An Approach to Model Abstraction of Pitting Corrosion in the Management of Spent Nuclear Fuel and High-Level Waste

Tae M. Ahn
U.S. Nuclear Regulatory Commission, MS: E2B2, Washington, DC 20555-0001

ABSTRACT

In the management of spent nuclear fuel (SNF) and high-level waste (HLW), metal canisters (or containers) serve to confine radionuclides during geologic disposal and extended dry storage. Corrosion of the metal can potentially compromise the confinement. If a canister were to fail, a limited amount of radionuclides may be released through an opening area. A conservative approach to safety assumes the conditions for pitting or crevice corrosion, or stress corrosion cracking (SCC). This presentation discusses the confinement and damage (i.e., opening area) associated with pitting corrosion, with some references to general and crevice corrosion, and SCC. Because of long time periods considered for the applications, large uncertainties are expected with modeling the degradation on the confinement and the opening area. Also, degradation models should be simple and conservative representations when incorporated in a system performance model. Stainless steels, nickel-based alloys, and carbon steels, and the chloride environment are considered.

In a non-passive metal, such as carbon steel, a pitting factor is defined by the ratio of the pit depth to the general corrosion depth mostly in anoxic neutral (non-chloride) environments such as geologic disposal in granitic hostrock. The pitting factors were plotted for a large number of data from long-term field tests and short-term laboratory tests [1]. Pitting occurs from the initial oxygen environment, followed by a very low general corrosion rate.

In the passive metals such as stainless steels or nickel-based alloys, pitting corrosion occurs on the free metal surface or inside crevice in the aqueous environment. Statistical theories on pitting corrosion initiation are available. A large number of initially formed pits are expected to repassivate in later time (i.e., latent repassivation). For example, a large number of pits initially formed in a crevice of nickel-based alloy (Alloy 22) repassivated under open-circuit conditions in 5M NaCl solution at 95 °C [203 °F] after ~ 10 days [2]. The opening area by pitting corrosion is limited. However, an exceptional case was reported for stainless steel under crevice corrosion, showing broad area attack in 5% NaCl fog at ambient temperature at about 20 days [3]. However, long-term effects have not been studied. Pits inside crevice may form when the crevice electrode potential is in the passive regime, reaching a modified breakdown potential in the crevice. When the crevice electrode potential reaches the anodic dissolution regime, faster dissolution of the crevice area may occur.

Pitting can be a precursory step for SCC, such as in a chloride-bearing environment with sufficient stress and aqueous condition. Data on SCC with pitting are available for stainless steels exposed to the coastal environment [4]. Statistical exercises are conducted to determine threshold stress intensification factors using the observed pit size [4] and an example weld stress, as measured in Japan [5]. Table 1 shows the calculated cumulative probability for possible stress intensifications [4], which fall in the range of values in the measured laboratory tests [4].

Probability	0.001	0.05	0.25	0.75	0.95
K (MPa $m^{1/2}$)	0.43	1.57	2.59	4.57	6.94

Table 1. Cumulative probability of stress intensification factor,
$K(MPa\ m^{1/2}) = \pi^{1/2}$ x stress x $(\text{crack size})^{1/2}$, 1 MPa $m^{1/2}$ = 0.91 ksi $in^{1/2}$

Disclaimer

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References

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