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Research and Application of Underwater Wet Welding Technology

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Abstract. Underwater wet welding has the characteristics of simple equipment and flexible operation. This paper introduces the basic principle of underwater wet welding, focusing on wet welding by welding materials, welding methods and the influence of water environment.

1. Introduction

With the rapid development of the national economy and the urgent need for energy strategy, marine engineering is constantly advancing to the deep sea. As an important technology in the field of marine engineering, underwater welding is receiving more and more attention. From the installation and construction of offshore oil and gas platforms to the laying and maintenance of submarine pipelines, from offshore salvage rescue work to emergency repair of large ships, underwater welding can be seen everywhere.

2. Difficulties in Underwater Welding

Due to the influence of water environment and underwater pressure, underwater arc combustion, excessive droplets, smelting state and joint performance will have great changes. The main influencing factors are as follows:

2.1. Low Visibility

Water has a strong reflection absorption effect on light, and the light attenuation is obvious. At the same time, the smoke and air bubbles generated during welding make the underwater visual effect very poor, which seriously affects the welding quality.

2.2. There are Many Pores

When the arc is high during welding, the water is decomposed to generate hydrogen, which is easily dissolved in the weld. When the molten metal is cooled, the pores are not easily discharged, and the joint is prone to cracks, which makes it difficult to ensure the quality of the weld.

2.3. The Cooling Rate is Too Fast

The thermal conductivity of water is more than 40 times higher than that of air, and the water has a strong cooling effect on the weld and the metal in the heat affected zone. Since the cooling rate at the weld is too fast, internal stress is formed, resulting in embrittlement of the weld structure, reduced toughness, and cracking.

3. Underwater Welding Method

According to the external environment of underwater welding, the existing underwater welding

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methods mainly include underwater wet welding, dry welding and partial dry welding.

3.1. Underwater Wet Welding
Wet welding means that the welded parts and the welding torch are directly exposed to the underwater environment, and the formation and burning of the arc is done in water. Whether a certain size and stable arc bubble can be formed around the arc during underwater welding is the primary condition for successful underwater welding. The gas in the arc bubble is mainly composed of hydrogen and oxygen formed by high-temperature dissociation of water vapor, and carbon monoxide and carbon dioxide gas which are decomposed and decomposed in the electrode coating, and a small amount of nitrogen and a trace amount of gaseous metal. Since the hydrogen content in the arc atmosphere is large, the hydrogen embrittlement sensitivity becomes a particularly critical problem, greatly reducing the weld strength. However, because wet welding has the advantages of simple equipment, low cost, flexible operation and strong applicability, it has been widely used in the construction, installation and maintenance of offshore engineering, especially in recent years, with the development of the offshore oil industry and various plant services. The increase in the number of years and the increase in the cost of repairing ships into the dock will lead to further development and application of wet underwater welding.

3.2. Underwater Dry Welding
Dry welding refers to the artificial dissection of a large area of water, including the weld, so that the submersible welder can weld in a dry gas phase environment. According to the specific shape, size and position of the engineering structure, it is usually necessary to design a corresponding air chamber. The air chamber needs to have a system of life maintenance, humidity regulation, monitoring, lighting, safety guarantee, communication, and long working time. The water surface support team is huge and the construction cost is high. Therefore, this method is mostly used for deep water, and requires material for preheating or post-weld heat treatment or structural welding with high quality requirements. According to the difference of gas pressure in the underwater air chamber, dry welding is divided into high pressure dry welding and normal pressure dry welding.

3.3. Local Dry Underwater Welding
Partial dry underwater welding uses gas to artificially displace water in a local area around the welded part to form a small gas phase zone in which the arc is stably burned. Local dry welding combines the advantages of both wet and dry processes. Due to the reduced harmful effects of water, the quality of welded joints is significantly improved compared to wet welding.

Underwater wet welding is to directly weld the workpiece in water. There is no isolation between the arc and the water. The arc is only protected by the bubbles generated during the welding process. Its outstanding advantage is that it does not require welding chambers and other auxiliary equipment. Compared with other welding methods, underwater wet welding has the advantages of simple equipment, low cost, flexible operation and strong adaptability, so it has been widely used in engineering and good. Development prospects and technological advancement space.

4. Research Progress of Underwater Wet Welding
The wet-welded welding materials are directly exposed to the water environment, with the advantages of low cost, convenient operation, high production efficiency and simple equipment. It has become a research hotspot of underwater welding technology and has broad development prospects. Underwater wet welding can be divided into electrode arc welding and flux cored wire welding[1].

4.1. Research on Underwater Electrode and Flux Cored Wire
The design of underwater special welding rod is the main subject of wet welding research. When using ordinary land welding rods for underwater welding, there are many weld holes and poor weld formation. When the welding water depth exceeds 30 m, the arc cannot be stably burned under pressure, and the welding process cannot be performed.

In order to adapt to the severe conditions of local dry underwater welding, Ying Liu[2] proposed a new TIG welding method for flux-cored wire. By analyzing the collected spectral information, it was found that elements such as K and Na are unique to the powder. The elements are used as tracking targets. The results show that the active elements K and Na in the powder are concentrated in the arc space above the molten pool, and their distribution is affected by the spacing of the filaments. The closer to the tungsten electrode, the more likely it is to contaminate the tungsten. Compared with the unfilled TIG welding, the arc temperature field of the flux-cored wire TIG welding is distorted to varying degrees by the influence of the droplet transfer. Among them, the arc temperature field of the drop transition is severely distorted, and the spatter is large during the welding process. Compared with the drop transition, the arc temperature field distribution of the slag column transition and the bridging transition is uniform and the welding process is stable, which is suitable for the use of the TIG welding method.

Ning Guo[3] independently developed an underwater wet self-shielded flux-cored wire, which obtained high-quality CCSE36 underwater wet-welded joints in a water depth of 30 m. The welds were well formed, without undercuts, welds, Defects such as pores and cracks. The joint tensile test was broken in the base metal zone, which indicates that there is no problem of joint softening during underwater wet welding. The joint did not break after the 180° bending test and no cracks were produced, indicating that the welded joint had good ductility and shape.

In view of the characteristics and problems of underwater wet welding, Xiaoming Bao[4] developed a neutral-rutile metal powder self-shielded flux-cored wire with a slag basicity of 1.077. The underwater welding test was carried out by using self-protecting flux cored wire, the coverage of weld slag was high, the slag removal property was good, and the weld bead was beautifully formed. Because Ni and Mn elements in this type of self-protecting flux-cored wire occupy a very important position, the content of Ni and Mn in the core is changed on the basis of the original core, and the effect on the slag after welding is analyzed. The influence of the change of Ni or Mn content in the cladding metal on the microstructure of the joint was tested and the mechanical properties of the welded joint were tested and analyzed to obtain the optimum range of Ni and Mn contents in the weld.

Ke Yang[5] studied the microstructure evolution of low-carbon steel flux-cored wire underwater wet-welded joints, and analyzed the effect of water cooling and decomposition on the microstructure of welded joints. The results show that under the underwater welding conditions, the width of the welded HAZ zone is narrower and the grain size of each zone is finer. The microstructure of the HAZ superheat zone of Q235 steel is mainly the mixed structure of lath martensite + granular bainite. The microstructure of the fine-grained zone is martensite + ferrite + hypoeutectoid. The width of the incompletely recrystallized zone is only a few grains wide, and the microstructure is coarse ferrite + pearlite.

4.2. Research on Welding Process

Compared with land welding, the influence of underwater welding on arc and heat loss is serious, resulting in welding quality far less than land. Research on welding process and improvement of welding process play an important role in improving welding quality.

Underwater wet welding is subject to multiple actions such as compression and quenching of water, and its welding process window is narrow, arc stability is poor, and operation requirements are demanding. Improving the arc stability and the quality of welded joints is one of the hotspots and difficulties in the research and application of underwater wet welding. L L Zhang[6] studied the influence law and mechanism of pre-coated water glass on underwater wet welding process. Water glass is an important welding arc stabilizer and surface active material because it is rich in low ionization elements such as potassium and sodium. The results show that in underwater wet welding, water glass is pre-coated in the welding groove of the workpiece, which can produce high ion density and low ionization potential near the underwater arc, which makes the welding arc more stable and the process window of underwater welding. expand.

Wenqian Cheng[7] studied the arc stability of ultrasonic assisted underwater wet welding. The results show that the ultrasonic assisted underwater wet welding has arc extinguishing zone, stable arcing zone and short circuit transition zone; with the increase of welding voltage, the arc extinction time and short circuit transition time decrease, the voltage and current coefficient of variation decreases; when the welding voltage When it is greater than 34V, almost no arc-extinguishing and short-circuit transition process occurs in the welding process, and the welding process is a stable arc welding process. Ultrasonic action can reduce the short circuit transition frequency and improve the stability of the welding arc. The force analysis of the droplets shows that the ultrasonic effect does not change the force type of the droplets and changes the force. The ultrasonic effect reduces the surface tension and the droplet transition is easier, so the number of times and time of the short circuit transition are reduced.

Fangjie Cheng[8] has successfully carried out underwater wet manual multi-layer multi-pass welding with different joint forms, and has carried out butt joint flat welding and lap joint horizontal welding in two water depths of 11 and 22 m in Bohai Sea. Welding test for vertical welding and T-joint vertical welding and ship-shaped position welding. The results show that no defects such as slag inclusion, porosity and unfusion are found in the butt joints and lap joints of the two water depths, and the two joints of the water depth and the lap joint satisfy the AWSD3 in various mechanical properties. 6M; 2010 requirements for Class B connectors. Compared with the weld with a depth of 11 m, the acicular ferrite in the columnar crystal region of the weld at 22 m water depth is reduced, and the bulk ferrite is significantly increased. There is little difference in the microstructure of the coarse-grained zone in the heat-affected zone of the two water-depth joints, which is mainly composed of lath-like martensite.

4.3. Influence of Water Environment on Wet Welding

Underwater wet welding is carried out directly in water. Under these conditions, the welding rod, arc and weldment are inevitably affected by the surrounding environment, which affects the welding metallurgical process and the welded joint structure. Studying the role of water environment in welding and taking corresponding protective measures is of great significance for improving welding quality.

Jing Feng[9] used a high-pressure test chamber to simulate a high-pressure environment, and conducted a V-groove butt-bonded low-carbon steel gas-shielded arc welding test under the condition of an environmental pressure of 0.5 MPa. The humidity monitoring system was used to monitor the surrounding process during the welding process. The humidity of the environment changes, and the mechanical properties of the weld and its microstructure analysis are performed. The results show that the impact toughness of the welded joint decreases with the increase of the relative humidity of the environment; the microstructure of the weld heat affected zone (HAZ) becomes coarse, and a small amount of bainite structure appears, but it can still meet the requirements of the American Welding Society. Requirements for underwater welding procedures (AWSD3.6M-2010).

Cuihua Zhao[10] studied the effects of lateral and longitudinal water flow on the stability of four underwater welding rod welding processes. The results show that the welds of these four kinds of welding rods have different degrees of deviation after welding in the lateral flow, and half of the welds are covered with no slag. In the longitudinal flow, the weld width of the welds is reduced to different extents. small. The weld quality of these four electrodes after welding at 0 ° C and 15 °C water was also investigated. The results show that the penetration depth of TS202A, TS206 and Broco in 0°C water increases, while the weld penetration of TS208 has no obvious change; the melting width of this electrode decreases with the decrease of water temperature, and the residual height decreases with water temperature. And increase. Comparing the weld metallurgy and hardness of the four kinds of welding rods at two water temperatures, it is found that the weld structure of TS260 after welding in 0°C water is obviously coarsened and the hardness is correspondingly increased, while the weld structure and hardness of TS208 and Broco are compared. No significant changes.

Guo Wei[11] studied the underwater arc welding arc spectrum and the influence of water environment of different media such as water, boric acid solution, LiOH solution and boric acid + Li mixed solution on the arc plasma composition and temperature of underwater welding. The arc plasma composition and temperature of onshore welding and underwater welding are compared and analyzed. The results show that different underwater environment media have little effect on the arc plasma composition and temperature of underwater welding. However, compared with onshore welding, underwater arc plasma composition has significantly increased H and O elements than onshore welding. In addition, during the underwater welding process, the arc temperature of the underwater welding is lower than that of the land due to the influence of the water environment.

5. Conclusion

With the development of marine engineering and the further development of deep-sea resources, the importance of underwater welding technology has become more and more prominent. Especially in recent years, with the continuous improvement of underwater welding technology, it is also wading in nuclear power, ports, bridges, etc. The industry has gradually become an indispensable technology, laying a solid technical foundation for China's long-term stable development in the energy field. However, compared with developed countries such as Europe and the United States, China's research on underwater welding started late, and many problems still need to be solved. Arc welding is still the main method of underwater welding. Among them, wet welding is gradually expanding in underwater engineering due to its low cost and simple operation. With the deepening of research on underwater special welding materials, the quality of underwater welding has been continuously improved. The development of new welding materials and the improvement of underwater welding arc stability are the main directions of underwater welding materials research.

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