Flow of In-Drift Water Through Stress Corrosion Cracks

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The U.S. Department of Energy is preparing a license application for the permanent disposal of high-level waste in a potential repository at Yucca Mountain, Nevada. The current waste package design consists of an outer container of a highly corrosion resistant Ni-Cr-Mo alloy (Alloy 22) surrounding a thicker Type 316 nuclear-grade stainless steel inner container. Drip shields, mail-box shaped and made of titanium alloys, may be installed above the waste packages at the time of permanent closure to protect the waste packages from rock fall and seepage water. Various degradation mechanisms, including stress corrosion cracking, may compromise the integrity of these engineered barriers. In this study, numerical modeling and physical experiments were conducted to understand the flow mechanisms of in-drift water through stress corrosion cracks.

Stress corrosion cracks can have various topologies, including elliptical cross sections. Groundwater flow through the cracks may not occur if capillary force is dominant over gravitational force. In such a case, the fluid is held inside the crack in the form of a vertical liquid column. The relative balance between gravitational and capillary forces is determined by crack dimensions and topology, and by fluid properties. A model based on Rayleigh-Taylor instability was developed to explore the stability of standing liquid columns in stress corrosion cracks. In this work, the instability of the lower liquid-air interface of an elliptical liquid column is analyzed by treating an ellipse as a perturbation of a circular cross-section. The perturbation is analyzed in two ways, one in which an ellipse and the corresponding reference circle are taken to have the same area, and another in which the two geometries are taken to have the same circumference. In both cases, it is found that the interface is more stable in the case of an elliptical geometry compared to the corresponding circular geometry. It is shown that this is due to the azimuthal asymmetry associated with the elliptical geometry. A calculation also was performed to estimate the growth rate of the disturbances and the ultimate breakup of the interface.

Experiments were conducted to verify the numerical analysis of stability of liquid columns and to determine the potential flow rate of groundwater through stress corrosion cracks. The experiments used an Alloy 22 plate {8.13 cm long × 6.6 cm wide × 2.54 cm thick [3.2 in long × 2.6 in wide × 1.0 in thick]} with a simulated stress corrosion crack {200 μm [7.87×10^{-3} in] aperture} generated by electrical discharge machining. Initial results indicate that flow through the crack does not occur unless water accumulates above the crack to a critical height. The experiments evaluated the flow rate of water (through the crack) as a function of crack length, temperature, fluid properties, and pooling height.