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Development of Quantitative Crack Analysis Techniques Using Neutron-Absorbing Liquid Penetrants

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Contrast agents for neutron radiography have been demonstrated for industrial applications; however, quantitative evaluations of these contrast agents are scarce in the published literature. This project will develop a quantitative tool to determine crack extent using processed neutron radiographs. This quantitative tool will be valuable for analyzing cracks in irradiated materials such as higher burnup fuels and advanced cladding materials where conventional crack measuring techniques are not possible

The East Radiography Station of the Neutron RADiography (NRAD) reactor at Idaho National Laboratory, imaged aluminum alloy crack test blocks prepared per American Society for Testing and Materials (ASTM) standards. Image processing extracted quantitative measurements of the crack area from the resulting film radiographs. A digital image threshold segregation process segregated the crack area was to black and the background to white. Testing different contrast agent solutions and varying the methods of infiltration provided data on the most effective infiltration and washing methods.

While the initial round of neutron radiography proved that digital image processing of gadolinium-enhanced crack radiographs could yield a quantitative measurement of crack extent, the resulting pixel counts were not clearly correlated to the amount of gadolinium in the crack. Neutron activation analysis (NAA) of the infiltrated cracks can provide a quantitative measurement of the amount of infiltrant in each crack; however, the low thermal neutron cross-sections of gadolinium-158 and gadolinium-160 make NAA difficult. Dysprosium is well-suited for NAA because it is chemically similar to gadolinium, possesses a high thermal neutron cross-section, and has a daughter product (dysprosium-165) with a 2.33 hour half-life.

The Geologic Survey TRIGA Reactor (GSTR) at the Denver Federal Center in Lakewood, Colorado irradiated small (<10g) aluminum alloy blocks containing dysprosium-infiltrated cracks. The resulting activity of the irradiated dysprosium provides a quantitative measurement of the amount of infiltrant in each crack, which can be compared to the crack extent measured using image processing technique.

Once the most effective infiltration and wash methods have been determined, infiltration solutions containing both a contrast agent for radiography and an isotope for NAA can be developed.Combining information from both NAA and neutron radiography provides a relationship between the total crack area in a digitally processed image and the mass of infiltrant in the crack(s). This relationship makes it possible to determine mass of crack extent solely from neutron radiography, allowing for crack size analysis of irradiated materials where NAA is not possible.

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