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Environment-Induced Degradation and Crack-Growth Studies of Candidate Target Materials

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Task 4

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BACKGROUND

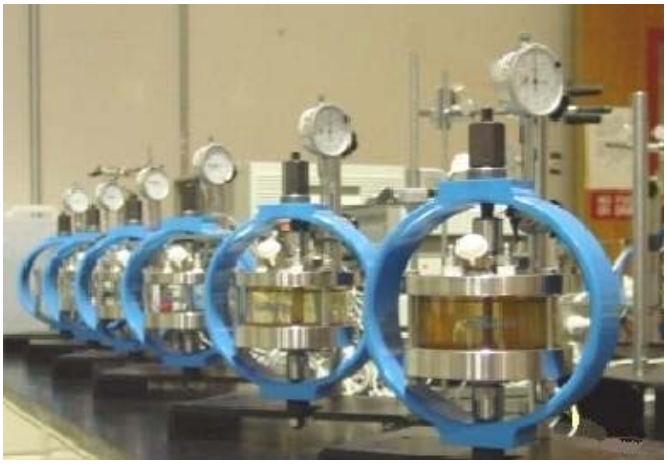
The primary objective of this task is to evaluate the potential for the environmentally-assisted cracking of candidate target materials for applications in spallation-neutron-target systems, such as accelerator-driven system for the transmutation of waste. The materials selected for evaluation and characterization are martensitic stainless steels (SS) including Alloys HT-9, EP 823 and Type 422 stainless steel.

More recently, this experimental program has been expanded to evaluate the effect of molten lead-bismuth eutectic (LBE) on the corrosion behavior of target materials in the presence of oxygen. Since the materials performance laboratory (MPL) at UNLV currently cannot accommodate this type of testing, the Delta loop, a molten LBE loop at the Los Alamos National Laboratory (LANL), is used to contain the stressed test specimens to evaluate the stress corrosion cracking (SCC), and localized corrosion behavior in the molten LBE environment. Since the magnitude of the applied load during these tests cannot be monitored or controlled (as in conventional SCC experiments) in the LBE environment, the test specimens will be self-loaded. Two types of specimen configurations, namely C-ring and U-bend, are used to perform these experiments. SCC tests using these types of self-loaded specimens are also being performed at the MPL in aqueous environments having neutral and acidic pH values at ambient and elevated temperatures.

RESEARCH OBJECTIVES AND METHODS

The susceptibility to stress corrosion cracking has been evaluated by using both smooth and notched uniaxial tensile specimens, which were pulled in two aqueous environments of different pH values at ambient and elevated temperatures using either a constant load or a slow-strain-rate (SSR) technique. The SSR testing was performed at a strain rate of 3.310^{-6} sec^{-1} to optimize the effects of mechanical constraints and environmental parameters. The notched specimens were used to increase the severity of cracking. The cracking susceptibility under a constant loading condition can be characterized either by the time-to-failure (TTF) or a threshold stress for SCC, below which no cracking occurs. For SSR testing, the cracking behavior was evaluated in terms of the ductility parameters such as percent elongation, percent reduction in area, and true fracture stress obtained from the stress-strain diagram.

Since electrochemistry can influence the localized corrosion (pitting and crevice) behavior, the susceptibility to localized attack was determined by cyclic potentiodynamic polarization (CPP) technique in similar environments. The SCC tests have so far been performed without applied potential. However, the most recent tests are being performed under controlled cathodic potential to study the effect of hydrogen on cracking susceptibility. The magnitude of controlled potential is based on the measured corrosion potential obtained in specific test environments.



Constant load test setup.

Crack-growth behavior of target materials during the transmutation process is of significant importance, particularly under irradiated conditions. In view of this rationale, sub-size compact tension specimens, irradiated and unirradiated, will be tested using fracture mechanics-based techniques. This type of testing will enable the evaluation of the radiation effect on the metallurgical properties including the hardness, yield strength and microstructures.

RESEARCH ACCOMPLISHMENTS

Ambient temperature mechanical properties of Alloys EP-823, HT-9 and Type 422 stainless steel were evaluated using smooth and notched tensile specimens.

A significant number of SCC tests using proof rings and smooth tensile specimens of martensitic Type 422 SS, and Alloys EP-823 and HT-9 have been completed in both neutral and acidic aqueous environments under constant load conditions at ambient temperature and 90°C. Additional tests are ongoing at reduced applied stresses to determine the threshold stress for SCC. Simultaneously, tests are being conducted using the notched tensile specimens.

SCC testing using SSR technique has been completed in aqueous environments at ambient temperature, 60°C, and 90°C involving smooth and notched tensile specimens of all three martensitic alloys.

SEM micrograph of a cracked specimen of Alloy HT-9.

Optical micrograph of etched sample of Alloy EP-823 (20 times magnification).

Extensive efforts were made to analyze the fracture modes in all broken specimens. Secondary cracks along the gage section of the broken specimen were evaluated by optical microscopy.

The susceptibility of all three alloys to pitting and crevice corrosion in both neutral and acidic aqueous solutions has been determined by using the CPP technique, based on a three-electrode polarization concept.

SCC testing using C-ring and U-bend specimens of Alloys HT-9 and EP-823 is in progress in acidic solution both in the presence and absence of air at ambient and elevated temperatures. Similar types of specimens will also be tested soon at LANL in the molten LBE environment.

HIGHLIGHTS

- "Stress Corrosion Cracking of Type 422 Stainless Steel for Applications in Spallation-Neutron-Target Systems," presented at SNS-JINS-NICEST, March 12, 2003, Oak Ridge, TN.
- "Stress Corrosion Cracking of Martensitic Stainless Steel for Transmutation Applications," presented at the 10th IHLRWM Conference, March 30-April 3, 2003 Las Vegas, NV.
- "Stress Corrosion Cracking of Type 422 Stainless Steel," presented at ANS Student Conference, April 2-5, 2003, Berkeley, CA.
- "Stress Corrosion Cracking of Target Materials," presented at ANS Student Conference, April 2-5, Berkeley, CA. Mohammad Hossain received Outstanding Paper Award.
- "Effects of Environmental Variables and Stress Concentration on Target Materials," presented at ANS Student Conference, April 2-5, Berkeley, CA.
- "Effects of Environmental Variables and Stress Concentration on Cracking of Spallation Target Materials," presented at 203rd Meeting of the ECS, April 27-May 2, 2003, Paris, France.
- "Environment-Induced Degradation of Spallation Target Materials," presented at ANS Annual Meeting, June 1-5, 2003, San Diego, CA.

FUTURE WORK

The third and final year of this task includes the following scope of work:

- Perform stress corrosion cracking and hydrogen embrittlement testing of all three types of martensitic stainless steels under controlled cathodic potentials.
- Perform localized corrosion testing using cyclic potentiodynamic polarization technique at elevated temperatures.
- Continue microstructural characterizations by optical microscopy and failure analyses by SEM.
- Analyze hydrogen content by secondary ion mass spectrometry (SIMS).

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