Experience in manufacturing a disposal canister

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1. Introduction

The primary engineered barrier of a geological disposal system is a disposal canister. The disposal canister should protect the release of radioactive material for a period. Two kinds of materials are widely studied for the disposal canister, copper and carbon steel. The copper is proposed for the period longer than hundred thousand years, and the carbon steel for the relatively shorter period. Sweden, Finland, and Canada consider copper as a candidate material, whilst France, Japan, and Switzerland consider carbon steel.

The safety of the Swedish and Finnish geological disposal systems is based on the 50 mm copper canister, which guarantees longer than 100,000 years of lifetime but requires huge amount of copper. KAERI designed several kinds of copper-cast iron canisters for the spent fuel and HLW from the pyroprocessing. KAERI has developed a cold spray coating technique for manufacturing a thinner copper outer shell. Using the cold spray coating technique, 1/10 scale disposal canister was fabricated with 10 mm copper layer [1].

KAERI plans to install a medium scale in-situ demonstration facility at KURT called In-DEBS (In-situ Demonstration of EBS performance at KURT). For this purpose, a cold spray coating machine was scaled up, and one 1/3 scale disposal canister was manufactured with 8 mm copper layer. In parallel with the scale-up, the long-term corrosion tests at KURT continue, and a COMSOL-based numerical model for the corrosion test is developed.

The main purpose of this paper is to introduce the progress in the development of a medium-size copper canister manufactured by the cold spray technique and corrosion study.

2. Scale-up of a copper disposal canister

In Swedish and Finnish program, oxygen-free, phosphorous-doped (OFP) copper was selected for a disposal canister. The greatest advantage of copper is thermodynamically stable in oxygen free waster in the absence of sulphide ions. Thus, the corrosion of copper stops once all the oxygen trapped around the canister was consumed. Copper under the geological disposal conditions (GDC) will be subject to the general corrosion. According to the Canadian estimation [2], the corrosion depth of copper under GDC was 1.27 mm for 1 million years. Compared with this thickness, the Swedish copper canister was too thick. Thus, KAERI designed a 10 mm copper canister for HLW from pyroprocessing [3]. It is difficult to make 10 mm copper canister with the conventional manufacturing methods such as pierce-and-drawing or extruding. Thus, KAERI tried a cold spray coating technique to make a 10 mm thick copper shell onto an inner cast-iron container directly. A small disposal canister was manufactured at a 1/10 scale applying the cold spray coating technique [1].

In this study KAERI developed and scaled up a cold spray coating machine (Fig. 1) to fabricate a medium size canister which would be used for the In-DEBS experiment. The gas heater capacity was upgraded by 40 percent. The nozzle and chamber of the machine were newly designed and tested. Through the preliminary test, the coating conditions were determined. The main gas temperature was set to be 550℃. Using the machine, a medium-size, 400 mm in diameter and 1,200 mm in height, disposal canister with 8 mm thickness was manufactured (Fig. 2). As described in the previous paper [1], the cold spray coating has several 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. In order to confirm the advantages, several kinds of tests were carried out. Also, to overcome the brittleness of the cold sprayed copper, annealing was tried at the elevated temperatures.

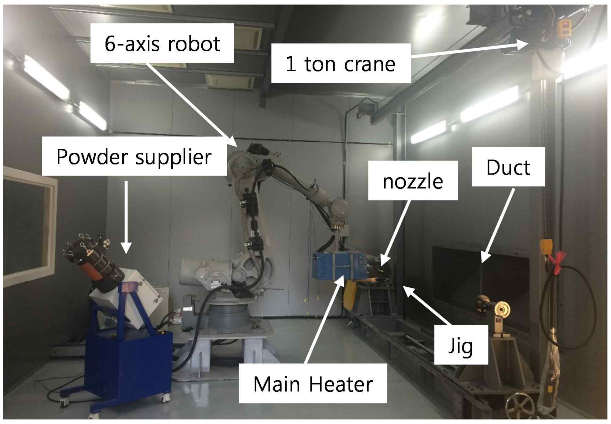

Fig. 1. Up-scaled cold spray coating machine.

Fig. 2. Cold spray coating of a medium-size canister.

3. Long-term Corrosion Test

The primary safety function of copper canister is containment of radionuclides. The radio-toxicity of HLW from pyro-processing sharply decreases below that of natural uranium after several hundred years [4]. It means that the containment period should be longer than 1,000 years after the closure of the repository. In-situ corrosion tests were performed in the simulated repository conditions. A series of very long-term corrosion tests using copper coupons have been carried out at the laboratory and the KURT. Fig. 3 shows the corrosion test periods and experimental apparatuses used. The corrosion tests in a laboratory (Lab test) and in KURT (KURT 2^{nd}) were finished.

As shown in Fig. 4, a coin shaped metal coupon inserted between two compact bentonite blocks is located within a corrosion cell made of titanium. The corrosion cell is designed for the bentonite blocks to contact with the flowing groundwater. Groundwater was taken from a borehole located in KURT (KAERI Underground Research Tunnel) and heated to 70℃. The corrosion tests (KURT 3^{rd} to 5^{th}) were designed to test several kinds of metals (coppers, titanium, cast iron, stainless steel) and two kinds of bentonites (Ca-type and Na-type). However, the groundwater condition was oxidizing due to the depth of a borehole.

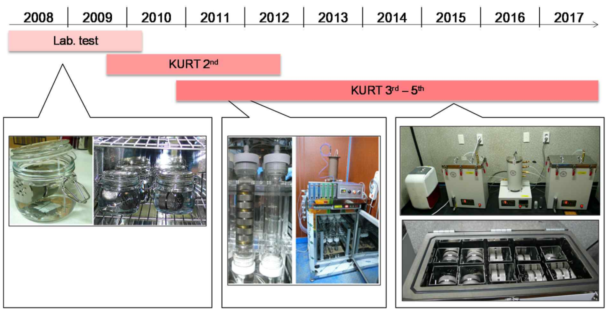

Fig.3. Long-term corrosion test schedule.

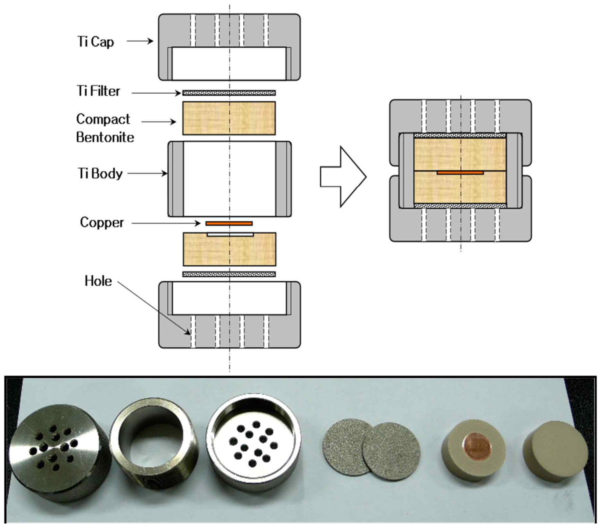

Fig. 4. Corrosion cell in a simulated environment.

4. Future plan and Conclusions

A medium-size disposal canister was successfully manufactured using a scaled-up cold spray coating machine. A full scale canister should be manufactured to demonstrate and test the performance of the canister. Also, the long-term corrosion tests should be carried out under the reducing conditions even though the corrosion tests at KURT under the oxidizing conditions were in progress. The reliable numerical modeling based on COMSOL should be developed further and validated using the experimental results.

Acknowledgement

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