Introduction on Research and Application of Exothermic Welding Technology

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Abstract. With the development of society, the welding process presents the trend of diversification, high efficiency and specialization. A variety of advanced modern welding processes begin to replace the traditional welding technology. Exothermic welding is one of them, which is widely used in all kinds of engineering construction due to a lot of advantages. However, exothermic welding also has its own shortcomings, this paper mainly expounded the main shortcomings of exothermic welding, and put forward some improvement methods. Aiming to deepen the understanding of exothermic welding and make better use of this modern welding process.

Keywords: Grounding; Exothermic welding; Defect; Application.

1. Introduction
Grounding facility is a kind of electrical safety measurement to ensure the normal work of electrical equipment and personal safety [1-2]. The grounding device can lead the leakage current, static charge and lightning current that may be generated on the electrical equipment and other production equipment into the underground, so as to avoid personal electric shock and possible fire, explosion as well as other accidents [3-5]. The grounding materials commonly used in China always include galvanized steel, pure copper, copper clad steel and so on, of which galvanized steel is used more than 90% [6]. This is mainly due to the fact that our country is not rich in copper resources, while western countries and the United States are generally used copper or copper clad steel grounding grid. With the development of technology and the improvement of service reliability of power grid, copper or copper clad steel grounding materials are gradually used to lay grounding grid in some key or large projects at home. However, the connection of copper or copper clad steel grounding materials is usually by exothermic welding process.

2. Definition and Application
Exothermic welding is a method by igniting the flux (or electric spark) to trigger the flux redox reaction, release a lot of heat and reduces the filler metal at the same time. The filler metal is finally cooled in the mold cavity to form a joint during welding, which is a kind of self propagating high temperature synthesis technology [7-9]. The characteristics of exothermic welding process are as follows: (1) High current load capacity. The current carrying capacity of the fusion point is equal to that of the base metal,
and there is no need for external power supply and it has good electrical conductivity during welding. (2) Strong resistance to high current impact. The solder joint can withstand repeated large surge current impact without degradation. (3) Stable resistance conversion. Under the impact of normal current and high current, the resistance value of the fusion point surface will not change. (4) Good mechanical properties. Welding point is a permanent molecular binding, which is not loose and aging, and has good mechanical properties. (5) Strong corrosion resistance. The joint after fusion welding has no residual stress and is covered by pure copper, which greatly enhances the corrosion resistance of the conductor. (6) Simple and reliable operation. The exothermic welding method is simple, the work time is short and the training is easy. It can be used to weld copper, copper alloy, all kinds of alloy steel and high resistance heating source. Therefore, exothermic welding is widely used in roads, power stations, distribution and transmission lines, railway electrification, mobile communication base stations and other projects, as well as in the construction of precision instruments, computer rooms, electronic medical equipment, radio and television equipment as an efficient and simple connection method for field construction. The common connection mode of exothermic welding is shown in Figure 1.

![Figure 1. Common welding methods of exothermic welding](image)

3. **Technological process**

Before exothermic welding, the mold and the copper bar join should all be cleaned, and then the cleaned copper bar should be placed in the center of the graphite mold cavity. Graphite mould is mainly composed of mould cover and mould body, and the structure of the mold body is mainly composed of reaction cavity, guide groove and mold cavity. Close the mold and lock the clamp → place the isolation washer at the bottom of the reaction chamber to prevent exothermic flux powder from leaking into the mold cavity → pour the exothermic flux powder into the reaction chamber → sprinkle ignition agent to the reaction chamber → cover the mold cover → ignite the agent with gun to make the exothermic flux powder react chemically → liquid copper melts and the isolation gasket flows into the cavity through the guide groove → two copper bars are fused into one. Finally, after the reaction is completed, let it stand for not less than 120 s, then open the mold and remove the exothermic welding slag [10].
4. Defects and improvements

For exothermic welding, the effect will be different with different environments. Defects such as slag inclusion and non-welding is always formed in the practical application of exothermic welding. Therefore, the discussion of shortcomings and improvement methods of exothermic welding is very meaningful. The common defects during exothermic welding process will be described next.

4.1. Shrinkage

The molten flux steel contacts the plate face and exothermic welding die respectively during welding, due to the heat conduction velocity of these two different medias is different in low temperature environment or inadequate preheating temperature, which will lead to overheating on one side of the model, so that the gas can not be completely discharged or insufficient feeding, resulting in shrinkage cavity and other casting defects [11-12]. However, if the preheating is not uniform such as the temperature of the local track surface at the preheating hole is high, the nearby steel liquid will be slowed down by high temperature solidification. During the long-term operation in the future, fatigue cracks may gradually be formed at the fatigue core, leading to early fatigue fracture of the weld, causing quality and safety problems. The improvement measurements are as follow: (1) Improve the structure of the mold, such as widening both sides of the cavity to increase the water content of the feeding steel at the joint. (2) For the air hole caused by unreasonable preheating process, the preheating scheme should be adjusted and strengthened in time, such as increasing the preheating time appropriately to ensure the preheating temperature in low temperature environment.

4.2. Porosity

Porosity is one of the main defects of exothermic welding, which is formed by the gas produced and released in the solidification process of weld [13-14]. The reasons are as follows: (1) when the welding materials are damped, the gas can not be discharged from the model in time during operation, which makes the joint appear pores. In order to solve this problem, a variety of moisture-proof measures should be taken from the production, transportation and storage of materials to the preheating of on-site construction, such as vacuum packaging of products, heating and drying of molds, etc. (2) the sedimentation time or the exothermic reaction time is not enough. If the exothermic reaction is not sufficient, pores will be formed in the sand mold. The main way to solve this problem is to make the exothermic reaction fully completed.

4.3. Inclusion

Slag inclusion is one of the common defects in exothermic welding casting structure. It is mainly due to premature opening of the die cover, as a result, there is not enough time to separate molten steel and welding slag, so the slag is not floated out in time and forms slag inclusion [15-16]. The improvement measurements are as follows: (1) Use wire brush or polishing machine to polish and clean the main connection part of welding, ensuring clean and dry appearance. (2) Pay attention to clean the mold to prevent slag from falling into it. (3) Run in and match the welding body joint with the die to make the joint fit closely. (4) Ensure that the flux reaction time and calm time is enough.

4.4. Unbonded

After exothermic welding, the area between the parts of the main body is called non-welding [17]. The formation reason is that the cutting of track section is not smooth, the treatment of section is not in place, and there is weak oxide layer on the surface, which all make the fusion uneven. In addition, uneven or insufficient preheating, such as inaccurate gap occlusion at the joint of die and deviation of preheating gun, which makes the end face cooling before complete melting, resulting in no welding. The solutions to this problem are as follows: (1) strictly control preheating technology and process. (2) Before welding, check and ensure that the width of rail joint is moderate. (3) Carefully clean the surface of welded joint. (4) Ensure that the mold is properly installed and engaged.
5. Conclusions
The analysis on main shortcomings and improvement methods of exothermic welding was introduced from the point of view of welding construction. However, different engineering welding may exist other shortcomings, which need specific analysis. In the process of exothermic welding, some shortcomings will directly lead to the increase of grounding resistance, unsatisfactory grounding shunt effect, and even may cause major safety accidents. Therefore, the deficiency of exothermic welding needs to be analyzed according to the actual situation. In the future work, we need to be good at summing up experience, find problems, and summarize the methods to overcome the lack of exothermic welding according to the actual situation.

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