CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Materials Science and Technology/2003 Conference
Project Number 20.06002.01.081; AI Number 06002.01.081.319

DATE/PLACE: November 9–12, 2003, Chicago, Illinois

AUTHOR: Yi-Ming Pan and Darrell S. Dunn

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PERSONS PRESENT: Y. Pan, and D. Dunn, (CNWRA), T. Ahn, A. Csontos, and A. Passarelli (NRC), representatives from Framatome ANP/Bechtel SAIC, Lawrence Livermore National Laboratory and other organizations.

BACKGROUND AND PURPOSE OF TRIP:

The Materials Science and Technology Conference featured technical symposia, technical committee meetings, and an exhibitor show. The main goals of attending the conference were to:

- Present papers authored by the CNWRA and NRC staff included in a symposium titled Effects of Processing on Materials Properties for Nuclear Waste Disposition
- Attend waste package performance related presentations on repository

SUMMARY OF PERTINENT POINTS:

Papers co-authored by the CNWRA and NRC staff and presented at the Materials Science and Technology conference are listed below:

"Risk Assessment of Uniform Corrosion and Localized Corrosion of Alloy 22," A. Passarelli, D. Dunn, O. Pensado, T. Bloomer, and T. Ahn

"Effects of Waste Package Fabrication Processes on Corrosion Resistance and Mechanical Properties of Alloy 22," D. Dunn, Y. Pan, L. Yang, and G. Cragnolino

"Precipitation of Topologically Close-Packed Phases and Thermodynamic Calculations for Alloy 22," Y. Pan, D. Dunn, and G. Cragnolino

"Pb Assisted Stress Corrosion Cracking Susceptibility of Alloy C-22 Weldments," A. Csontos, Y. Pan, D. Dunn, and G. Cragnolino

Papers presented by the CNWRA and NRC staff were well received, prompted questions and subsequent discussions.

The symposium on Effects of Processing on Materials Properties of Nuclear Waste Disposition comprised three technical sessions with a total of 22 presentations. The session topics were (i) fabrication, corrosion and passivity; (ii) phase stability and environmental cracking; and

(iii) alloy development and environmental degradation. Brief summaries of selected papers presented at the symposium are given below.

Fabrication, Corrosion and Passivity Session

The session was opened by an invited presentation from G. Gordon (Framatome ANP/Bechtel SAC) who presented an overview of the recent DOE activities including the waste package design and fabrication methods. Degradation modes considered by the DOE include general and localized corrosion, stress corrosion cracking, hydrogen induced cracking, and microbiologically influenced corrosion. A description of the residual stress mitigation methods including laser peening and controlled plasticity burnishing was also presented. Some tests show the formation of compressive stresses more than 2 mm deep. Laser peening was described as a base process with controlled plasticity burnishing as an alternate method. Possible changes to the waste package design were not discussed but the use of alternative methods such as extrusions to eliminate some welds was mentioned. In addition, the use of Ti Grade 29 (Ti-6Al-4V + Ru) was mentioned as an alternate to Ti Grade 24. Ti Grade 29 is available and is less expensive compared to Ti Grade 24.

F. Wong (Lawrence Livermore National Laboratory) presented a study of using reduced pressure electron beam welding as a waste package outer-lid closure method. The study was conducted to assess the technical benefits and cost savings compared to using cold wire gas tungsten arc welding. Some of the benefits included elimination of filler wire, faster welding, reduced distortion, reduced weld joint preparation machining and favorable residual stress profiles. The assessment of residual stresses was conducted by sectioning a welded sample and measuring the distortion. Based on a finite element model analyses, the maximum residual tensile stresses are near the center of the weld thickness because this is the last volume of the weld pool to solidify for a single pass weld. Residual stress mitigation methods such as laser peening and controlled plasticity burnishing can also be used. Material evaluation shows similar Mo segregation characteristics and comparative corrosion rates except for a finer dendrite structure.

G. McMacillon (University of Nevada Reno) presented some preliminary results for measuring the passive current density of Alloy 22. The effort was aimed at generating high accuracy repeatable results which could be used to obtain parameters for the point defect model for passive film growth and ultimately model long-term passive dissolution processes. Several problems were encountered including initiation of crevice corrosion in a 4 molar NaCl at temperatures as low as 30 °C. Additional work will be conducted in dilute chloride solutions to avoid initiation of crevice corrosion.

G. McMacillon (University of Nevada Reno) also presented, a paper for F. Song, the results of straining electrode tests for Alloy 22. The tests were conducted to obtain information on the oxide film repassivation kinetics. The value of "n" which is used in the slip dissolution stress corrosion crack propagation model was found to be greater than 0.8, indicating that crack growth is restricted by the fast repassivation kinetics of the chromium oxide film.

The final paper of the session was presented by D. Shoesmith (University of Western Ontario) and was focused on the passivity of Ni-Cr-Mo alloys such as Alloys C22, C276, C4, and C2000. Tests conducted in acidic chloride solutions suggest that the impedance of the oxide film is greater than 5×10^5 ohms. Analysis by time-of-flight secondary ion mass spectroscopy (SIMS) revealed the development of a segregated oxide film with Mo and W located in the outer layer and Cr and Ni in the inner oxide layer. Different passive film structures were observed for different alloys as a result of the different Cr, Mo and W contents.

Phase Stability and Environmental Cracking Session

F. Wong (Lawrence Livermore National Laboratory) presented the updated aging and phase stability model that provides predictive insight into the long-term metallurgical stability of Alloy 22 under relevant repository conditions. This model uses theoretical calculations based on thermodynamic and kinetic concepts and principles. Extrapolations of the calculated time-temperature-transformation diagrams indicate that the phase stability of Alloy 22 is not a concern for temperatures below 200 °C. Additional work will be conducted taking account of phase formation at grain boundaries.

P. Andresen (GE Global Research) presented results of experiments on stress corrosion cracking initiation and growth of Alloy 22 and Ti Grade 7 in concentrated, high-pH groundwater environments. These long-term tests were conducted to evaluate the stress corrosion cracking behavior of smooth, constant load and compact tension crack growth specimens under various metallurgical conditions (solution annealed, cold worked and thermally aged). Crack initiation testing in Basic Saturated Water at 105 °C using Keno smooth tensile specimens shows no initiation in Alloy 22 in any metallurgical condition. Stable, long-term stress corrosion crack growth rates were measured in Basic Saturated Water at 110 °C using compact tension specimens of Ti Grade 7 (1×10^{-8} mm/s) and Alloy 22 ($1-8 \times 10^{-10}$ mm/s). These measurements are in a reasonable agreement with the slip dissolution model predictions.

J. Rankin (Lawrence Livermore National Laboratory) presented results of laser peening studies for minimizing the potential for stress corrosion cracking in closure welds. The current approach is to preclude the stress corrosion cracking degradation mode by mitigating the tensile residual stresses using laser peening which introduces compressive residual stresses at the surface of the weld. Controlled plasticity burnishing is considered as an alternative process. The residual stress measurements were performed on gas tungsten arc welded Alloy 22 by measuring distortion from deformed cut parts. Preliminary results indicate that laser peening produced a deep, compressive surface layer about 20 percent of a range of thickness (5-35 mm). Final forming of waste packages could also be performed using the laser peening forming method.

Alloy Development and Environmental Degradation Session

R. Carranza (Comision Nacional de Energia Atomica, Argentina) presented a paper co-authored by R. Rebak (Lawrence Livermore National Laboratory) on the influence of halide ions on the passivity of Alloy 22. Polarization and electrochemical impedance tests were conducted in NaCl, NaF, and NaCl + NaF electrolytes at pH 2, 6 and 9. The polarization tests showed the presence of an anodic peak that has been attributed to the oxidation state of Mo in the passive film. The position of the anodic peak decreased to lower potentials as the pH was increased. The anodic peaks were well defined in NaF electrolytes. In pure NaCl, the anodic peak was masked by large anodic current that may be the result of transpassive dissolution or another reaction. Thermal treatments that are known to form long-range ordering and topologically close-packed phases did not result in increased corrosion rates.

R. Rebak (Lawrence Livermore National Laboratory) presented results of tests on the corrosion rates of Ti Grades 7, 16, an 12 in simulated concentrated groundwaters at 60 and 90 °C. The tests were conducted in the long-term corrosion test facility at Lawrence Livermore National Laboratory and corrosion rates were determined by weight loss. The highest corrosion rates were observed for Ti Grade 12 in simulated concentrated water and were less than 100 nm/year. It was noted that Ti Grade 12 is not a candidate for engineered barrier system components and tests conducted on this alloy were for comparison purposes. Local penetration was observed on the Ti Grade 12 specimen, however, there was no crevice attack. The precipitation of salts containing Si, Ca, and Mg was reported. No effect of welding was observed.

C. Robino (Idaho National Engineering and Environmental Laboratory) presented progress on the development of a Ni-Cr-Mo-Gd alloy for critically control. The selection of Gd was based on the high thermal neutron absorption cross section. Processing of the alloy is important to obtain mechanical properties that meet the requirement of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. The alloy shows good weldability, however, the fracture toughness of the alloy is near the minimum acceptable value. Additional work on processing will be conducted to improve the mechanical properties.

CONCLUSIONS

The symposium on Effects of Processing on Materials Properties for Nuclear Waste Disposition provided an excellent opportunity to obtain latest information on the activities supported by the DOE for the high-level waste repository program. The participation at the Materials Science and Technology conference was also an excellent avenue to keep up with the latest advances in emerging materials science technology and applications.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

None.

SIGNATURES:

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11/21/03
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