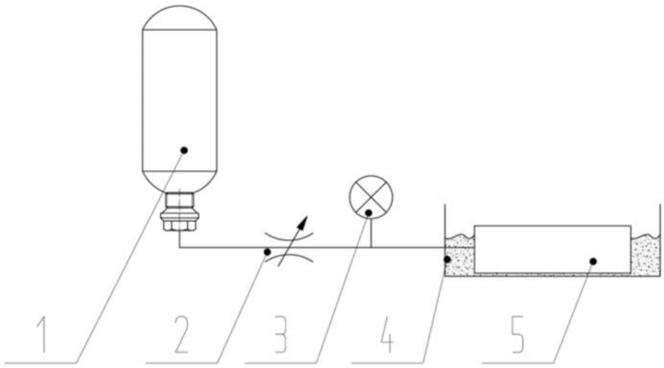


Figure 8 Schematic diagram of the sealing experimental structure

1 gas cylinder; 2 pressure regulating valves; 3 pressure gauges; 4 sink; 5 tested parts

Figure 14 Actual diagram of the sealing experiment

Test device design

Due to the limitations of the structure and size of the sampling cylinder valve, in addition to the common circular seal of the open edge, it also needs to be a plane seal, and the plane seal can not directly use the existing standard parts of the seal ring, resulting in its gas sealing is difficult to achieve. In order to ensure the safety of the test device, this paper will use compressed air as the experimental gas, rather than natural gas under actual conditions, to prevent gas explosion. The working principle of the test device is to apply hydraulic pressure to the whole valve body, and weld the quick-insert joint male head on the side of the sealing cylinder, and drive air pressure into the cylinder through the quick-insert joint. After setting different amounts of air pressure, the internal air pressure of the whole device is measured when the valve is kept closed, so as to test the sealing performance of the sealing surface.

In this scheme, we consider nitrile rubber as sealing materials. The design scheme is to make an integrated sealing ring from the irregularly shaped customized mold, as shown in Figure. The scheme also realizes the compression of the sealing ring on each contact surface is consistent, and it is not easy to slip out of the sealing slot during the valve rotation, and the sealing performance is good.

Figure15 Custom mold for irregular perforated sealing rings

This scheme refers to the planar hybrid sealing scheme of the flat cover plate, that is, the processing of the Butyl rubber shaped seal ring is fixed on the static sampling cylinder, and the fixing method of the cover plate and the sampling cylinder is changed from fixing with multiple bolts to using the cover plate with large size thread, which reduces the difficulty in processing and reduces the number of parts. The physical appearance of the assembly structure is shown in Figure . The structural design diagram of the sealing method is shown in Figure .

Figure 16 Physical drawing of metal plane hybrid seal of threaded tooth cover

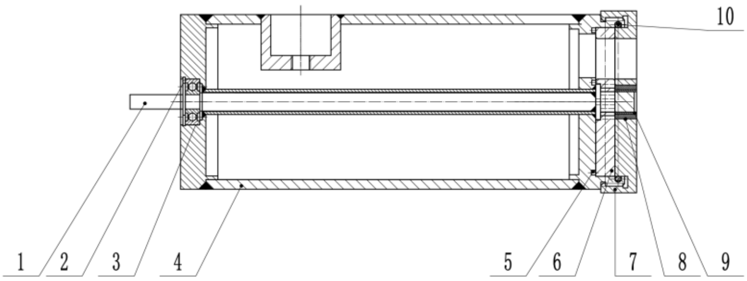


Figure 17 Structural diagram of metal plane hybrid seal of threaded tooth cover

1 a central rotating shaft, 2 an elastic retaining ring for the hole, 3. a deep groove ball bearing, 4 a sampling cylinder, 5 a right door sealing ring I, 6 a right door, 7 a right side cover plate, 8 a copper sleeve, 9 a shaft sleeve, 10 a right door sealing ring 2

The experimental results of tightness under this scheme are shown in

Table .

Table 5 Experimental results of metal-plane mixed sealing of threaded tooth covers

Group number	Maximum pressure（MPa）	Pressure after 1 hour（MPa）	Pressure after 3 hour（MPa）
1	0.383	0.380	0.347
2	0.383	0.378	0.335
3	0.383	0.375	0.341

The average initial preload pressure of graphite copper + sealing ring + end cap bolt is 0.58MPa, after 3 hours, the average value of pressurized gas is 0.56MPa, with a pressure retention rate of 96.5%; after 18 hours, the average value is 0.38MPa, with a pressure retention rate of 65.5%. In summary, graphite copper + sealing ring + end cap bolt fixing pretightening meets the sealing requirements of the sealing cavity.

V.CONCLUSIUON

The The underground coal seam closed sampling device is mainly applicable to the soft medium layer coal sample, avoiding the complicated and lengthy operation of the existing sampling device in China that needs to drill first and then sample, and also avoiding the risk of drilling collapse and drill rod drill bit loss. The overall structure is simple and easy to process, and the modular design is easy to disassemble and maintain, the coring process is simple to operate, and it is convenient to connect with various drills and drill tools.

Through data calculation, it can be concluded that the inner bearing group of the device plays a certain role in the working process of the device, which makes the internal structure speed slow when the external drill pipe rotates at high speed, and achieves a certain effect of double barrel single action, which makes the structure stability of the device good.

Compared with the traditional sampling device, the underground coal seam closed sampling device provided in this paper has shorter sampling time, sufficient sampling amount and better pressure retaining effect. Compared with the original related devices, this device reduces the cost and can provide accurate basic parameters for coal mine gas control.

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