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Discussion on Failure Causes of Coal Mine Drill Pipe and Comprehensive Anti-corrosion

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Abstract

Coal mine drill pipe is an important drilling tool in drilling equipment, and its corrosion failure is an important factor hindering the improvement of drilling efficiency. This paper summarizes the corrosion status of coal mine drill pipe and the causes of drill pipe failure, and expounds the comprehensive anti-corrosion measures of coal mine drill pipe.

Keywords

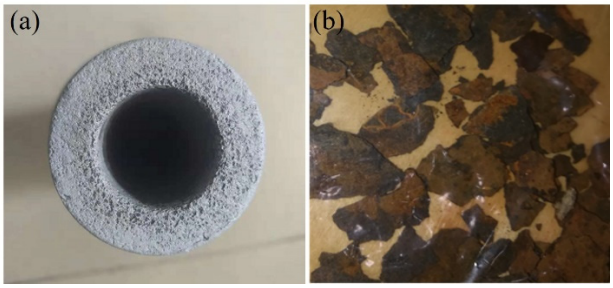
Drill Pipe; Corrosion; Comprehensive Anti-corrosion.

1. Introduction

A With the continuous development of the coal industry, directional wells and ultra-deep wells have emerged. The drilling conditions are becoming more and more complex, which requires the continuous improvement of drilling technology and equipment, and the requirements for drill pipe performance are also increasing. In the electrochemical corrosion environment, all kinds of drilling tools and mechanical equipment used in drilling engineering will be affected by corrosion, so it is urgent to speed up the development of drill pipes with high strength, corrosion resistance and fatigue resistance.

2. Discussion on the Cause of Drill Pipe Failure

In the process of directional drilling construction of coal seam gas extraction, the corrosion of drilling tools occurs from time to time. For example, Gubei Coal Mine in Huainan, Anhui Province, Xiaozhuang Coal Mine in Binchang, Shaanxi Province, Hujiahe Coal Mine, Huangling No.2 Coal Mine of Huangling Mining Group, Yushuling Coal Mine in Xinjiang and other coal mines have serious corrosion of drilling tools in the process of gas extraction. The corrosion of drilling tools on site is shown in Figure 1. However, the anti-corrosion technology of drilling tools for drilling construction in the domestic coal mine market is still blank.



(a) Pitting diagram (b) Inner wall off iron sheet diagram

Fig 1. On-site drilling tool corrosion

In the corrosive environment, drilling tools and mechanical equipment will be affected by corrosion, and the mine drill pipe is the main tool for transmitting power and transporting punching water and mud. The medium often contains corrosive substances, and the drill pipe

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has been in a dynamic state during the drilling process, which will aggravate the corrosion. During the construction of the drill pipe, it is subjected to alternating stress and is under the harsh conditions of friction and collision with the borehole wall. It often becomes the weakest link in the whole drilling equipment and tools, and perforation or complete fracture caused by crack development occurs from time to time. In the directional drilling construction, the iron slag corroded by the drill pipe will enter the screw motor, resulting in the failure of the screw motor, as shown in Figure 2. These will seriously affect the efficiency of drilling construction and cause great economic losses to the drilling project.

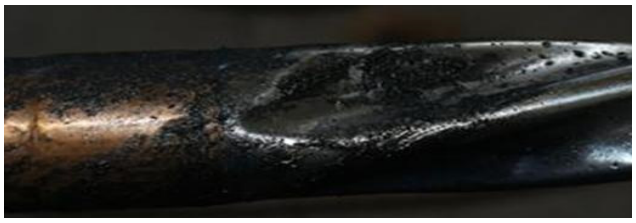

Fig 2. Screw motor failure diagram

The drill pipe is in the coexistence environment of various corrosive media such as H_2S, CO_2, Cl^- and hydrate, which will cause serious corrosion to the drill pipe. Moreover, in the process of drilling, the drill pipe also bears a variety of forces such as tension, torsion and rotary centrifugation. These comprehensive factors lead to pitting corrosion, crack, puncture and even fracture of the drill pipe.

Researchers have carried out experimental analysis on the causes of drill pipe failure, and confirmed that electrochemical corrosion and stress corrosion are the main factors causing drill pipe failure. Chen Meng [1] found that the coating on the inner wall of the drill pipe fell off seriously, and some of the drill pipe bodies had obvious corrosion phenomena. Through the analysis of the morphology of the corrosion pits of the failed drill pipe, the morphology of the corrosion products and the composition of the micro-area, and the evaluation of the coating quality, it was found that the reason for the falling off of the inner wall of the drill pipe and the corrosion of the rod body was that Cl-in the brine slurry destroyed and penetrated the coating structure, which catalyzed and accelerated the corrosion of the dissolved oxygen to the drill pipe substrate.

Chen Meng et al. [2] studied and analyzed the corrosion failure of S135 steel grade drill pipe in a well. The research showed that the oxygen content on the inner surface of the drill pipe was high, and there was stress concentration in the transition zone. It leads to serious pitting corrosion on the surface of this area, which in turn leads to the expansion of fatigue cracks, which leads to the corrosion fatigue failure of drill pipe.

Wang Xianlin [3] analyzed the problem of large area corrosion pits on the surface of φ127mm G105 drill pipe of a mining company after two years of service. Through mechanical property test, metallographic microstructure and energy spectrum analysis, it was found that the corrosion failure of drill pipe was mainly caused by the action of extremely strong corrosive media (O_2, Ca^{2+}, Mg^{2+} and coal seam water). The corrosion mechanism was mainly oxygen corrosion, under-deposit corrosion caused by Ca^{2+} plasma and galvanic corrosion caused by coal seam water.

Zhao Jinfeng [4] found that the inner wall of nickel-plated drill pipe in an oilfield was seriously corroded. The macroscopic and microscopic analysis of the corrosion products on the inner wall of the drill pipe and the micro-area composition analysis were carried out. The results show that the main reason for the corrosion is that there are leakage plating and micro holes in

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the coating, and the H2S in the crude oil is dissolved in water to form sulfuric acid to accelerate the corrosion of the drill pipe, and the existence of Cl^- further aggravates the local corrosion.

3. Research on Anti-corrosion Technology of Drill Pipe

After understanding the causes of the failure of the drill pipe, the anti-corrosion of the drill pipe mainly starts from the following three aspects:

(1) Change the drill pipe surface itself with different metallographic structure;

(2) Change the chemical properties of the drilling fluid in contact with the drill pipe;

(3) The corrosion inhibitor or scale inhibitor is used to separate the drill pipe from the surface of the drilling fluid.

The commonly used anti-corrosion measures for metals include cathodic protection, adding corrosion inhibitors, coating and coating, etc. Due to the special working conditions of the drill pipe, the main methods of anti-corrosion of drill pipe are adding corrosion inhibitor, selecting corrosion resistant steel, coating inner coating and cathodic protection.

3.1. Corrosion Inhibitor

In the American Society for Materials and Testing ' Standard Definition of Terms for Corrosion and Corrosion Tests ', corrosion inhibitors are chemicals or mixtures of several chemicals that can prevent or slow down corrosion when present in the environment (medium) at an appropriate concentration and form. Generally speaking, corrosion inhibitors refer to those substances that play a protective role on the metal surface. Adding trace or small amount of such chemicals can significantly reduce the corrosion rate of metal materials in this medium to zero. At the same time, it can keep the original physical and mechanical properties of metal materials unchanged. Rational use of corrosion inhibitors is an effective method to prevent corrosion of metals and their alloys in environmental media. Corrosion inhibitor technology has become one of the most widely used methods in anti-corrosion technology due to its good effect and high economic benefits. Especially in the production and processing of petroleum products, chemical cleaning, atmospheric environment, industrial water, machinery, instrument manufacturing and petrochemical production process, corrosion inhibition technology has become one of the main means of anti-corrosion.

In 2002, FMC Corp applied for a patent for a drilling tool preservative, which is composed of alkaline earth or transition metal salt and transition metal heteropoly complex anion to form a deepwater solution. The anti-corrosion additive is in a solid phase stable state to ensure its predetermined concentration, stability and improved dispersibility. The protective layer formed by it is more resistant to corrosion than the oxide layer formed by conventional preservatives. The solution excludes or minimizes metal pitting formed in contact with salt water, and is especially suitable for use in high temperature (257 °C) environments to protect the metal surface of oil and gas drilling, mining and storage systems. In addition, the correct use of corrosion inhibitors can also effectively control corrosion without wasting resources, such as adding corrosion inhibitors to drilling fluids, completion fluids or workover fluids, or directly applying them to the metal surface.

Corrosion inhibitors are widely used in the field of anti-corrosion of oil mining equipment, but the applicability to the coal mining industry is not high. The pump truck injects water or mud into the borehole to complete the punching and directly discharges it, which cannot be recycled. If you want to carry out corrosion inhibition on the drill pipe, you need to consume a lot of corrosion inhibitors, and the cost is high. As industrial water, because of the large amount of water, the amount of P discharged into the water environment is quite large, and a large amount of P enters the water body, which is very easy to cause eutrophication of the water body. This kind of anti-corrosion research close to biochemical technology is a relatively new field. The

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control technology of H_2S corrosion can be studied from the aspects of reducing the concentration of soluble sulfide in drilling by oxidation or pH control. There are still some difficulties in the actual situation.

3.2. Optimization of Steel

The drill pipe is an indispensable tool in the process of coal mining, and the selection of its material directly affects the drilling efficiency and safety. The materials of coal mine drill pipe mainly include carbon steel, alloy steel, brazing steel and stainless steel. The selection of these materials depends on factors such as drilling conditions, cost budget and service life.

For the influence of drill pipe material on corrosion, Wang Xinhu et al conducted corrosion fatigue life test, tensile performance test and composition analysis on S135 steel grade drill pipe materials from four manufacturers. The results show that although the chemical composition and material properties of the four drill pipes meet the requirements of the standard, and the tensile strength of the materials is basically the same, the corrosion fatigue life varies greatly. The mechanism of corrosion fatigue crack propagation is that the coexistence of anodic dissolution and hydrogen induced cracking accelerates the fatigue crack propagation. The low-magnification structure pickling test and microstructure analysis of the materials showed that the metal structure of the four drill pipes, especially the low-magnification structure, was significantly different. The macrostructure reflects the degree of composition segregation, inclusion content and distribution. The composition segregation and inclusions lead to the anodic dissolution of the material, especially the acceleration of hydrogen-induced cracking, which leads to the reduction of corrosion fatigue life. The above research shows that reasonable material selection has a great influence on the H2S corrosion control of drill pipe. In terms of material selection and improvement of pipe materials, new processes can be adopted, such as reducing non-metallic inclusions in steel by refining to improve the sulfur resistance of pipe materials, or using appropriate smelting process to produce ultra-low sulfur and low phosphorus drill pipe steel, so that the drill pipe can obtain high transverse impact toughness. Reasonable material selection makes the anti-corrosion effect of drill pipe remarkable.

(1) Carbon steel is one of the most widely used coal mine drill pipe materials. It has the advantages of low price and easy manufacture, so it is deeply loved by the coal mining industry. By controlling the carbon content and heat treatment, its high temperature, high pressure and corrosion resistance can be further improved. However, the wear resistance and strength of carbon steel are relatively low, and problems such as bending and fracture may occur during use.

(2) Alloy steel has higher strength and hardness than carbon steel, and can better resist the influence of high temperature, high pressure and wear. Its durability and stability are relatively good, suitable for long-term use. However, the price of alloy steel is higher than that of carbon steel, and the manufacturing process is more complicated.

(3) The main components of the brazing steel are cobalt, nickel, chromium and other elements, which make it show good corrosion resistance and strength at low temperature and high temperature. The drill steel not only has high strength, good rigidity, but also has strong wear resistance, which is very suitable for sticking and fine hole drilling of coal seam core. In addition, the drill steel drill pipe is flexible and convenient to operate, and is the preferred material in coal mine drilling.

(4) Stainless steel can also be used as the material of coal mine drill pipe. Its biggest feature is excellent corrosion resistance, can be used in complex water environment, and has a long service life. But the relatively high price of stainless steel may increase drilling costs.

When selecting the material of drill pipe, it is necessary to consider the drilling conditions, cost budget and service life. Each material has its own advantages and disadvantages. Coal mining enterprises should choose according to their own needs and actual situation. Reducing costs

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and increasing efficiency is one of the important goals pursued by enterprises in the operation process, aiming to increase profits and competitiveness by improving efficiency and reducing costs. For the existing mining drill pipe, the production demand mostly serves the geological conditions of the coal seam, and there are not many choices for the steel matrix of the drill pipe. The main reason is that the cost of different steel is different. If the selection of the steel matrix of the anti-corrosion drill pipe is considered unilaterally, the cost will be greatly increased.

3.3. Coating the Inner Coating

The comprehensive anti-corrosion of drill pipe can not only reduce economic losses, but also reduce pollution to the environment, save resources and energy. Anticorrosion surface engineering technology is a relatively effective means of corrosion control. At present, internal coating anti-corrosion technology is widely used in anti-corrosion measures of drill pipe and drill pipe joints at home and abroad [6]. When different coatings are applied to the inner wall of drill pipe, their adhesion, acid and alkali resistance, roughness, wear resistance, high temperature and high pressure resistance and torsion resistance will also directly affect the anti-corrosion quality of the coating.

(1) Epoxy phenolic coating: PC coating is a modified epoxy phenolic coating for drill pipe developed by Tuboscope company. The coating has strong adhesion (grade B or above), wide range of acid and alkali resistance (pH = 3.0 ~ 12.5) and good temperature resistance (121 °C). TK-34XT is also a high wear resistance drill pipe coating developed by Tuboscope company, which is a modified epoxy phenolic coating. Zhang Guixin et al tested the coating properties of TK-34XT. The results are as follows: the coating surface did not change after soaking in acid, alkali and salt media for 3 months, the coating remained intact for 16 h under high temperature and high pressure (148 °C, 70 Mpa), 0.78 μm roughness, A-level adhesion, and the coating lost 11 mg after 1000 cycles of rotation under 10 kN load. The above performance indicators can meet the drilling process requirements.

Duan Shaoming et al. [7] synthesized a heat-resistant polymer by high-temperature crosslinking reaction of modified phenolic resin and epoxy resin, and used it as a film-forming resin to prepare epoxy phenolic coatings. The coating has good corrosion resistance to H_2S, crude oil, CO_2 and sewage. It has excellent wear resistance and high-temperature and high-pressure resistance (180 °C, 70MPa, pH = 12.5). The coating does not blister and fall off after 8000 hours of salt spray, and the thermal decomposition temperature is higher than 260 °C. It can be applied to anti-corrosion of tubing, casing and drill pipe.

As a relatively mature anti-corrosion coating for drill pipe, the modified epoxy phenolic coating has excellent comprehensive anti-corrosion performance, which is closely related to factors such as film-forming resin, pigments and fillers, and additives.

(2) Powder coatings: The volatile organic gas (VOC) of solvent-based coatings not only pollutes the environment but also damages the health of the body. Because the powder coating formulation system does not contain organic solvents and is environmentally friendly, its market potential is huge.

The friction coefficient of powder coating is low. If it is applied to drill pipe anticorrosion, the drilling fluid flow can be increased and the mining cost can be reduced. Wang inspired a kind of oil drill pipe inner coating including phenolic resin primer and epoxy phenolic modified powder coating. Its adhesion, high-temperature and high-pressure resistance, torsion resistance, wear resistance and tensile properties all meet the requirements of SY/T0544-2010 standard.

(3) Spraying process: Advanced spraying process can directly affect the effectiveness and durability of the coating, reduce coating loss and thus reduce the cost of spraying. When the primer and topcoat of the inner coating of the drill pipe are both-liquid, the liquid spraying process is adopted. The American Tuboscope company uses a high-pressure airless spraying

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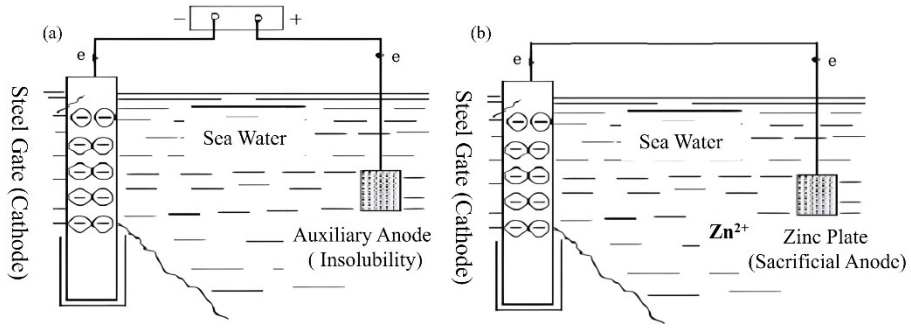
equipment to carry out the double-layer spraying of the primer and topcoat of the DPC coating. When the inner coating of drill pipe is powder coating, the friction electrostatic powder spraying process is adopted. Shanghai Tuboket Petroleum Pipeline company ltd invents a powder inner coating spraying process for drilling and drilling drill pipe, which simplifies the liquid coating process. Multi-channel thin coating and topcoat baking furnace equipment.

The inner wall coating of drill pipe is an important anti-corrosion technology of drill pipe, which can effectively improve the service life and drilling efficiency of drill pipe, thus reducing drilling cost and improving exploration effect. In the application of this anti-corrosion technology, it is necessary to pay attention to the selection of appropriate materials, coating process and coating thickness, and to carry out coating quality testing to ensure that the implementation effect of this technology is in line with expectations. The corrosion problems of coal mine drill pipe and oil drilling drill pipe are due to the fact that the internal fluid of drill pipe is mostly material containing corrosive medium, and the application of anti-corrosion technology of inner coating of coal mine drill pipe is relatively less. Therefore, the coal mine drill pipe can be studied with reference to the anti-corrosion technology of oil drill pipe, so as to better solve the corrosion problem of drill pipe.

3.4. Cathodic Protection

Cathodic protection technology is an extremely important measure in metal corrosion and protection. It is widely used in underground, water areas and chemical environments where metals can react with metals, especially in long-distance pipelines, concrete metal buildings, seaports and ships. Cathodic protection technology is based on the electrochemical principle of metal corrosion. This principle is that the metal surface flows into enough cathode current to cause cathodic polarization on the substrate surface and slow down the metal corrosion rate. Cathodic protection technology is divided into two categories [8]: sacrificial anode protection method and forced current protection method, as shown in Figure 3. The sacrificial anode protection method is to select a metal or alloy with strong reducibility to connect with the protected substrate. The metal with strong reducibility is used as the anode to undergo an oxidation reaction to cause electrons to flow into the protected substrate, which has an anti-corrosion effect. The forced current protection method is to polarize the matrix as a cathode by applying an external current, thereby generating cathodic protection. The forced current protection method requires external power supply and auxiliary anode to form a complete cathodic protection system. The external current can adjust the voltage and current according to the actual corrosion situation, and increase the cathodic protection distance.



(a) Impressed current method (b) Sacrificial anode method

Fig 3. Cathodic protection technology diagram

In the corrosion and protection of mining drill pipe, due to the special working conditions of drill pipe, the cathodic protection method of applied current is not applicable. In the sacrificial anode protection method, the anode used is a difficult problem. Without affecting drilling and

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water injection grouting, how to select the appropriate metal material to attach to the surface of the drill pipe, as well as the high-pressure resistance and torsion resistance of the anode, are all problems that need to be solved, and there are still some difficulties.

4. Summary

(1) The main reason for the corrosion failure of the drill pipe is that after the coating is damaged, the drill pipe caused by the extremely strong corrosive medium in the mud has pitting corrosion, crack, puncture and even fracture.

(2) The development trend of comprehensive anti-corrosion technology of coal mine drill pipe is to adopt new material drill pipe, corrosion inhibitor, develop new drill pipe inner coating and new surface engineering technology. These technologies can not only reduce economic losses, but also save resources and energy.

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