Review of Chloride-Induced Stress Corrosion Cracking Issue and Mitigation Technology of Spent Fuel Dry Storage Canister

Donghee Lee* and Yongdeog Kim
KHNP Central Research Institute, 70, Yuseong-daero 1312beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*donghee.lee@khnp.co.kr

1. Introduction

According to the 'basic plan of HLW management' announced by Korean government, a spent fuel(SF) dry storage facility will be construct in NPP sites[1]. In the US, SF dry storage facility has been in operation for a long period of time and many studies have been conducted. In particular, the importance of research on aging management of a dry storage canister has been emerged recently. A typical aging phenomenon of the SF dry storage canister is Chloride-Induced Stress Corrosion Cracking (CISCC). In the case of Korea, the sea is composed of three sides. It is expected that it will be affected by chloride ion during dry storage. Therefore, this paper reviews various mitigation technologies applicable to the CISCC of stainless steel canister on the SF dry storage cask.

2. Pending Issue of the CISCC

In general, a canister made of austenitic stainless steel can cause a CISCC under saline environment with high welding residual stresses present in the canister [3]. Crack growth caused by the CISCC can penetrate the walls of the canister and cause a leakage. Furthermore, crack growth can cause breakage of the canister, which can lead to do harm a containment safety requirement of the canister. To prevent this phenomenon, the CISCC mitigation technology should be studied sufficiently.

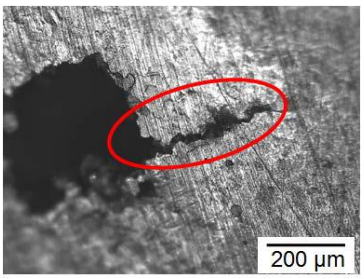

Fig. 1. Pit Serving as Initiation Point for CISCC.

3. Methods of the CISCC mitigation [4]

For CISCC of austenitic stainless steel, there are three components that must be simultaneously present for CISCC degradation to occur as bellows; elevated tensile stress, susceptible material and Corrosive or aggressive environment. In particular, these factors all may be present for the welded regions of the stainless steel canisters. Removing one or more of the components listed above will effectively mitigate the potential for CISCC of the canister external surfaces.

3.1 Applicability for Remediation of Existing Corrosion and Cracks

Some mitigation techniques can also provide remediation or repair of cracked canisters. Examples of such techniques are laser beam overlay/cladding, friction stir welding and encapsulation. In general, techniques which are capable of remediating existing cracks are those which are capable of (1) creating a pressure boundary that does not include the cracked area of material, (2) isolating the crack such that either chemical half-reaction of the corrosion cell cannot occur, or (3) eliminating the crack.

3.2 Surface Stress Improvement Techniques

The surface stress improvement techniques generally work by inducing a plastic strain in a layer of material near the surface of application which results in an elastic relaxation that generates compressive stresses. The potential deleterious effect of the additional cold work is negated by the presence of compressive residual stress, which removes the tensile stress needed for SCC to occur. All of the techniques described below are in-use by the nuclear industry to mitigate the susceptibility to SCC; shock-based (laser & water jet) peening, shot

peening, low plasticity burnishing and ultrasonic-driven surface stress improvement techniques. Each technique is generally known to achieve 1 mm depth of compressive residual stress.

3.3 Use of Corrosion Resistant Materials

The use of materials resistant to CISCC under atmospheric dry storage conditions can prevent the occurrence of SCC in austenitic stainless steels by applying a certain material that CISCC cannot readily initiate and propagate through. The combination of mechanical, thermal, and atmospheric corrosion requirements that a material used in construction of a canister needs to meet significantly narrows the range of appropriate materials. The highly alloyed nature of the materials described below serves to make their implementation less economically viable for many locations; **I**ron-based alloys, nickel-based alloys

3.4 Isolation of Surface from Corrosive Environment

Even if the canister material is susceptible to CISCC in the presence of deliquescent chlorides, susceptibility to CISCC can be reduced or eliminated by ensuring that this corrosive environment does not develop on the surface of the canister. There is the three approaches to isolating surfaces of the welded stainless steel canister from a corrosive environment: addition of material as a barrier between the canister surface and the environment, application of a coating to the canister surface and modification of the environment within the over pack to ensure that a corrosive environment does not develop.

Fig. 2. Laser Beam (left), Ultrasonic Peening (right).

4. Conclusion

This paper reviews the CISCC mitigation technique for a dry storage canister made of austenitic stainless steel. The CISCC occurs caused by elevated tensile stress, susceptible material, or corrosive or aggressive environment. To mitigate the occurrence of CISCC, it is necessary to reduce the tensile residual stresses as well as using of a material resistant to CISCC under dry storage conditions or modifying the canister surrounding environment to sequester corrosive species from CISCC-susceptible material. This paper is expected to help to make a strategy on the CISCC mitigation of dry storage containers in the future.

REFERENCES

[1] Notice of the Ministry of Trade, Industry and Energy, 'Basic Policy on High Level Radioactive Waste Management' (2016)

[2] EPRI Report 1003416, "Technical Bases for Extended Dry Storage of Spent Nuclear Fuel", Palo Alto, CA, 2002.

[3] U.S NRC, " Assessment of Stress Corrosion Cracking Susceptibility for Austenitic Stainless Steels Exposed to Atmospheric Chloride and Non-Chloride Salts", 2014

[4] EPRI Report 3002008193, "Aging management Guidance to Address Potential Chloride-Induced Stress Corrosion Cracking of Welded Stainless Steel Canisters, 2017.