

Stray Current Corrosion of Aluminum Electrolysis System

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Abstract: The aluminum smelting process requires large amounts of electricity, and the leakage of current from aluminum cells is through the earth forming stray current. Stray current induce corrosion on metallic pipeline and steel in concrete, leading to severe localized attack. Stray current corrosion in the metallic pipeline is totally similar to the classic; stray current rarely can corrosive consequences on steel in concrete, because steel in alkaline and chloride-free concrete is passive, and the high electrical resistivity of concrete. If the driving voltage is increased, the steel embedded in the concrete can be induced to corrode. Stray current corrosion of steel in concrete under single load can be divided into accelerated corrosion and steady development in 2 stages. Stray current can obviously increase the transmission rate of chloride ion into concrete and reduce the time of chloride ion penetrating the concrete to the surface of the steel bar.

1. Introduction

Aluminum is one of the most commonly used metallic elements. Due to its low density, high corrosion resistance and mechanical strength to mass ratio, aluminum alloys are used as a major structural material in aircrafts, buildings, machinery parts, and food wraps. Aluminum would be ideal if this lightness could be combined with the mechanical properties of the Ferrous metals [1]. Aluminum is the most recyclable of all materials.

Aluminum is a highly reactive metal that forms a strong chemical bond with oxygen, so aluminum cannot be produced by the electrolysis of an aluminum salt dissolved in water because of the high reactivity of aluminum with the protons of water and the subsequent formation of hydrogen gas. Therefore, aluminum must be extracted from a solution of purified alumina in a molten salt by electrolysis. The electrolytic process was discovered and patented in 1886 separately and almost simultaneously by Charles Martin Hall and Paul L.T. Héroult. Aluminum oxide is dissolved in molten cryolite, and the molten mixture is electrolyzed using carbon electrodes by passing a direct electric current through it producing pure aluminum metal. Therefore, it is called the Hall-Héroult process for manufacturing aluminum. The key discovery in the development of the aluminum process was that cryolite or sodium hexafluoroaluminate (Na_3AlF_6) was a suitable solvent for the dissolution and electrolysis of alumina (Figure 1). This process is the only method by which aluminum is produced industrially today [1].

In the last 10-20 years many aluminum producers have increased the amperage in their cells, the 600 kA pilot pots were started in August 2012 in China. The primary aluminum producers increased the productivity by raising the current. The annual production capacity for a potline of 300 prebake cells operating at 600 kA and 93% current efficiency is 492,132 mt/year [2].



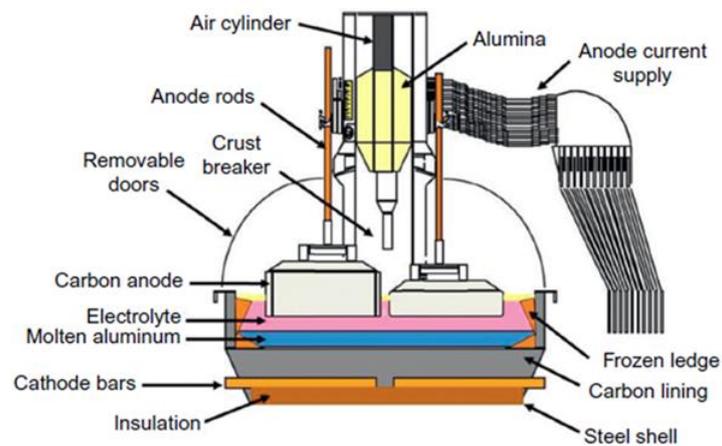


Figure 1 Prebaked anode aluminum electrolysis cell

Electrolysis cells in aluminum plants are arranged in long rows, called potlines where the cells are connected in an electrical series circuit with the transformer and rectifier systems located at one end of the potline. A typical aluminum smelter consists of one to three potlines. Modern 600 kA prebake cells are positioned in a side-by-side arrangement in potlines, as shown in Figure 2. In most designs, the cells are situated above ground with solid aluminum bus bars located at ground level below them with current flow from one cell to another.



Figure 2 Potline of 600 kA prebake aluminum cells

The smelting process requires large amounts of electricity. The inherent risk is the leakage of current from aluminum cells so that part of the current path is through the earth, it is usually known as stray current.

The current deviated from its intended path and escaped to the electrolyte (the soil, concrete or seawater) is called stray current. Stray current may originate from the electrical railways, electrolysis plants, cathodic protection systems, electric cables and large electric plants. It will corrode the metal structures, the damage they do is known as stray current corrosion.

2. Stray Current Corrosion

Stray current, arising from aluminum electrolysis system, induce corrosion on metal pipeline and steel in concrete of aluminum electrolysis plants, leading to severe localized attack [3].

In normal circumstances, the current should be in accordance with the design requirements specified in the flow in the conductor. If some reason, a part of the current left the specified flow in the

original conductor should not be current. This part of the current is called stray current. Stray current mainly comes from the railway current traction system, the cathodic protection system, the DC transmission line and the electrolysis system, and so on. When stray current from outside the prescribed flow into the loop, where the buried metallic pipeline is negatively charged, known as the cathode, in cathode area is generally not affected by stray current corrosion, if the potential value of negative cathode area, surface hydrogen evolution reaction occurs of metallic pipeline, resulting in the area of anti-corrosion coating delamination. Where the current flowing out is called anode. Under the action of stray current, a severe electrochemical reaction occurs in the anode area, which leads to the electrochemical corrosion of metallic pipeline, stray current corrosion. The corrosion of stray current seriously affects the service life and safety of buried metallic pipeline. In extreme conditions, the leakage of metal pipelines and the pollution of soil environment can be caused.

2.1 Corrosion Behavior of Metallic Pipeline

Stray current corrosion in the metallic pipeline is totally similar to the classic one. Where the buried metallic pipeline as the cathode, is generally not affected by the stray current corrosion. If the potential value of a negative area is extremely high, hydrogen evolution reaction occurs on metallic pipeline surface, anti-corrosion coating at the cathodic region will be delaminated. Where stray current flowing out is called anode, a severe electrochemical reaction occurs in the anode area, which leads to the electrochemical corrosion of metallic pipeline (Figure 3). Stray current corrosion may affect the lifetime and safety of the metallic pipeline. Under extreme conditions, induce leakage of metallic pipeline and pollution of soil environment can be caused.

In the early process of anodic dissolution of stray current response of steel, oxidation corrosion products of Fe; after the reaction reaches a certain degree, the surface of the metallic pipeline mutation, passivation film to form a layer of compact, anodic polarization voltage jump; oxygen atom transfer reaction through the base metal and the formation of the passive film anode polarization electric field the passivation film, external passivation film was dissolved and the formation of corrosion products, the passivation film formation and dissolution process caused by alternating polarization voltage oscillation.

Stray current corrosion is very intense. When the 1A DC stray current flows out of the metallic pipeline, it will cause about 10 kilograms of metal iron corrosion in a year. If the 10 kilograms of iron concentrate in 1 square centimeters, it will be equivalent to penetrating 12 meters deep. Especially for the pipeline protected by anticorrosive coating, no anticorrosive coating can be covered by 100%. There will be some pores in the coating, and the damage will also be caused in the construction. If the current is concentrated at a very small corrosion layer, the large current density is focused on the metallic pipeline at this point, then a perforation accident may soon be formed.

Mainly the following characteristics of stray current: (1) stray current corrosion is common, the corrosion of underground metallic pipeline accounted for more than 60% times of perforation; (2) the corrosion speed of up to 10-15 mm / year; (3) stray current corrosion is hidden. No easy to find, easy to cause the occurrence of major accidents in underground metallic pipeline; (4) large losses caused by stray current corrosion.

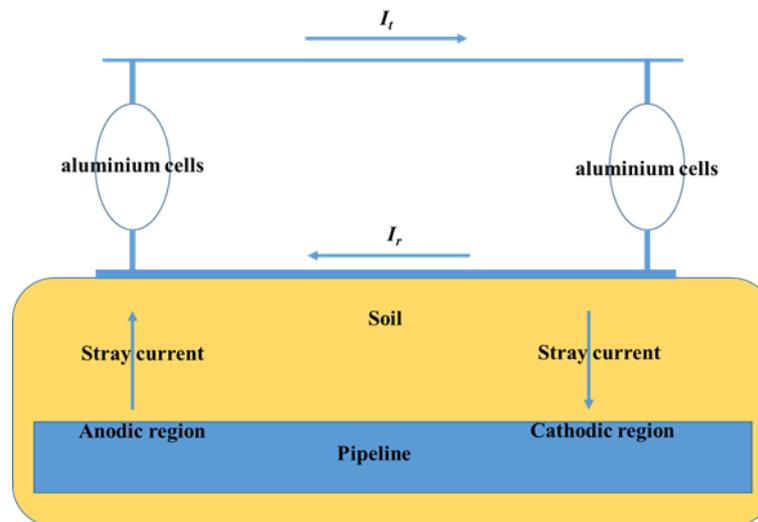


Figure 3 Stray current from aluminum electrolysis system to the metallic pipeline

2.2 Corrosion Behavior of Steel in Concrete

Stray current can also flow through reinforced or prestressed concrete structure and produce electric field inside the concrete structure, which can cause stray current corrosion to the embedded steel in the concrete structure. Concrete, like soil, can be considered an electrolyte system, and the steel in the concrete can pass through stray current. The previous works showed that stray current have not corrosive, in contrast to steel in the soil, because steel without chloride ion in alkaline is passive state. Experimental tests show that non-carbonated and chloride-free state can strengthen the passive state in the concrete, has very resistivity high, requiring a very large driving voltage to produce stray current corrosion [4-5].

Stray current corrosion of steel in concrete under single load can be divided into accelerated corrosion and steady development in 2 stages, and the corrosion of concrete chloride alone under the action of steel is a slow and steady development, and caused by stray current corrosion rate of steel reinforcement corrosion rate with chloride ions caused by the large.

Stray current can obviously increase the transmission rate of chloride ion into concrete and reduce the time of chloride ion penetrating the concrete to the surface of the steel bar. When stray current existed when the chloride ion is accelerated to the concrete invasion, its diffusion depth average value is 7~8 times the natural diffusion conditions, at the same time, the chloride ion is approximately a parabolic distribution in the concrete, and in the vertical direction of the maximum depth of reinforced ion intrusion. The greater the stray current intensity, the higher the chloride concentration and the longer the corrosion age, the higher the chloride content in the deep layer of the concrete is, the greater the durability of the structure will be.

Corrosion of the reinforced concrete structure is accelerated under the double factor corrosion of the stray current and chlorine salt. Due to the coupling of stray current and chloride ion, stray current can accelerate chloride ion to migrate into the concrete, and the corrosion rate of the steel bar increases obviously, shortening the time of cracking from the passivation state to the concrete protection layer in the concrete.

3. Conclusion

The aluminum smelting requires large amounts of electricity, the leakage of current from aluminum cells is through the earth forming stray current. Stray current induce corrosion on metallic pipeline and steel in concrete, leading to severe localized attack.

Stray current corrosion in the metallic pipeline is totally similar to the classic one. Where the buried metallic pipeline as the cathode, is generally not affected by the stray current corrosion. Where

stray current flowing out is called anode, a severe electrochemical reaction occurs in the anode area, which leads to the electrochemical corrosion of metallic pipeline. Stray current corrosion is very intense. When the 1A DC stray current flows out of the metallic pipeline, it will cause about 10 kilograms of metal iron corrosion in a year.

Stray current rarely have corrosive consequences on steel in concrete, because steel in alkaline and chloride-free concrete is passive, and the high electrical resistivity of concrete. If the driving voltage is increased, the steel embedded in the concrete can be induced to corrode. Stray current corrosion of steel in concrete under single load can be divided into accelerated corrosion and steady development in 2 stages. Stray current can obviously increase the transmission rate of chloride ion into concrete and reduce the time of chloride ion penetrating the concrete to the surface of the steel bar.

Acknowledgements

This work was financially supported by Science and Technology Research Project in Henan Province of China (162102210325)

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