

Analysis of Chinese Patents on Cathodic Protection by Applied Current Method in Marine Sector

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Abstract: The resource problem is the top priority of China's current development, while the ocean is an inexhaustible treasure. The development and utilization of marine resources has always been the key direction of development. The characteristics of offshore engineering operation equipment are: first, the scale of the platform is particularly large, and second, it is long-term in the harsh environment such as moisture and salinity [1]. Therefore, the anti-corrosion of offshore platforms is the research hotspot of relevant technicians, this paper systematically summarizes the patent application of external current in cathodic protection of anti-corrosion technology. It analyzes the patent type, affiliated institution, important applicant, application field and other related contents. The results show that enterprises prefer to actually invent devices, while scientific research institutions, universities and colleges are more about the creation of technical methods.

Keywords: Cathodic protection; Offshore platform; Impressed current; Patent analysis.

1. Introduction

With the current human science and technology continue to innovate and improve, the development and utilization of the marine cognition continues to improve, the ocean is a treasure gifted to mankind by nature, the development of marine resources is more and more the top priority, the marine industry in various fields of technology continues to mature, such as undersea oil development, marine mining refining, marine chemical extraction, clean energy preparation, human resources for the use of the ocean is gradually deepening the development of resource utilization. Since the 1960s, the field of marine engineering technology continues to develop, the design life of large-scale projects at sea are up to several decades [2]. With the deeper exploration of the sea, the more complex the device equipment, the requirements for corrosion protection are also higher and higher. Therefore, the cathodic protection of equipment against corrosion is also more and more important. Cathodic protection is an important method to prevent steel structure from corrosion by seawater, which can effectively increase the life of the marine platform [3]. Cathodic protection method is the most commonly used means of electrochemical corrosion protection, cathodic protection and monitoring is currently more mature and widely used anti-corrosion technology [4].

Cathodic protection is currently common in China is divided into two major categories, namely, the applied current method and the sacrificial anode method, the sacrificial anode method is the use of the principle of the primary battery, so that the party with a strong reduction as a protective party, and the protected party constitutes the primary battery. The party with strong reducing power will become the negative electrode and gradually consume the sacrifice by oxidizing reaction, and the protected party will not be corroded. The law of applied current is to apply an applied current to the surface structure of the corroded party, so that the protected party becomes the cathode, the electronic jump is inhibited, and the corrosion is weakened or even avoided. In the actual application, according to the project in different external corrosion environment cost considerations can choose a specific technology device. China from the 1980s began to

put into use a variety of large-scale marine platforms, and the vast majority of marine platforms are selected sacrificial anode cathodic protection. With the growth of service life, many marine platforms have reached the end of the service life, so they need to re-maintain and repair the cathodic protection equipment. The sacrificial anode method requires a lot of engineering work underwater. First of all, underwater operation maintenance and repair difficulties, conditions and technology have high requirements, and the safety situation is unknown, for the safety of maintenance personnel cannot be guaranteed. Secondly, such a huge amount of work, the cost of high cost, especially many of the reality of the extreme conditions of the cost is more expensive; and sacrificial anode consumes a large amount of consumables, for energy and resource consumption is also a non-negligible problem; Sacrificial anode protection process, the reaction of a large number of pollutants released in the marine land will cause serious ecological problems and damage to a variety of reactions of the metal ions released on the future of the natural ecosystem will also cause a serious problem. The metal ions released by various reactions will also cause hidden problems to the natural ecosystem in the future. Therefore, compared with the sacrificial anode, using the applied current technology in cathodic protection method will use more obvious advantages. The applied current is an environmentally friendly cathodic protection technology with low technical difficulty, simple and fast installation, low burden on the platform, and no metal ion pollution, especially suitable for cathodic protection of platforms in medium waters and deep-water areas [5].

2. Data Source and Search Method

The data of this paper comes from CNKI, the full-text database of Chinese journals, and the deadline for data retrieval is August 29, 2023. The search method adopts the keywords of patent name, and the specific search formula is: 1) Subject term = applied current. 2) Subject term = cathodic protection. 3) Subject term = marine anticorrosion. The patent data information obtained from the merger is integrated into the initial sample library, and the number of documents in the remaining sample library is 100 by checking and screening

and selecting the reasonably relevant patents, and finally summarizing. In addition, it should be specially declared that: 1) the related confidential patents are not in the sample library. 2) some of the patents that have been filed from 2021 to 2022 but have not been disclosed yet are not in this search result, so the data in the text library has some deviation from the real data.

3. Patent Type Analysis

Fig. 1 shows the patent types of the sample library of the applied current cathodic protection method. In Figure 1, there are 45 invention patents, and their proportion is 45%; there are 55 utility model patents, and their proportion is 55%.

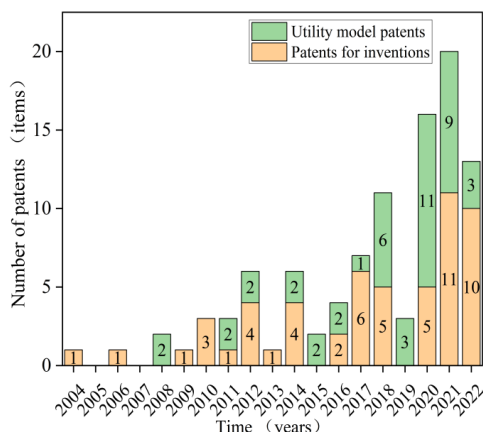


Figure 1. Patent type analysis

The number of patent applications for applied current cathodic protection has increased significantly since 2017, and the use of applied current involves more remote anodes, tensile anodes, fixed anodes, etc. [6], which is based on the practical technology of the program, so the utility model patents in the sample library occupy most of the patents, followed by invention patents, and the related appearance patents were not retrieved.

4. Analysis of the Situation of The Institution or Unit to Which the Applicant Belongs

In order to understand the importance of the applied current method of cathodic protection in units of different natures, as well as the development status of the related industry, the institutional situation of its patent applicants was statistically analyzed. Figure 2 shows the institutional situation of the applicants, and the proportion of patent applications for applied current cathodic protection technology by various enterprises is 71%, and the proportion of scientific research units and universities and colleges and others is 25%. Through analysis, the core content of the main R&D of enterprises is the specific device structure after the application project of applied current cathodic protection on the ocean, and the core content of the main R&D of universities and scientific research institutes is various process methods in the field of applied current cathodic protection. The applied current cathodic protection technology belongs to the field of functional application technology and emphasizes practicability; therefore, all kinds of enterprises pay more attention to the research of applied current cathodic protection technology.

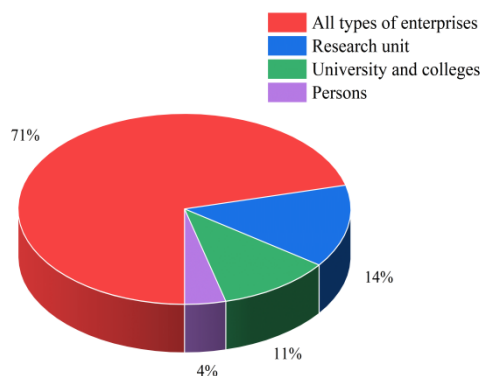


Figure 2. Information on the applicant's organization

Universities and enterprises with more applications are selected for analysis, among which the number of patent applications of 6 important applicants is 31, and the number of patent applications and application units are shown in Fig. 3. As can be seen from Fig. 3, among the top 6 important applicants, there are 4 enterprises with 18 patent applications, and the proportion of total patents applied by enterprises is 71%, indicating that enterprises pay more attention to the applied current cathodic protection technology, especially the protection device and monitoring device. With long-term investment in R&D, certain technical advantages have been accumulated, indicating that the enterprises have more mature independent R&D capability.

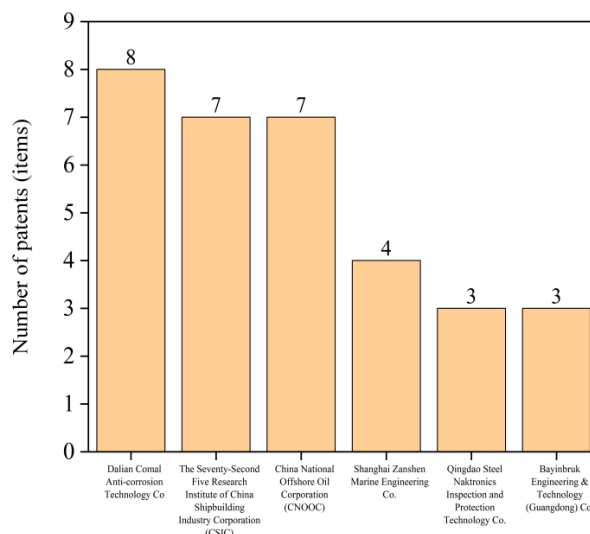


Figure 3. Number of patents filed by significant applicants

4.1. Dalian Comal Anti-corrosion Technology Co.

Dalian Comal Anti-Corrosion Technology Co., Ltd. owns 5 invention patents and 3 utility model patents, and its core technology is the anticorrosion device for ships and marine engineering and the measurement and control system for applied current cathodic protection. The technology dopes a double solid reference electrode device with silver chloride and zinc. Developed an applied current cathodic protection electrode device that can be used in the deep sea, the device's main devices are silver chloride reference electrode, zinc reference electrode, wire, sealing insulation gasket, fixed cable connector, connector, flange, zinc reference electrode, the cable connector flange at the upper end and the silver chloride reference electrode is connected to the flange at the lower end and the zinc reference electrode is connected to the

main body of the internal cavity is equipped with a composite cable connecting the lead-out line, the silver chloride reference electrode, the cable connector and the zinc reference electrode. The inner cavity of the main body is equipped with a connector connecting the composite cable lead wire, the lead wire of the silver chloride reference electrode and the lead wire of the zinc reference electrode. Finally, the gap and the surface of the device are sealed with waterproof glue [7], so that the marine engineering anticorrosion device can adapt to the harsh deep-sea environment, and is suitable for the field of cathodic protection with applied current.

4.2. The Seventy-Second Five Research Institute of China Shipbuilding Industry Corporation (CSIC)

China Shipbuilding Industry Corporation Seventh 25th Research Institute invented 7 items of applied current cathodic protection, of which 6 invention patents, utility model patents for 1, the unit specializes in naval materials and technology and applied research, belongs to the military scientific research institutions, and its invention focuses on the composite anode assembly, the main device consists of anode body, conductive rod, anode bracket, sealing material and casing is composed of. It is mainly applied to offshore projects, such as large ships, pontoons, oil storage vessels, and hydraulic gates and other types of marine metal structures.

4.3. China National Offshore Oil Corporation (CNOOC)

CNOOC has invented 7 patents of applied current cathodic protection, including 4 patents of invention and 3 patents of utility model. These patents include applied current cathodic protection equipment devices, installation process methods and monitoring systems. The invention is an applied current cathodic protection device, which is composed of a process assembly containing an auxiliary anode, an anode tray, an anode bracket, a watertight cover and a terminal. The composition method is to fix the tray on the bracket, the top of the tray has a limit slot which can be used to install the auxiliary anode, the bottom of the tray is fastened with a watertight cover to form a cavity, the tray is opened to connect the limit slot and the watertight cavity with the insertion and connection holes, one end of the junction post is extended to the insertion and connection holes to connect to the auxiliary anode and the other end of the junction post is then connected to the anode's cable and the anode's cable is extended out of the watertight cover, and it can be used in combination with its cabinet-type constant potential meter to reduce the required anode. Joint use, reducing the amount of anode required, significantly reducing the cost pressure [8].

4.4. Research Institutes

Qingdao Institute of Marine Corrosion invented an applied current cathodic protection device on a jack-up platform, and the main device consists of an auxiliary anode, a reference electrode, a current control device and a cable. The current control equipment is installed on the jack-up platform, the auxiliary anode and the reference electrode are fixed on the pile boots of the platform, the auxiliary anode and the reference electrode can be electrically connected to the current control equipment through the cable, and the cable then enters into the pile boots of the platform through the water sealing part. The invention of this research institute has

low operation difficulty, easy installation, long service life, low cost, and no hidden danger of marine ecological pollution [9].

4.5. Other Universities

Wuhan University of Technology, on the other hand, invented a ship applied current cathodic corrosion prevention system. Utilizing the feedback information of the PID of the automatic control system, various parameters are adjusted according to the real-time status of the ship in the marine environment, and the size of the applied current is controlled to adjust the optimal protection voltage [10].

And North China University of Water Conservancy and Hydropower invented a corrosion inhibition method of hydraulic metal using graphite as anode. In the environment where the hydraulic metal is added to a strong electrolyte, and then connect it to the reference electrode with a wire to form a closed loop, the auxiliary anode is connected to the metal components using a wire, the auxiliary anode is connected to the positive electrode, and the metal components are connected to the negative electrode, to be polarized, if the voltage on the surface of the metal components is lower than a certain critical value, then it means that the corrosion is inhibited. And the appropriate corrosion characteristics can be selected by modulating the electrolyte added [11].

5. Analysis of Technical Fields of Patent Applications

Table 1 shows the number of technical patent applications in the field of applied current cathodic protection marine area and its proportion. According to Table 1, it can be seen that the number of patent applications related to process methods in the sample library is 34, accounting for 34% of the entire sample library.

Table 1. Number and percentage of patent applications for implied current cathodic protection process methods

Field	Process method	Device structure	system design
Quantities	34	60	18
Proportions	34%	60%	18%

The number of patent applications related to device structure is 60, accounting for 60% of the entire sample pool. The number of patent applications related to system design is 18, accounting for a relatively small proportion of 18%. Since some of the patents in the sample involve multiple related technical fields, there is an overlap, and the sum of all field's accounts for more than 100%.

5.1. Patent analysis of applied current cathodic protection process method

Figure 4 shows the trend of patent applications for the applied current cathodic protection process. Before 2010, there was no significant innovation in the applied current technology in China, and due to the historical reasons, the majority of offshore platforms were designed with more sacrificial anode programs. However, the sacrificial anode method to service life after the maintenance of complex, costly, technical difficulties, so the applied current method of cathodic protection began to be developed.

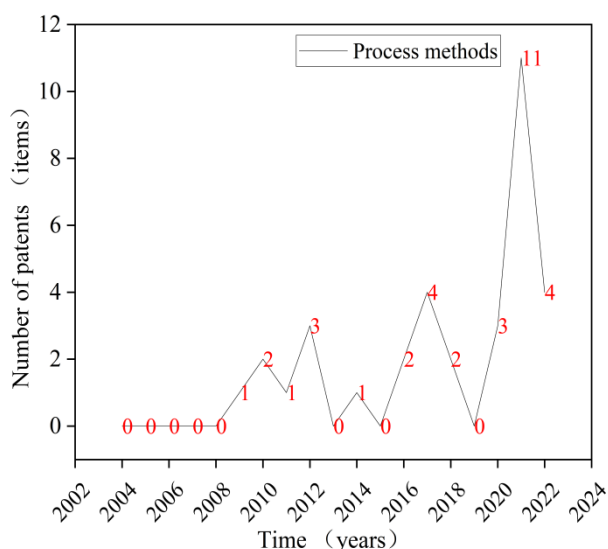


Figure 4. Trend of Patent Application Age of Impressed Current Cathodic Protection Process Methods

5.2. Analysis of patents of applied current cathodic protection device structure

As can be seen from Table 1, there are 60 patents related to the structure of applied current cathodic protection device, accounting for the majority of the total sample library. Figure 5 shows the trend of patent applications for the structure of applied current cathodic protection device. Since 2004, China has started to research and develop equipment and devices for specific applications, and the number of patent applications for this technology has increased significantly over time, with 2020 being the year with the largest number of applications in recent years, with 12 patents applied for.

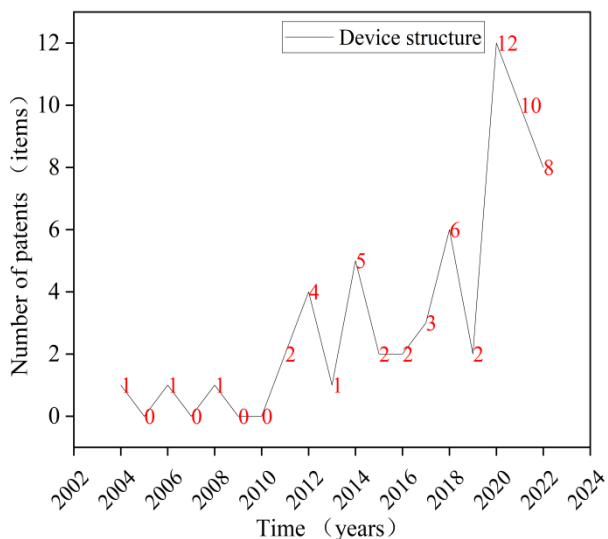


Figure 5. Trend of Patent Application Age of Impressed Current Cathodic Protection Device Structure

With the continuous progress of our knowledge of the ocean, various large-scale marine platforms spring up, but at the same time bring the technical requirements also continue to improve, marine corrosion is the key to the core issues, and cathodic protection in the external current device is simple to operate, low economic costs, has become more and more an indispensable member of the family of corrosion protection.

5.3. Analysis of patents for the design of applied current cathodic protection system

As shown in Table 1, the number of patent applications for the design of applied current cathodic protection system in the sample pool is 18, accounting for 18% of the whole sample pool. Figure 6 shows the trend of patent application chronology of applied current cathodic protection system design. Since 2015, the design of the applied current cathodic protection system has attracted the attention of relevant technicians, and in the recent years, the number of relevant system designs has been increasing.

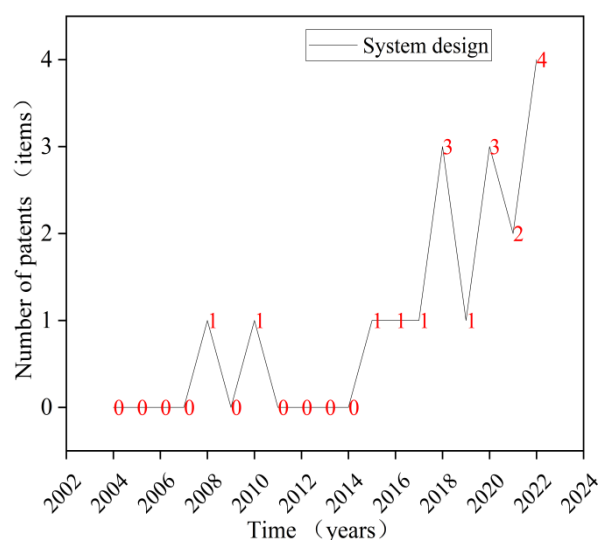


Figure 6. Patent analysis of applied current cathodic protection system design

There are four disadvantages of applied current cathodic protection: 1) Compared with the sacrificial anode method, the applied current method requires an external power source to work properly, so the design of the marine power source is a field that still needs to be developed continuously. 2) Although the underwater construction is simpler than that of the sacrificial anode, the overall technological requirements are still high. 3) The amount of maintenance is high in the later period, and it requires irregular overhauling. 4) The investment cost is low, but the operation cost is high. 5) The investment cost is low, but the operation cost is high, and the operation cost is high. 6) The system design has been developed in accordance with the requirements of the sacrificial anode method. Higher.

6. Summary Analysis of Applied Current Cathodic Protection Patents

According to the technical content of applied current cathodic protection patents, the proportion of utility model patents and invention patents in applied current cathodic protection patents is 45%, and the proportion of invention patents is 55%. before 2011, China's applied current cathodic protection technology was in the period of slow growth, and the number of patent applications was relatively small; after 2011 the number of applications for this kind of patents increased significantly, and the related technical research gradually matured, and the enterprises accounted for the highest proportion of the important applicants. Among the important applicants, the proportion of enterprises is the highest, and the main innovators are Dalian Comal Anti-

Corrosion Technology Co. These enterprises have long-term investment in applied current cathodic protection and also accumulated certain technical advantages.

The patents of China's applied current cathodic protection mainly include three technical fields: process method, device structure and system design technology. The process method mainly includes designing different construction optimization production methods under different marine environment platforms for the specific required environment. Device structure mainly includes various equipment and facilities in practical application, which is also the center area that enterprises pay most attention to. While universities and research institutes pay more attention to the system design of applied current cathodic protection, how to control and monitor in the marine environment. Applied current cathodic protection is mainly applied in cathodic protection corrosion.

As China's knowledge of marine resources increases, and the importance of the technology of marine resources utilization increases, the future of the applied current cathodic protection technology will be further developed.

7. Suggestions for the Development of Applied Current Cathodic Protection

Auxiliary anode is one of the core of applied current cathodic protection, hoping that the state will increase the investment of resources in applied current cathodic protection, improve the basic treatment of scientific researchers, attract more talents to enter into basic scientific research, actively promote the cooperation between industry, academia, and research, and vigorously enhance the sustainable use of marine platform equipment to realize the efficient and green application of marine resources. 2) Strengthen the breakthrough of applied current cathodic protection technology rare earth elements are good for the corrosion resistance of metals, but there is still a lot of room for improvement in the development of its application to the field of applied current cathodic protection, which is used to improve the function of auxiliary anodes^[12]. For example, titanium anode, which can be applied to different environments such as seawater, fresh water, oil wells, is currently considered a more ideal auxiliary anode material.^[13]

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