Inhibition of Corrosion in a Low Environmental Impact Method

Anticorrosion technology for sluice gates using a new method of reinforcing passive films on stainless steel

Recently, stainless steel is being used more extensively as a material for sluice gates. Even if made of stainless steel, however, some parts of sluice gates can corrode. We have therefore developed an eco-friendly passivation treatment method that allows passivation treatment to be conducted at factories and construction sites to improve the corrosion resistance of stainless steel. We then confirmed the effectiveness of new treatment method on actual sluice gates.

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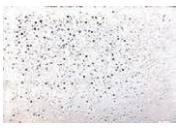
Rust formed on a stainless steel sluice gate

Sluice gates

Sluice gates are installed across rivers or water channels to control the flow distribution, volume of water or to utilize the water. They are categorized into several types according to the objectives, i. e., diversion sluice gates, regulation floodgates, tide sluices, and control sluice gates, etc. Diversion sluice gates divert river streams, regulation floodgates control the water level of a dam or a lake, tide sluices limit the water level of a river, caused by a storm surge or a tsunami, to prevent a flood, and control sluice gates prevent the reverse flow of water from a main to branch streams.

Currently used sluice gates in Japan are also categorized according to the structure, i. e., slide gates, roller gates, and miter gates, etc. The slide gate has a gate-leaf simply sliding up/down between two facing guide grooves. A roller gate has rollers at both ends of the gate leaves. These rollers ensure smooth move up/down of gate leaves. This makes roller gates applicable to large-scale sluice gates, which are subjected to high water pressure. In addition, roller gates are often used for river structures because of the easy and high-reliability water seal. Both slide gates and roller gates mainly employ the wire rope winch to open/close the gate leaves. A miter gate has a double-door structure. This structure makes the gate difficult to open/close under water pressure, but it does not need any top structure. Therefore, the miter gate is often used in a water channel such as a canal through which tall vessels pass.

	No treatment	Passivation treatment (conventional method)	Passivation treatment (new method: immersion)	Passivation treatment (new method: gel)
Before testing				
After testing				

Comparison of corrosion states among passivation treatment methods

Besides the aforementioned types, IHI Infrastructure Systems Co., Ltd. has independently developed a type of sluice gate called a dolphin gate, which is a system designed to regulate the flow rate or water level by rotating a semi-cylindrical gate leave. The dolphin gate has no gatepost above water level unlike the roller gate. This structure enables to lower the height and to minimize the damage to the landscape.

Corrosion of stainless steel sluice gates

Recently, stainless steel is used increasingly as a material of sluice gates according to the need of the running-cost reduction and improving maintainability.

Stainless steel intrinsically has higher corrosion resistance than ordinary steel materials thanks to the passive film consisting of two layers, a chromium oxide layer and a hydroxide layer. However, sluice gates used in the salt-damage environments, such as brackish estuaries or mountain dams using the snow-melting agent, sometimes arise damages: a moth-eaten-appearance pitting corrosion on the surface, crevice corrosion or stress corrosion cracking, etc. They sometimes require to repair.

Passivation treatment of sluice gates

For these reasons, the passivation treatment is applied to the sluice gates to improve their corrosion resistance.

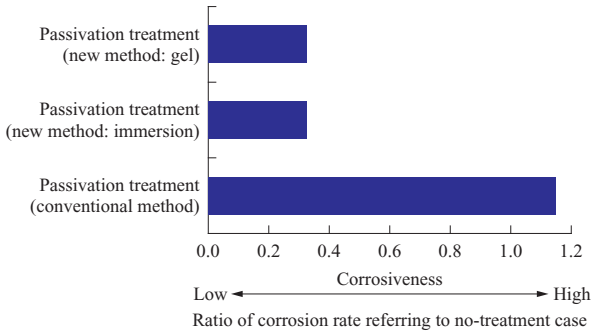
The manufacturing process of sluice gates at the factory typically includes some steps: machining → pickling → passivation treatment, and at the construction site: assembly/welding of parts → grinder finishing. Stainless steel intrinsically has high corrosion resistance because of a passive film. However, under processing such as machining and polishing, it becomes susceptible to corrosion because the passive film is removed from those surface. At a factory, the corrosion of processed parts can be inhibited by applying a passivation treatment after the machining. At a construction site, however, it is difficult environment to perform pickling after grinder finishing because environmental load is high. Therefore, the corrosion can easily be arose in such environment.

Immersion treatment in nitric acid or chromic acid has generally been used as a passivation treatment method for large-size stainless steel products such as sluice gates. However, the significant impacts on the environment, due to strongly acidic solutions, have remained to be addressed. Thus, we recently developed an eco-friendly passivation treatment method that provides excellent corrosion resistance, thereby solving this issue.

A sample plate being applied with the hydrogen peroxide gel

Eco-friendly passivation treatment method

We used hydrogen peroxide solution as the processing solution for passivation treatment instead of the conventional nitric acid. Hydrogen peroxide solution is a weakly acidic (pH: 5–6) and unstable substance. It has the character



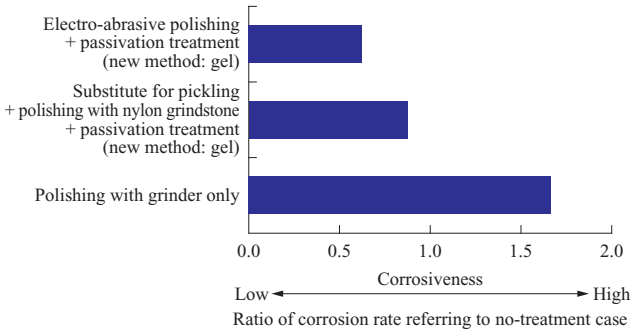
Comparison of corrosion rate various passivation treatment methods

decomposing the organic substances or iron into harmless water and oxygen. When it reacts with chromium on the surface of stainless steel, it produces water and chromic oxide, contributing to the corrosion resistance of stainless steel. Furthermore, the reaction products are harmless water and oxygen only, hydrogen peroxide solution can be used for treatment not only in a factory but also at a construction site where outflow to a river or an ocean is concerned about.

In order to verify the effectiveness of hydrogen peroxide solution, an accelerated pitting-corrosion test was conducted on SUS304 stainless steel samples immersed in a simulated salt-damage environment after being treated in hydrogen peroxide solution. The test results demonstrated that samples treated with hydrogen peroxide solution were superior in terms of corrosion resistance to untreated samples and those subjected to the conventional treatment method.

Treatment method for improving workability

Even though hydrogen peroxide solution has been proven to be effective as a means of improving corrosion resistance, it is impossible to immerse large steel materials in a processing solution at a construction site. Even if the processing solution is directly applied to the steel materials, it cannot remain to adhere to the target surfaces long enough to form an adequate passive film, being required for the improvement of corrosion resistance. To solve this problem, we developed a stably adhering hydrogen peroxide gel by adding sodium carboxymethyl-cellulose (CMC) to hydrogen peroxide solution as a thickener to give viscosity. We conducted a drip test using samples and successfully confirmed that the hydrogen peroxide gel did not drip and kept wet during two hours of treatment even if the sample plates were erected and brushed. In addition, we conducted an accelerated pitting corrosion test using SUS304 stainless steel samples in above mentioned method and compared their corrosion resistance. A comparison in corrosion rate was made between samples subjected to treatment with hydrogen peroxide gel and those subjected to immersion treatment with hydrogen peroxide solution. The samples treated with hydrogen peroxide gel exhibited corrosion resistance comparable to that of the samples subjected to immersion treatment. Given this, it was demonstrated that hydrogen peroxide gel thickened by sodium CMC is a practical treatment solution.



Comparison in corrosion condition among polishing methods

Treatment substituting for pickling and polishing with a grinder

Even though above eco-friendly passivation treatment method has been developed, the conventional method still has significant impacts on the environment because pickling also uses strongly acidic liquid, preceeding the passivation treatment. In addition, polishing with a grinder, which is performed at the construction site, strips the steel of the passive film that has been formed on it. As a result, pickling and passivation treatment need to be done twice. We therefore devised a method substituting these successive steps with the following two steps: simultaneously pickling with a weakly acidic aqueous solution of an eco-friendly substance such as acetic acid, citric acid, or malic acid, and physical polishing with a nylon grindstone; and subsequent passivation treatment with hydrogen peroxide gel.

As a result of trial for many different weakly acidic chemical agents, it was demonstrated that the mixture of salt and malic acid was the most effective. It was also shown that the addition of malic acid to hydrogen peroxide gel in passivation treatment improved corrosion resistance.

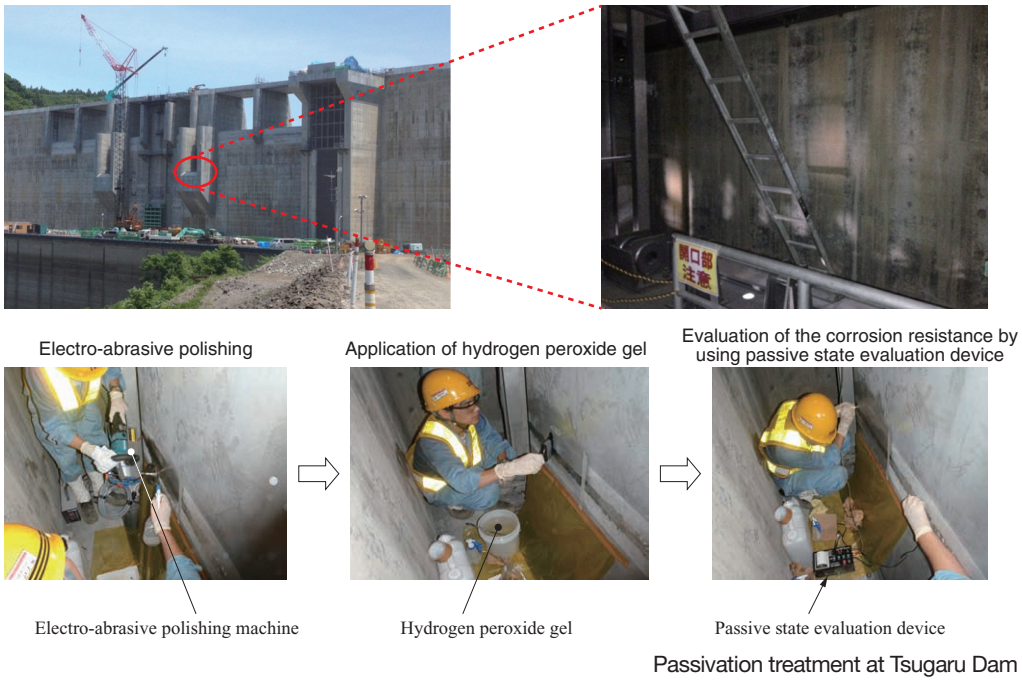
Electro-abrasive polishing instead of conventional pickling and polishing

Whereas it was clarified that a mixture of salt and malic acid was effective as an alternative processing solution for pickling, it was shown that physical polishing with a nylon grindstone might create uneven corrosion resistance, depending on the polishing conditions of the nylon grindstone. We therefore focused our attention on an electro-abrasive polishing method, which further facilitates chemical action and enables stable physical polishing. Electro-abrasive polishing is a method that combines electrolytic polishing, which has an effect equivalent to pickling, with mechanical polishing. A non-woven fabric is immersed in above mentioned mixture of salt and malic acid, and then it is attached to a stainless-steel-polishing electrode. Finally, the electrode is energized as an anode to polish the stainless steel member. This method eliminates the need to immerse steel materials in a processing solution as required by conventional pickling, enabling treatment at a construction site as well.

We conducted an accelerated pitting corrosion test using SUS304 stainless steel samples that had been heat-treated in atmosphere at 600°C to simulate burning by welding, and then confirmed the validity of electro-abrasive polishing. As a result, we successfully confirmed that in terms of corrosion resistance, electro-abrasive polishing was superior to polishing with a grinder as well as to the treatment that combines the substitute for pickling with grinding with a nylon grindstone.

Application to actual sluice gates and verification of effectiveness

The recently developed method has already been used for the



Passivation treatment at Tsugaru Dam

Passivation treatment at Tsuruda Dam

sluice gates at Tsugaru Dam (Aomori Prefecture) and Tsuruda Dam (Kagoshima Prefecture).

For Tsugaru Dam, the gate leaves (two gates; 4.4 m^2) were treated. For Tsuruda Dam, the girder ends on the side surfaces of each gate leaf (Nos. 1 to 3) were treated over an area of 5.19 m^2.

For both dams, we evaluated the locations that had been subjected to one of the treatment types using a passive state evaluation device and confirmed that the corrosion resistance of the parts subjected to electro-abrasive polishing and passivation treatment had improved. No corrosion was identified with the visual inspection, even after more than a year since treatment.

Future outlook

With the aim of improving the corrosion resistance of stainless steel sluice gates, we developed an eco-friendly passivation treatment method that allows for the implementation of passivation treatment at factories and construction sites.

Our next step is to optimize the conditions for electro-abrasive polishing, including the type and concentration of processing solution, as well as processing time, in order to enable treatment to be implemented at construction sites, thereby increasing the number of applications to sluice gates. In addition, we will verify the effectiveness of this method to microbially induced corrosion, which frequently occurs on stainless steel discharge conduits.

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