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

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BACKGROUND

The primary objective of this task was to evaluate the effects of environmental and mechanical parameters on environment-induced degradations of candidate target structural materials for applications in spallation-neutron-target systems. The materials selected for evaluation and characterization were martensitic stainless steels including Alloys HT-9, EP-823, and 422. Accelerator-driven transmutation systems involve bombarding a target material such as molten lead-bismuth-eutectic (LBE) by a proton beam, thereby producing neutrons. The molten LBE target will be contained in a subsystem structural container made of a suitable material such as Alloys HT-9, EP-823, and 422. During the transmutation process, the target structural material may become susceptible to different types of environment-induced degradations such as stress corrosion cracking (SCC), hydrogen embrittlement (HE), and localized (pitting and crevice) corrosion. While the performance of these candidate materials in the presence of a molten LBE is yet to be evaluated, substantial work has been performed in this task to evaluate the corrosion behavior of these alloys in aqueous environments of interest. These baseline data can eventually be utilized to compare them to those yet to be generated in the molten LBE environment.

RESEARCH OBJECTIVES AND METHODS

This investigation was focused on the evaluation of the susceptibility of all three martensitic alloys to SCC, HE, and localized corrosion in neutral and acidic aqueous environments at ambient and elevated temperatures. State-of-the-art experimental techniques including constant-load (CL), slow-strain-rate (SSR), and cyclic potentiodynamic polarization (CPP) were employed to evaluate these corrosion phenomena.

RESEARCH ACCOMPLISHMENTS

The significant results derived from this task are summarized as follows:
- No failures were observed in smooth specimens of Alloys EP-823 and 422 in the neutral solution when tested at CL. However, Alloy HT-9 showed failure in the 90°C neutral solution at an applied stress (V_a) of 112 ksi.
- All three alloys exhibited failure in the 90°C acidic solution at 95% of their YS values. Alloys HT-9 and 422 also showed failures at V_a of 90 and 85% of their YS values, but no failure was observed with Alloy EP-823 at stresses below 0.95 YS.
- The magnitudes of the threshold stress (V_th) for cracking for Alloys EP-823, HT-9 and 422 were 100, 95, and 98 ksi (689, 655, and 676 MPa), respectively based on CL testing in the 90°C acidic solution. The presence of a notch in the test specimen reduced the V_th values in all three alloys.
- The results of SSR testing in the acidic solution involving smooth specimens showed gradual reduction in ductility parameters (percent elongation - %El and percent reduction in area-%RA), time-to-failure (TTF), and true failure stress (σ_f) with increasing temperature, indicating a synergistic effect of pH and temperature in enhancing the cracking susceptibility. The presence of a notch in the specimen produced enhanced SCC susceptibility due to the stress concentration. However, the σ_f value was increased due to plastic constraint resulting from the applied stress and temperature conditions.
from triaxial stress field at the notch.

- The magnitude of %El, %RA, TTF, and $\sigma_{\text{f}}$ was reduced under an applied potential of -1,000 mV (Ag/AgCl) compared to those obtained without an applied potential.
- The failure mode at the primary fracture face of the specimen tested in the neutral solution, determined by SEM, was characterized by dimpled microstructure, indicating ductile failures. However, intergranular and/or transgranular brittle failures were observed in the acidic environment.
- Secondary cracks with branching were observed by optical microscopy on all three tested materials along the gage section of the specimens tested in the acidic solution.

**TASK 4 PROFILE**

**Start Date:** June 2001  
**Completion Date:** December 2004

**Theses Generated:**

**Journal Articles:**

**Conference Proceedings:**

**Research Staff**
- Ajit K. Roy, Ph.D., Principal Investigator, Associate Professor, Mechanical Engineering Department

**Students**
- Phani P. Gudipati, Mohammad K. Hossain, Ramprashad Prabhakaran, Sudheer Sama, and Venkataramakrishnan Selvaraj, Graduate Students, Mechanical Engineering Department
- Nikita Agarwal, Undergraduate Student, Electrical Engineering Department
- Aaron Tippetts, Undergraduate Student, Mechanical Engineering Department

**Collaborators**
- Ning Li, Ph.D., LBE Project Leader, Los Alamos National Laboratory
- Stuart A. Maloy, Ph.D., AFCI Materials Team Leader, Los Alamos National Laboratory