System development of pure nickel plating process for RPV cladding repair

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1. Introduction

The carbon/low alloy steel of a RPV(Reactor Pressure Vessel) bottom region was exposed to primary water due to an accident of a thermal sleeve detachment of cladding layer. The damaged area might be grown every year due to the less corrosion resistance. Repairing the inside of the reactor vessel is challenging because of high radiation levels and poor accessibility. One promising repair method is Ni electrochemical deposition(ECD) by using nickel [1]. Electrolytic plating inside a damaged region does not induce deformation and hence a negligible residual stress, so a post heat treatment for a stress relief is not required, thus avoiding the associated heat affected zone. Especially, it has also been reported that Ni plating of a relatively higher deposition rate and a lower internal stress are obtained in a Ni sulfamate bath rather than Ni chloride and sulfate baths [2].

The ECD technology used to repair the cladding was approved in 2013 as the ASME code case N-840(CC N-840). The CC N-840 defines the requirements and variables controlled by the ECD in underwater cladding repair application [3].

This article aims to address how the plating process was established to create the test procedures and to discuss what factors should be taken into account in order to produce a uniform coating layer.

2. Procedure for establishment of ECD conditions

2.1 Functions of the plating system

Fig. 1 shows the sequential plating tank, which is designed to allow the Ni plating solution to be transported sequentially, including the pretreatment solution. The four magnetic pumps quickly transferred the pretreatment solutions to induce degreasing, activation and strike layer formation on the Type 304 stainless steel specimen. The metering pump transferred the Ni plating solution at a rate of 300cc/min to induce a plating reaction. Since the strike formation and the Ni plating solution should be performed at a temperature of 40 to 60 degrees Celsius, a sequential plating bath is equipped with a heater. And a stirrer is equipped to stir the plating solution of 1.39mol/l of Ni sulfamate and 0.65mol/l of boric acid.

Fig. 2 shows the plating chamber connected to the sequential plating bath.

The plating chamber is located above Type 304 stainless steel. Which is pressed onto the specimen by the suction force of the vacuum pump so that the circulating plating liquid does not leak out.

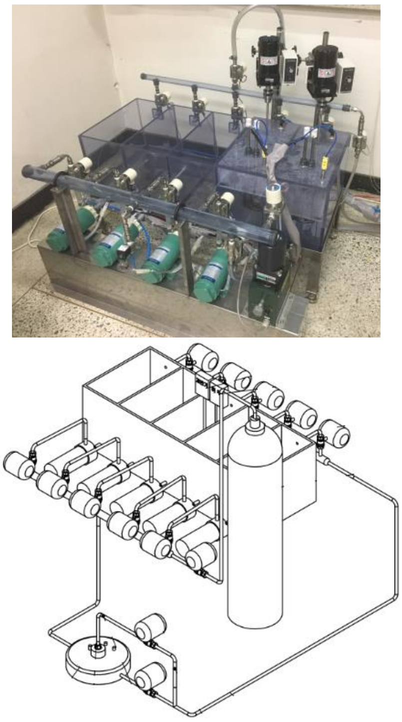

Fig. 1 Photograph of the sequential plating tank developed by KAERI.

Fig. 2 Photograph of the plating chamber on the Type 304 stainless steel specimen developed by KAERI.

2.2 Preparation of test procedures

All the processes except for filling the plating solution into the plating bath were operated by touching through the control panel.

The purpose of the test procedure development is to ensure that the person who first accesses the device can do the same while watching the procedure. Therefore, all the actions from the beginning to the end were written with photographs.

Since the plating conditions are limited by temperature, pH, current density, plating time, and so on, it is easy to follow. The preparation process, however, was harsh because a sequence of operation was performed in accordance with the manufactured apparatus.

When the temperature of the plating solution falls below 40 degrees, precipitates are formed. This is because the dissolved boric acid has solidified again. This boric acid acts as a levelling agent for the plated layer, reduces internal stress and buffers the solution. However, as mentioned above, it is easy to solidify and becomes the main cause of the clogging of the pumps.

Therefore, it was necessary to heat the plating solution separately from the hot plate before the plating, and at the same time, to fill the plating bath with pure water to heat it to 60 degrees. This warmed pure water will circulate for cleaning of the plating system before proceeding with the Ni plating after the strike plating. Then the plating solution will not remain in the piping and the pump will not clog. These are well reflected in the test procedure.

In addition, the test procedure includes several certifications, which include items asking if you have performed each procedure well. All answers should be checked 'yes', and the author and the signer must be signed at the bottom.

3. Considerations for the intended plating layer

There is a special point in the plating chamber, in which the anode is located. Due to the characteristics of the plating, the current is more likely to be distributed at the edge of the cathode when the current is applied, which is why the plating layer is formed unevenly on the edge of the specimen [4]. To solve this problem, the nickel anode is wrapped in a PVC basket with a small hole as shown in Fig. 3. Then, the nickel cations generated by the oxidation of the anode

are directed to the cathode, but it can not move along the current distribution but only through the hole. The next thing to do is rotate this basket. The cations will be uniformly deposited on the specimen through the rotating holes.

Fig. 3 Anode assembly with shielding basket (left side) and without shielding basket (right side)

4. Strategy for cladding repair at NPPs

After the development of the technology is completed, the maintenance entity develops a device for field application, and the power generation utility submits the license document to the regulatory agency for the repair of the damaged area.

When the repair using the plating technology developed through this process is carried out, it is expected that the safety of the nuclear power plant will be greatly improved and the operation efficiency will be greatly improved also by shortening the maintenance period.

5. Conclusions

- The carbon/low alloy steel of a RPV bottom region was exposed to primary water due to an accident of a thermal sleeve detachment of cladding layer.
- The code case N-840 was approved by ASME for the application of pure nickel plating technology.
- A device for plating was designed and test procedures were developed to establish the plating process.
- Current distribution is most important, so a shielding basket was attached to the anode electrode to suppress the current density distribution at the edge of the plating layer.
- It is expected that the safety of the nuclear power plant will be greatly improved and the operation efficiency will be greatly improved also by shortening the maintenance period.

REFERENCES

[1] Myong-Jin Kim, Dong Jin Kim, Joung Soo Kim, Hong Pyo Kim, Seong Sik Hwang, "TECHNICAL BASIS FOR PROPOSED CODE CASE OF ALTERNATIVE RULES FOR CLADDING REPAIR BY UNDERWATER ELECTROCHEMICAL DEPOSITION IN CLASS 1 AND 2 APPLICATIONS", 2013 ASME Pressure Vessels and Piping Division Conference, PVP2013-97857, 2013

[2] Dong-jin Kim, Myong Jin Kim, Joung Soo Kim, Hong Pyo Kim, "Material characteristics of Ni-P-B electrodeposits obtained from a sulfamate solution", Surface & Coatings Technology 202 (2008) 2519-2526.

[3] Code Case N-840, "Cladding repair by Underwater Electrochemical Deposition in Class 1 and 2 Applications Section XI, Division 1, Jan. 23, 2014.

[4]https://www.nickelinstitute.org/MediaCentre/Publications/NickelPlatingHandbook.aspx