New Models Predict How Cracks May Grow in Nuclear Reactor Materials

EPRI has developed models to predict irradiation-assisted stress corrosion crack growth rates and to assess remaining life of stainless steel materials in boiling water and pressurized water reactors.

Irradiation-assisted stress corrosion cracking (IASCC) has been observed in austenitic stainless steel components in both PWRs and BWRs operating under both normal water chemistry (NWC) and hydrogen water chemistry (HWC). When detected, plant owners typically estimate crack growth rates and perform structural integrity assessments to inform run-repair decisions.

Current crack growth disposition curves found in EPRI guidelines are based on a limited set of data from the early 2000s, and are applicable up to a neutron fluence or dose of 4.3 dpa (displacements per atom). As plants age, fluence for some components can exceed this value, meaning that improved data and models are needed to address the effect of key parameters such as fluence, stress intensity factor, temperature and environment.

Considerably more crack growth rate data are available now, particularly in hydrogen water chemistry and PWR primary water environments. Consequently, EPRI has developed new disposition curves using the larger data set. An expert panel evaluated crack growth rate measurements on irradiated specimens of austenitic stainless steels tested in light water reactor environments. The panel ranked the observations of crack growth rate based on the apparent quality of the experiment, validity of the data, and absence of obvious experimental flaws or anomalies.

Two preliminary crack growth rate models were considered, one using fluence as the irradiation variable and the other using irradiated yield stress, which is strongly correlated with fluence. For several reasons described in EPRI report 3002003103, the final models use irradiated yield stress as the measure of irradiation damage. The new disposition curves are an improvement over the earlier curves found in BWRVIP-99-A and MRP-227-A, mainly because the larger database provides more confidence in the fit, and the inclusion of additional variables provides more accuracy and flexibility in applications. For example, the new curves improve crack growth rate estimates by using irradiated yield stress, application temperature, fluence, type of material, and cold work fraction before irradiation. A comparison of the NWC model with the NWC calibration data (see figure) shows that the data are well distributed about the 1:1 lines over more than three orders of magnitude without apparent trends or fitting anomalies.

The models were compared to crack growth data from inspections of BWR core shrouds under normal water chemistry and hydrogen water chemistry conditions. The improved EPRI models provided a conservative bound to the field data, increasing confidence in the application of these models to irradiated vessel internals.

The new disposition curves can be applied at higher dose, such as might be needed for crack depth estimates associated with future license renewals. The older curves are not considered applicable outside their calibration dose range (0.71 to 4.3 dpa).

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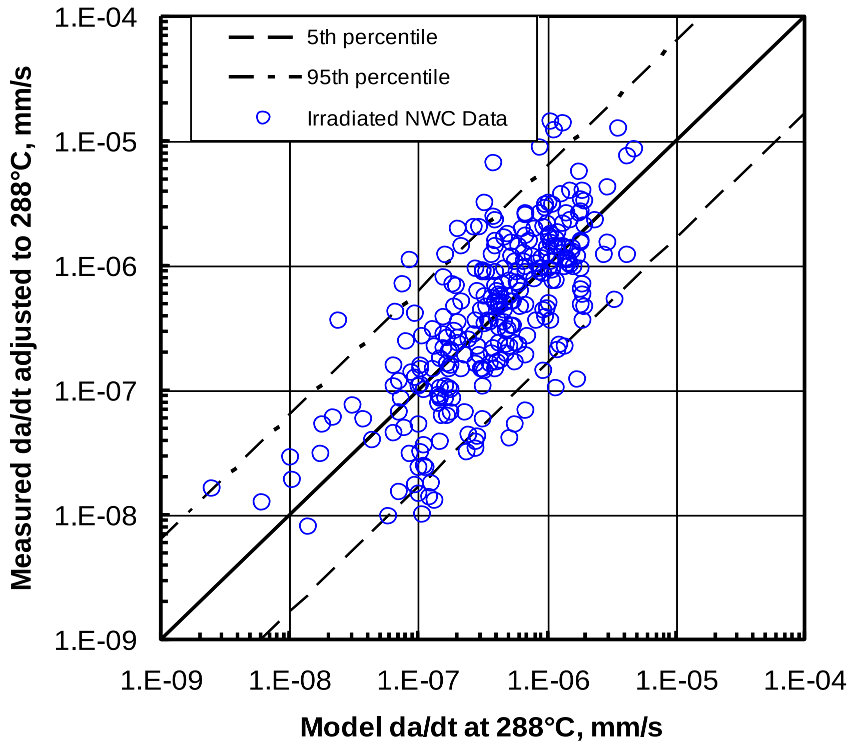

Goodness of Fit of Measured Calibration Data with Crack Growth Model

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