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Hydrogen-Induced Embrittlement of Candidate Target Materials for Applications in Spallation-Neutron-Target Systems

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Task 4

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GOAL AND BACKGROUND

Spallation-neutron-sources, such as those under investigation for use in accelerator-driven transmutation systems, generate neutrons through the collision of high-energy protons, or charged hydrogen atoms, with heavy metal targets such as lead. As a result, these systems also tend to deposit a significant amount of hydrogen in the materials of the transmuter target and superstructure. This can result in accelerated corrosion and changes in the properties of the exposed materials. Of particular importance is a phenomenon called hydrogen embrittlement, in which materials lose their ductility (ability to deform under stress) and become brittle (more susceptible to fracture) after reacting with hydrogen. Given the extreme temperature ranges and large quantities of hydrogen expected in the accelerator-driven transmutation systems, these phenomena are of particular importance to the transmutation program.

This research program will examine the effects of hydrogen on hydrogen embrittlement, environment-induced stress corrosion cracking (SCC), and other hydrogen induced/enhanced corrosion phenomena in target materials. The UNLV research group will also examine the effectiveness of various surface and heat treatments in minimizing the impact of these phenomena in candidate materials. It is hoped that establishing a baseline performance of these materials in a hydrogen rich environment (analogous to the expected in-proton-beam environment of the target systems) will pave the way for conducting in-proton-beam radiation experiments and eventually support the materials qualification needed for facility design and operation.

OBJECTIVES

The principal research objective of the UNLV research program is to examine the phenomena of hydrogen embrittlement, stress corrosion cracking, and other hydrogen induced/enhanced corrosion phenomena in candidate materials for use in a spallation-neutron-source. Working with the national program, stainless steel alloys HT-9, EP-823, and EP-422 have been selected as the candidate materials for investigation at this time.

The research group plans to examine these phenomena with the following methodology. Tensile specimens under constant load and slow-strain-rate (SSR) conditions will be used to evaluate alloy susceptibility to stress corrosion cracking and hydrogen embrittlement in environments of interest. Optical microscopy and scanning electron microscopy will be used to evaluate the extent and morphology of cracking of these alloys. The concentration of hydrogen resulting from cathodic charging will be analyzed using secondary ion mass spectrometry (SIMS). Attempts will be made to correlate the resultant cracking parameters to the microstructures for the different stainless steels and heat treatments. Further, the localized corrosion behavior of these alloys is being evaluated by electrochemical polarization techniques.

RESEARCH ACCOMPLISHMENTS

The first major challenge facing the UNLV research group was to bring the capabilities to perform the proposed work to the University. This was accomplished through the establishment of the Materials Performance Laboratory (MPL), a materials performance user facility, at UNLV. Capabilities of this facility include the ability to conduct thermal treatments, metallographic evaluation, sample preparation, mechanical testing, and corrosion studies involving aqueous environments at elevated and ambient temperatures.

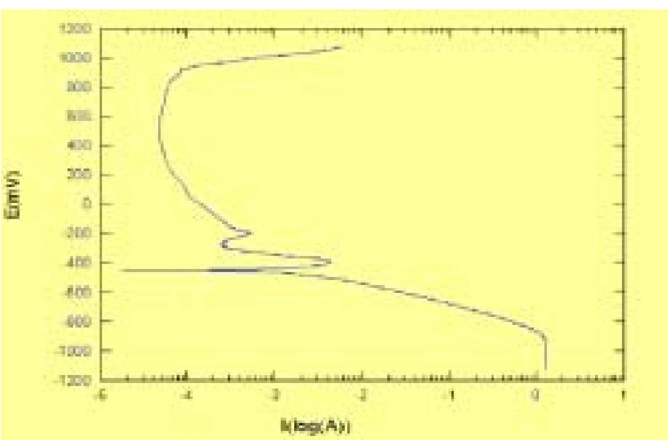
Once the experimental facilities became available, the sample stock materials for the initial experimental campaign were prepared. The material stock was then subjected to various thermal treatments at UNLV before the sample specimens were prepared. One set of each material stock was heat treated to produce quenched and tempered metallurgical microstructures typical of martensitic stainless steels. These heat-treated materials were sent to a different off-site facility to machine tensile specimens for evaluation of their ambient temperature mechanical properties and their susceptibility to SCC/HE in aqueous environments of interest. Simultaneously, efforts are well underway to machine small cylindrical specimens to perform electrochemical polarization experiments. Evaluation of the SCC behavior has now been well established and analysis of the tensile specimens machined from heat-treated bars is now underway.

Data quantifying the percent chemical composition for three heats of each metallurgic alloy was acquired for 14 different elements. Additionally, the ambient temperature mechanical properties of one alloy (EP-823) were tested. Constant-load SCC tests of that same alloy are currently in progress.

The experimental setups for constant-load SCC testing and electrochemical polarization studies are shown on the next page. A typical calibration curve showing potentiodynamic polarization behavior of Type 430 ferritic steel in 1N sulfuric acid solution at 30^{o}C follows.

Constant-Load SCC Test Setup

Electrochemical Polarization Test Setup



Potentiodynamic Polarization Curve for Type 430 Ferritic Stainless Steel in 1N H_2SO_4 Solution at 30^oC, Scan Rate: 0.166 mV/sec (ASTM G 5).

HIGHLIGHTS

- Two graduate students are currently working towards M.S. and Ph.D. degrees – Mark Jones and Md. Kamal Hossain, respectively. The "prospectus of thesis" is currently being developed for both students.
- Four technical papers are being written based on results from this research. These papers will be presented at the annual conferences of the "Electrochemical Society" and "NACE International".

CONTINUED PROGRESS AND FUTURE GOALS

The testing campaign for all three types of martensitic stainless steels will continue. The testing campaign includes performing heat treatments on the remaining formulations of all three test materials, performing localized corrosion testing using electrochemical techniques, performing metallurgical evaluations (including microstructural characterizations), and conducting failure analyses using the Scanning Electron Microscope. Data and results will be prepared for technical and scientific presentations for both presentations and publications.

Additionally, tests involving slow-strain rate units and electrochemical equipment are being performed to establish the testing techniques and related parameters. It is anticipated that all testing techniques will be standardized prior to their implementation in MPL.

MPL weekly student and staff meeting.

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