A cold spray coating technique for manufacturing a disposal canister

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1. Introduction

The final solution for the management of a high-level waste (HLW) including spent fuels should be a geological disposal. All the geological disposal systems depend on a disposal canister for the isolation of radionuclides from the biosphere for a period between a thousand years and hundred thousand years.

Most countries operating NPPs are developing their own disposal canisters depending on their geological conditions or characteristics of HLW. Copper and carbon steel are the widely used materials as the outer shell of a disposal canister. Copper was selected as a canister material in Sweden due to its high corrosion-resistant properties. Swedish geological disposal system was developed based on the 5 cm copper canister, which guarantees more than 100,000 years of lifespan but requires high cost for manufacturing.

KAERI has developed several kinds of copper-cast iron canisters for PWR and CANDU spent fuel and HLW from the pyroprocessing. Recently, KAERI tried to develop a new technique for manufacturing a thinner copper outer shell to save the amount of copper. So far the cold spray coating technique showed a good result to fabricate a 10 mm copper canister.

The main purpose of this paper is to introduce the properties of a copper canister fabricated by the cold spray technique and future plan for the scale-up of manufacturing facility.

2. Manufacture of a canister

The inner container of the disposal canister can be fabricated simply at a casting foundry. An inner container has been successfully made at half scale by a casting method. However, it is difficult to make the thickness of the outer-shell of the copper in a disposal canister 10 mm because it is too thin to apply to conventional manufacturing methods like piercing and drawing, extruding, and forging due to the flexibility of pure copper. Thus, a cold spray coating method is first applied to make a 10 mm thick copper shell onto an inner cast-iron container directly.

The cold spray coating technology is relatively new. It spurts soft metal powders ranged from 1 μm to around 50 μm (maximum 200 μm) in diameter onto a target surface at supersonic speed with the aid of a carrier gas. A solid state coating is then achieved due to the plastic deformation from the kinetic energy. Cold spray coating has advantages in that the layer formed is clean, dense, and thick compared with the thermal sprayed coating. Cold spray coated copper shows a high Modulus and its breaking strength is 2-3 times higher; however, it is slightly brittle. This coating also has an attractive advantage in that the copper is not oxidized entirely maintaining its basic purity.

A small disposal canister is manufactured at a 1/10 scale applying the cold spray coating method. The inner container is fabricated by casting and machining. The thickness of the copper layer formed on the surface using the cold spray coating method is over 10 mm (Fig. 1). The bottom part is also formed by cold spray coating.

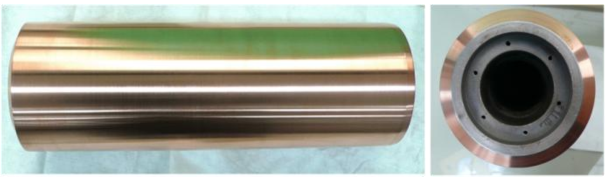

Fig. 1. Copper-cast iron disposal canister at 1/10 scale fabricated by cold spray coating.

3. Corrosion resistance

The copper coating was studied to determine if it can resist corrosion for 1,000 years at a deep disposal place. The disposal canister will be disposed of into a deep geological formation at a depth of 500 m below ground.

The major ionic components of the groundwater sampled from KURT at a depth of 200 m are analyzed. The Eh of the groundwater is about -380 mV, which is less than the corrosion potential of copper, -100 mV. The pH of the groundwater indicates weak alkaline of pH 8.1. The temperature is constant to about 15.4℃ throughout the whole year.

Environmental corrosion tests were performed for various coppers in a simulated repository condition in a laboratory. The test specimens were placed between Gyeongju compacted bentonite blocks in a water-permeable titanium vessel, and then immerged in groundwater collected from KURT. The results of a 2-year test showed that all the coppers exhibited extremely low corrosion rates of less than 1 μm/yr, and there were no signs of local corrosion on the surfaces (Fig. 2).

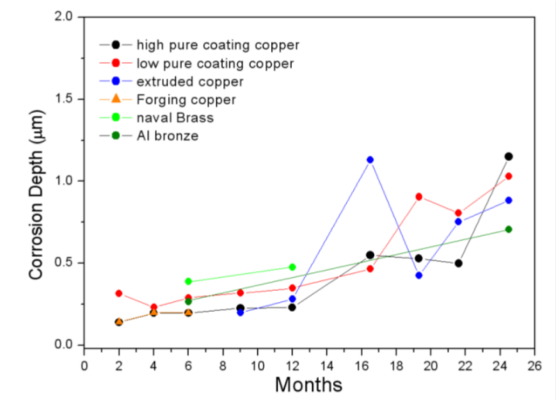

Fig. 2. Corrosion depths of copper specimens in a simulated environment in a laboratory.

A long-term corrosion test was performed at KURT, in which groundwater collected from a deep borehole was then transferred to a titanium vessel continuously to simulate a deep geological repository condition. The corrosion rate was less than 0.2 μm/yr. The corrosion depths of the coated coppers are not as different as other normal coppers. Consequently, it was concluded that a 10 mm thick coated copper shell is sufficient as a corrosion barrier for 1,000 years under the disposal environments. Using the corrosion rates measured at KURT, the lifetime of a copper canister was estimated. The corrosion depth of most coppers appeared to be less than 0.2 μm for 365 days. Even if the corrosion rate is conservatively set to 0.2 μm/yr, the lifetime of a 10 mm thick copper canister is expected to be much longer than 10,000 years.

4. Future plan

A new fabrication technique was successively introduced to manufacture a small scale disposal canister. 1/10 scale disposal canister showed a good containment performance from the corrosion experiments conducted at a laboratory and in KURT. The size of a real scale canister for HLW is around 100 cm in diameter and 175 cm in height, which means that the scale-up of the canister should be demonstrated to be utilized in the future. During the five year R&D project from 2012 to 2016, KAERI plans to demonstrate the manufacture of a 1/3 scale 10 mm thick disposal canister using the cold spray coating technique. The performance of a engineered barrier system (EBS) including the canister will be demonstrated at the DEBS (Demonstration of EBS, Fig. 3) facility in KURT. The corrosion behavior of cold sprayed copper will be investigated at the in-situ facility, and the Thermo-Hydro-Mechanical behavior of the EBS will be studied at the facility, and the experimental results will be used for the validation of a THM program which will be developed by KAERI. The final validation results will be reviewed through the DECOVALEX-2015 international co-work project.

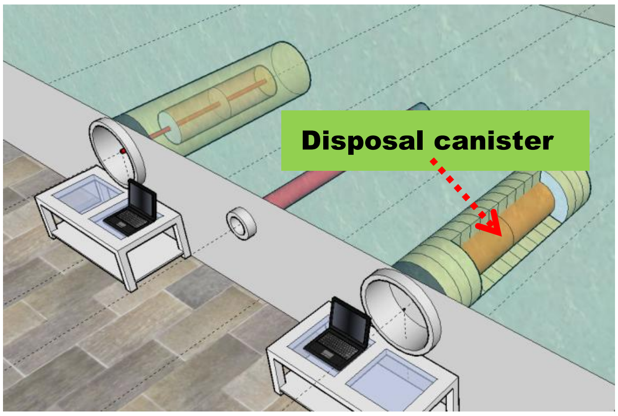

Fig. 3. DEBS-KURT facility for the demonstration of EBS performance.

5. Conclusion

The copper disposal canister for HLW was successfully manufactured using a new technique, cold spray coating. The cold sprayed copper showed a good corrosion resistance under the KURT condition. Based on the previous research results, KAERI plans to demonstrate the manufacture of a 1/3 scale 10 mm thick disposal canister using the cold spray coating technique during the next stage R&D project.

Acknowledgement

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