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Electric-Discharge-Machining Techniques for Evaluating Tritium Effects on Materials (U)*

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In this investigation, new ways to evaluate the long-term effects of tritium on the structural properties of components were developed. Electric-discharge machining (EDM) techniques for cutting tensile and fracture toughness samples from tritium-exposed regions of returned reservoirs were demonstrated. An existing electric discharge machine was used to cut sub-size tensile and fracture toughness samples from the inside surfaces of reservoir mock-ups. Tensile properties from the EDM tensile samples were similar to those measured using full-size samples cut from similar stock. Although the existing equipment could not be used for machining tritium-exposed hardware, off-the-shelf EDM units are available that could. With the right equipment and the required radiological controls in place, similar machining and testing techniques could be used to directly measure the effects of tritium on the properties of material cut from reservoir returns. Stress-strain properties from tritium-exposed reservoirs would improve finite-element modeling of reservoir performance because the data would be representative of the true state of the reservoir material in the field. Tensile data from samples cut directly from reservoirs would also complement existing shelf storage and burst test data of the Life Storage Program and help answer questions about a specific reservoir's processing history and properties. This work was performed under Enhanced Surveillance Campaign Task TSR12, "Enhanced Surveillance of Advanced Design Reservoirs."

Background

Tritium and its decay product, helium, change the structural properties of stainless steels. Tritium exposed steels generally exhibit higher yield strength, lower elongation and ductility, lower fracture toughness and increased susceptibility to crack growth under sustained loads. The degree of property change depends on the tritium exposure history because it results from the dissolution and diffusion of tritium into the steel and its radioactive decay to helium. Most of the quantitative data that is used to characterize the effects of tritium has been collected from long-term storage and burst tests of accelerated aged reservoirs. Indirect measurements using tensile and fracture toughness tests on samples exposed to tritium prior to testing have also been used. Invariably, questions arise as to the exact condition of a reservoir because its tritium exposure history and material processing history is different from those used in simulated tests.

Today, modern numerical computational techniques like those used in the Enhanced Surveillance Campaign are available to better predict reservoir aging and performance. However, these tools require accurate material property data. Until now, direct measurements of the effects of tritium on the properties of reservoir material seemed exceedingly difficult because the affected material is in the near-surface regions of the reservoir walls. The material properties in that region are highly dependent on reservoir geometry and the steep concentration gradients of tritium and helium. Techniques are needed to directly measure the effects of tritium on the properties of returned reservoirs for complete structural integrity assessments.

Results

Miniature longitudinal tensile specimens, 0.020 in thick, were sectioned from the inner and outer wall of a 0.5 in Schedule 10 Type 304L stainless steel pipe (wall thickness 0.083 in). Pipe was chosen because it roughly resembled several reservoirs and because multiple tests were required to develop the technique, including fixturing and EDM process parameters. Cutting the tensile specimens took two steps and required the fabrication of a V-block holder to accurately position the pipe on the EDM table.

The first step was to remove a 1.25 in long, 0.020 in thick, semicircular section from the inner and outer diameters of the pipe. The semicircular sections were then Gas Tungsten Arc (GTA) welded to a rod and the longitudinal tensile specimens were cut. Curved transverse tensile specimens were also cut from the semicircular sections. Typical results are shown in Figure 1. Fracture toughness samples were also cut using similar techniques (Figure 2). Heat input into the specimens during the GTA welding process, was minimized by fabricating a clamping fixture. The materials used in this demonstration were not tritium-exposed. However, a similar machine could be purchased and used in the same facility with the proper radiological controls for cutting samples from tritium-exposed alloys.

Tensile samples were pulled to failure on a mechanical tensile machine. Similarly collected stress-strain data from reservoir material could be used as material inputs to reservoir burst testing modeling efforts. The stress-strain data have been shown to be similar to that collected from full-size tensile samples; however, values of elongation will have to be adjusted for the smaller gage length.

Conclusions and Recommendations

The results of this investigation demonstrate that:

1. A variety of test samples can be machined from any location and orientation in a reservoir.

2. Tensile and fracture toughness samples can be machined from reservoir base metal and welds, heat-affected zones and tritium affected regions near the surface.

3. Tensile properties measured appear to be similar to those measured from full-size specimens. Minor corrections to may be needed to account for the effects of specimen curvature and EDM recast layers.

We recommend that development activities continue to:

1. Investigate effect of recast layer on properties of EDM samples.

2. Compare fracture toughness properties of samples cut from reservoir with historical fracture toughness measurements on samples cut from forward-extruded cylinders.

3. Purchase and install an EDM for fabricating samples from tritium-exposed reservoir components.

4. Use sub-size samples machined by EDM techniques to measure the properties of thin material sections.

5. Use collected data in computer models to better predict reservoir burst and cracking behavior.

Figure 1. Tensile specimen wire EDM cut from 0.5 inch, SCH. 10 pipe. a) Semicircular section 0.020 in thick sectioned from tube OD. b) Longitudinal-tensile specimen. c) Transverse tensile specimens.

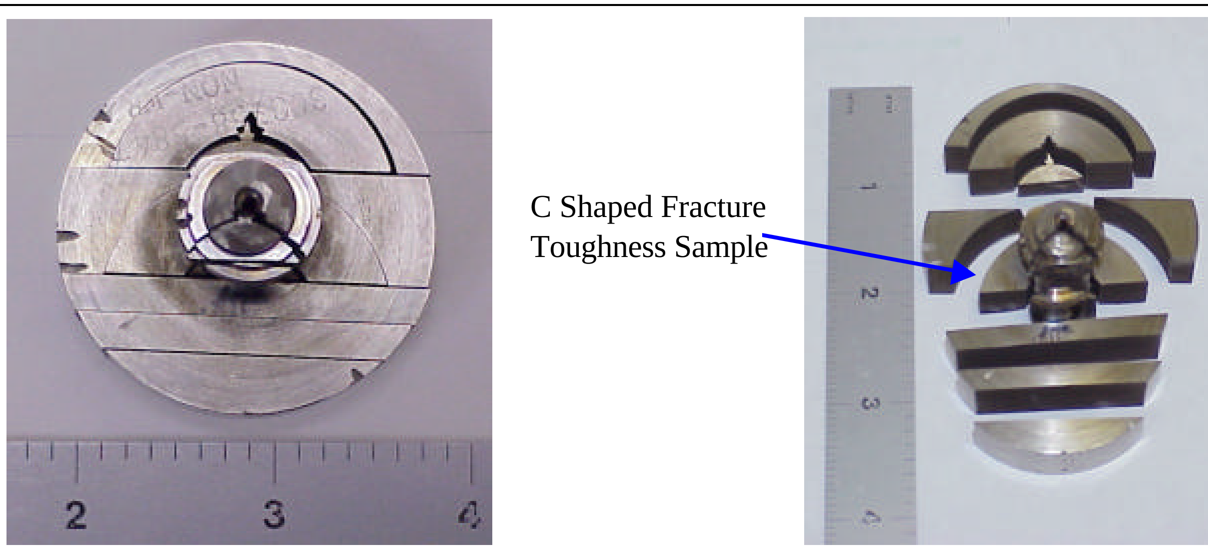

Figure 2. Fracture Toughness Samples Cut From Boss of Mock-Up. Some additional wire electrical discharge machining will be required to finish the fracture toughness samples.