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Study on Remote Control Underwater Welding Technology Applied in Nuclear Power Station

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Abstract

At present, the work of welding repair for nuclear power station is carried out by the driving welder and the quality is difficult to be ensure. The technology of remote control underwater local dry welding is the development current. So, a suit of remote control underwater local dry automatic welding system for metal inert-gas welding has been developed. It`s key component is a pressure vessel, which can simulate the 30 meter water depth environment. There are three cameras in the welding cabin which can monitor the run state of equipment and welding process. The results of 15 meter water depth welding experiment for 304 and 321 stainless steel show that, the system can satisfy requirements of local dry welding test. These research productions have the vital significance for the development of nuclear power station underwater welding repair technology.

keywords: Nuclear Power Station; Local Dry Welding; Stainless steel

1. Introduction

Since the 1990s, in the overseas, automatic underwater welding repair technology of nuclear power station has been researched cosmically, including Laser welding, GMAW, FCAW, etc and most of them adopt underwater local dry welding[1].

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The technology of underwater local dry welding was invented in the middle of 20 century [2], this method can be used to underwater welding repair for stell structure in the shallow sea and nuclear power station. In our country, study of this technology has been carried out from 20 century 70 years, but because the large-scale construction of nuclear station is started later, its construction and maintenance mainly rely on foreign technology strength,at present.

This research has studied the remote control underwater welding technology for the nuclear power station maintenance. The contents of it includes: underwater welding test device, local dry welding drainage cover and underwater welding process. The results of 304 and 321 stainless steel underwater local dry welding test show that: The welding quality of work piece is satisfied. Weld penetration testing, ultrasonic inspection, ray inspection and mechanical test are completely qualified. Welding test device runs safely and reliably. It can simulate the environment of 15 meters water depth and realize the remote control automatic welding. The local dry welding cover can build local dry environment effectively to ensure the higher welding quality.

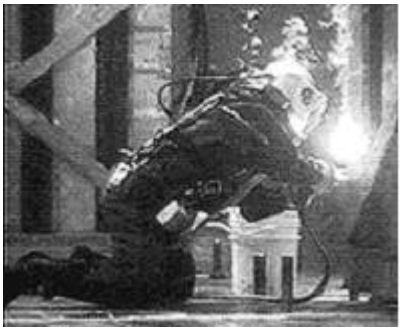

Fig.1 Underwater Welding

2. Underwater welding test device

Fig.2 Underwater welding test device

Underwater welding test device nuclear power station is mainly composed of underwater welding test tank (fig.2), hydraulic drive welding platform (fig.3), air compressor, protect gas store system, electronic control system, monitor system and remote welding operation controller etc. The underwater welding test tank is a vertical tank as the nuclear reactor[3]. In welding experiments, the test tank will be filled with water at bottom and felled high-pressure air by air compressor to build the environment of under water. Diameter of the test tank is 1.6m. The highest working pressure of it achieves to 0.3 MPa.

The welding platform is composed of mobile mechanism, level adjusting mechanism, swinging

mechanism and height adjustment mechanism, which can realize the relative movement between welding torch and work piece. For underwater welding test, welding platform can dive or rise through the lifting mechanism. Lifting mechanism and welding platform are both derived by hydraulic cylinder controlled with the proportion servo valve.

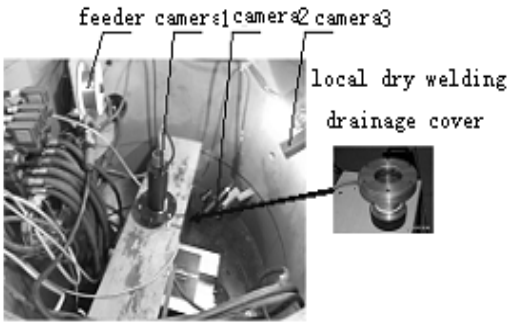

Fig.3 Hydraulic drive welding platform

Local dry welding drainage cover is a key component of underwater remote control welding equipment (fig.4)[4]. Welding monitor camera is installed on the top of drainage cover. An automatic welding lens is placed at its front-end which can according to the light intensity changes adjust the shading degree automatically. So the camera can be used not only for arc monitoring in welding process, but also for check before or after welding. Welding torch inserts the drainage cover from side[5]. Argon gas filled in the drainage cover forms a local dry space around the torch meanwhile as the welding process protection gas. Welding quality is depended on cover size, gasket materials and the type of gas inlet. The drainage cover diameter can be determined by the relationship between weld cooling speed and welding speed. The computation formula is[6]:

$$D_{min} = 2 \times t_{500} \times V_{welding}$$

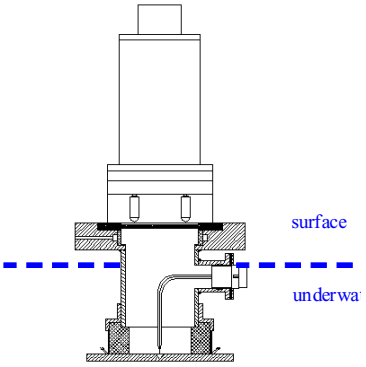

Fig .4 Structure of local dry welding drainage cover

Otherwise, reasonable length-diameter ratio is the key to ensure that, gas flow in drainage cover keeps laminar state[7][8]. Through calculation and analysis, which is more reasonable that, the drainage cover diameter is 130mm and height is 90mm. In addition, the way of gas intake will also have great influence of flow state. The airflow should be decelerated through a metal net, after it enters the drainage cover,

what can ensure that, the air flow distributes reasonably, welding arc burns stably and smoke will be ejected smoothly.

In fact, the design of drainage cover not only can adopt the conventional and empirical way, but also it can be improved further more through the computational fluid dynamics software (for example FLUENT). Base on boundary conditions and initial conditions, such as drainage cover size, inlet way, inlet velocity and so on, the gas velocity distribution, stress distribution and flow state for different parameters can be obtained and canalized by FLUENT software (fig.5). Through that, the structure of drainage cover will be optimized and the stability of the gas flow also can be improved.

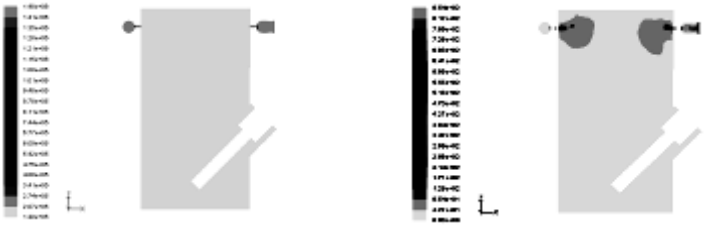

Fig. 5.(a) pressure distribution of gas in drainage cover;(b) velocity distribution of gas in drainage cover

3. Welding experiment

Local dry resurfacing welding and butt welding experiments of 304 and 321 stainless steel have been carried out, which is in the environment of normal pressure,5m water depth and 15m water depth.

Welding power source used in the experiment is Kemppi intelligent digital MIG welding power source. The electric parameters can be inputed through PRO 4200 multi-function panel. This power source adopts unified input[7]. Welding current can match wire speed automatically after the particular welding program has been selected. The other motion parameters of hydraulic driven welding platform are inputted through the special manual control box.

In order to analyse the influence of welding current and arc voltage on welding quality, the hannover arc welding quality analysis system has been used to collect and record parameters real-time(fig.6). In addition,it can also further process and analyze the saved test data by analysis software of this system , which can be used to summarize the relationship between welding quality and welding process parameters.

Fig. 6 Hannover arc welding quality analysis system

The welding test results show that the welding experiment system can operate safely and steadily, the system can achieve the local dry underwater welding. The design of drainage cover is reasonable, it can realize the required functions, such as drainage, welding protect, ejecting smoke and so on. The system

satisfies requirements of welding test for different pressure. The weld appearance is good and no obvious flaw has been found(fig.7).

(c) back side of butt weld

Inspection results of 304 stainless steel work piece weld in environment of 15m water depth show that the welding quality is perfect and satisfies reservation request.

- Penetration test

The resurfacing weld and butt weld of 304 stainless steel produced at the environment of under water 15m depth have been tested by HD penetration material, there is no overweight defects have been found.

- Ultrasonic testing

The resurfacing weld and butt weld of 304 stainless steel produced at the environment of under water 15m depth have been tested by USN - 60 ultrasonic apparatus, there is no defects have been found and the weld quality is eligible.

- Ray test

The butt weld of 304 stainless steel produced at the environment of under water 15m depth has been tested by 2515X rays machine, the results of ray film show that the weld quality is satisfied.

- Mechanics performance test

The results of mechanics performance test for 304 stainless steel welded underwater 15m depth show than the mechanical properties satisfy requirements(Tab.1).

Table. 1 Mechanic performance

Mechanic performance	Tensile strength(N/mm^2)	Extension rate (%)	Impact energy(J)	180°Cold bend	Hardness(HB)

Resurfacing weld	615	36	80	PERFECT	194
Butt weld	570	38	78	PERFECT	192

5. Conclusion

- Underwater welding experiment device can simulates the environment of underwater 0~15m depth, what has laid a foundation for the study of underwater high-pressure welding technology.
- The design of drainage cover is reasonable, it can set up a local dry space in the underwater high-pressure environment. Welding protection gas in the drainage cover flows placidly and the welding arc can stably in it.
- The experiment results of underwater local dry welding for 304 and 321 stainless steel show that, welding quality weld penetration test, ultrasonic test, ray test and mechanical test are approving.
- The underwater local dry welding experiment system provides a platform to the underwater welding process research of material used in nuclear power station . What has the important meaning for development of nuclear power repairing technology in China.

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