Industrial Practice of Special Welding Technology for Aluminium Electrolysis Cells

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Abstract

In the aluminium electrolysis industry, electrical conductors are primarily connected through welding. This paper investigates direct welding between dissimilar metals such as steel and aluminium, as well as full-section welding of steel sections with very large cross-sections.

The physical properties of steel and aluminium differ significantly, making direct welding susceptible to the formation of brittle compounds and cracks. This study demonstrates that a special welding process, utilizing an auxiliary flux, and selecting effective welding materials and parameters can effectively inhibit compound formation and reduce cracking. Through extensive testing and optimization of welding process conditions and parameters, excellent weld joints with high electrical conductivity and weld strength are achieved. Industrial practice has proven that this technique is suitable for current applications in the aluminium electrolysis industry.

To address the shortcomings of traditional large-section welding between steel sections, this paper proposes a special welding method that achieves joints with properties comparable to those of the base metal. Practical application demonstrates that this technology is effective for current applications in the aluminium electrolysis industry.

Keywords: Welding parameters, Auxiliary flux, Full-section, Intermetallic compound, Electrical conductor.

1. Introduction

With the continuous development and advancement of aluminium electrolysis technology, electrolysis cells are becoming increasingly larger, and the corresponding conductors, such as anode rods, cathode collector bars, aluminium busbars, and aluminium flexibles, are also becoming larger in size. Due to production, processing, and transportation, these workpieces often require welding before use. This paper investigates a steel-aluminium direct welding technique and a narrow-gap full-section welding technique for large-section workpieces. These techniques are applied to direct welding of dissimilar steel and aluminium materials and narrow-gap full-section welding of same materials of large cross-section, respectively. These techniques are primarily used in the aluminium electrolysis industry and are discussed below.

1.1 Research Background on Steel-Aluminium Direct Welding Technology

In the aluminium electrolysis industry, explosion welding clads are currently primarily used for transitional connections between dissimilar metals, such as the welding of anode aluminium rods and steel yokes in anode rod assemblies, and the welding of cathode aluminium flexibles and cathode steel collector bars. Due to the high production cost and inconsistent quality of explosion welding blocks, aluminium smelters invest heavily in developing steel-aluminium dissimilar metal welding.

The physical properties of steel and aluminium are very different, as shown in Table 1, and steel is almost insoluble in aluminium. Therefore, it is easy to generate excessive amounts of brittle intermetallic compounds such as FeAl, $FeAl_3$, and Fe_2Al_5 using ordinary fusion welding technology. When the thickness of the interface compound layer is controlled below 10 µm, the obtained joint can meet the use requirements [1]. As the thickness of the intermetallic compound layer increases, the mechanical properties of the welded joint will decrease sharply. Therefore, controlling the generation of intermetallic compounds is the biggest obstacle to achieving good direct steel-aluminium welding.

Table 1. Comparison of physical properties of steel and aluminium.

Material	Melting Point, °C	Thermal Conductivity W/m·K	Density g/cm^3	Coefficient of Linear Expansion, 10^{-6}/K
Carbon steel Q355	1534	77.5	7.86	11.76
Pure aluminium 1060	660	217.7	2.70	24

Although there are currently some methods that can achieve direct welding of steel and aluminium, they are often costly, inefficient, and difficult to apply in batches in actual production due to high costs, poor operability, and the requirement that the weldment must reach a specific shape.

1.2 Research Background of Narrow-Gap Full-Section Welding Technology for Large-Section Workpieces of the Same Metal Material

In aluminium electrolysis cells, cathode steel collector bars are welded using steel connecting plates, which are manually welded layer by layer into the joint. The high ambient temperature and strong magnetic field during collector bar steel welding significantly impact welding efficiency and quality, they also pose safety risks. Furthermore, the varying welding skills of workers make inspection of completed joints difficult, leading to potentially serious accidents during the cell operation caused by poor welding quality.

Traditional anode steel stub welding is often manual arc welding with a groove. The effective welding area at the joint is far less than the effective cross-section of the base material. The strength and conductivity of the weld are quite different from those of the base material. The welded joint has a short service life after grooving, requires frequent repairs, and has a high cost of use.

In response to the traditional welding repair method of large-section workpieces of the same material, this paper proposes a narrow-gap full-section welding technology. By controlling the heat input, the weld and the base material are completely fused. Protective agents are added during welding to refine the grains and to prevent high-temperature oxidation of the base material. Welded joints with good performance were obtained in the experiment. This method was tested in a magnetic field and it was not affected by it. At present, this method has been widely used on construction sites, which can significantly improve welding quality and efficiency, reduce personnel workload, and reduce voltage drop at the joint and production operation costs.

To date, this technology has shown positive results, reducing the weld voltage drop by approximately 10 mV compared to traditional welding methods.
(Note: The traditional explosive welding method requires replacement every five years. The replacement frequency is around six years after adopting aluminium-steel direct welding.)

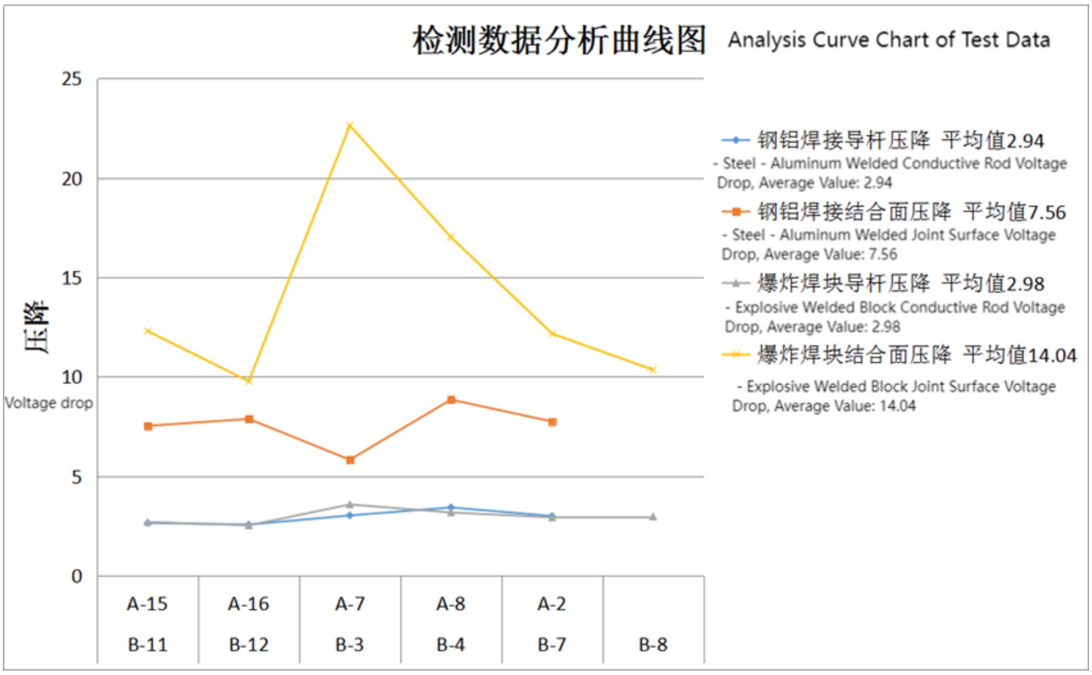

Figure 14. Measured voltage drop at connections. Traditional versus present work.

5.2 Narrow-Gap Full-Section Welding Technology for Large-Cross-Section Workpieces

(1) The narrow-gap full-section welding method changes the welding method for large-section steel connectors, enabling full-section welding. The entire process is automated, eliminating human interference and significantly improving welding efficiency. The mechanical properties of the finished welded joint are comparable to those of the original base material, and its electrical conductivity is comparable to that of the base material. This effectively reduces the voltage drop across the welded joint, which is of great significance for energy conservation and consumption reduction in aluminium electrolysis production.
(2) The narrow gap full-section welding of cathode steel collector bars can be applied to the welding of cathode collector bars with different specifications and sizes in various potlines under strong magnetic field environments. It has been applied in most domestic aluminium smelters with positive field results.
(3) Full-section welding of anode steel stubs significantly improves welding efficiency, ensuring that the finished joints can reach the lifespan of the new steel stubs, significantly reducing production and operating costs.

6. References

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