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Effect of Silicon Content on the Corrosion Resistance and Radiation-Induced Embrittlement of Materials for Advanced Heavy Liquid Metal Nuclear Systems: Quarterly Progress Report (November 2005 – January 2006)

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Quarterly Progress Report
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Introduction

The purpose of this collaborative research project involving the University of Nevada Las Vegas (UNLV), Los Alamos National Laboratory (LANL) and Idaho State University (ISU) is to evaluate the effect of silicon (Si) content on the corrosion behavior and radiation-induced embrittlement of martensitic stainless steels having chemical compositions similar to that of the modified 9Cr-1Mo steel. Recent studies at LANL involving Alloy EP-823 of different Si content have demonstrated that increased Si content in this alloy may enhance the corrosion resistance in molten lead-bismuth-eutectic (LBE). Since very little data exists in the open literature on the beneficial effect of Si content on the corrosion properties, it seemed appropriate to initiate a research project to address this technical issue. This task is intended to study the effect of Si content not only on the corrosion resistance but also on the radiation-induced embrittlement of martensitic stainless steels. The susceptibility of these alloys with different Si content to stress corrosion cracking, general corrosion and localized corrosion will be evaluated in the molten LBE and aqueous environments of different pH values using state-of-the-art testing techniques. Testing in the aqueous media is intended to develop baseline data for comparison purpose. Radiation-induced embrittlement of these alloys will initially be studied by irradiating the test specimens with bremmstrahlung gamma radiation from 20-40 MeV electron beams at ISU. These gammas induce (γ, n) reactions in the giant dipole energy region. The principal radiation damage from these irradiations, in turn, stems from the recoiling residual nucleus (with average kinetic energy of approximately 20,000 eV) after the neutrons are emitted. The high penetrability of gammas, whose range is of order one meter in steel, ensures that the resulting damage will be uniform over the volume of the sample. The induced activity of these specimens will have very short half-lives (typically minutes) due the systematics of (slightly) proton-rich nuclei. The resulting radiation-induced hardening can subsequently be evaluated by proper experimental techniques. Later, similar studies can be performed using specimens radiated by neutrons at LANL.

Personnel

The current project participants are listed below.

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Recent Accomplishments

- Tensile properties of T91 grade steels containing 0.5, 1.0, 1.5 and 2.0 weight percent (wt%) silicon (Si) have been evaluated at temperatures ranging between ambient and 550°C. The engineering stress vs. strain (s-e) diagrams for all four heats of T-91 grade steels are illustrated in Figures 1-4, located in the technical portion. As anticipated, the magnitudes of both the yield strength and the ultimate tensile strength were reduced with increasing temperature.

- The extent of failure strain (e_f) was not significantly affected by the variation in the testing temperature for steels containing 0.5 and 1 wt% Si. However, the magnitude of e_f was gradually reduced in steels containing 1.5 and 2 wt% Si in the temperature regime of ambient to 400 ^{o}C, followed by a significant increase at 550^{o}C, as shown in Figures 3 and 4, respectively. The occurrence of reduced e_f in this temperature regime may possibly be attributed to dynamic strain ageing (DSA), which is currently under investigation by transmission electron microscopy (TEM).

- Stress corrosion cracking (SCC) evaluation by the slow strain rate (SSR) technique is in progress involving steel containing 0.5 and 1.5 wt% Si. The effect of controlled potential on the SCC susceptibility will also be studied soon.

- The localized corrosion study by cyclic potentiodynamic polarization (CPP) technique revealed active-passive behavior with a positive hysterisis loop for steels containing 0.5 and 1.5 wt% Si. A typical CPP diagram is shown in Figure 5. The magnitude of E_{corr} became more active with increasing temperature. This behavior is consistent with the previous data on steels containing 1 and 2 wt% Si.

Problem

No problems are anticipated.

Status of Funds

Expenditures incurred during this quarter are within the target amount allocated.

Plans for the Next Quarter

- Perform SCC testing using T91 grade steels containing 0.5 and 1.5 wt% Si by SSR technique with and without controlled potentials.

- Perform Charpy impact testing using V-notch specimens.

● Perform crack-growth experiments using compact-tension and double-cantilever-beam specimens.

● Continue DSA study by TEM.

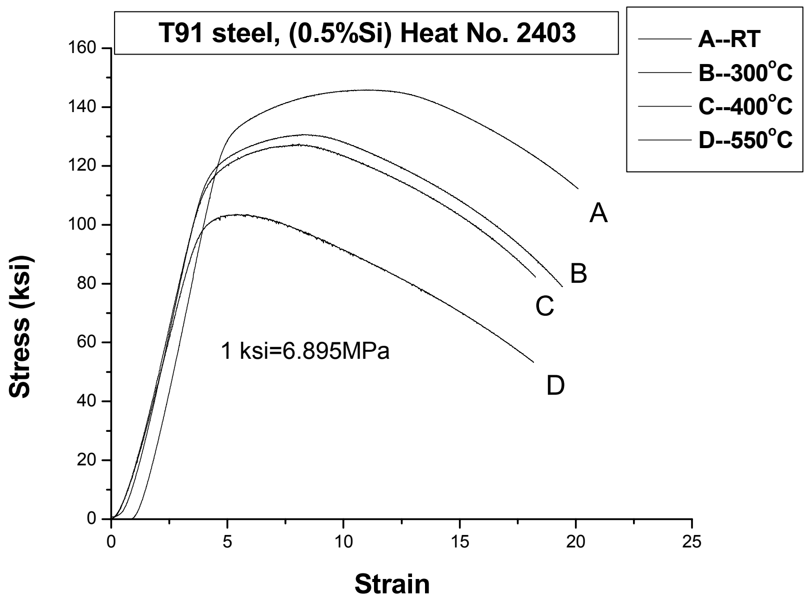

Figure 1. s-e Diagram versus Temperature

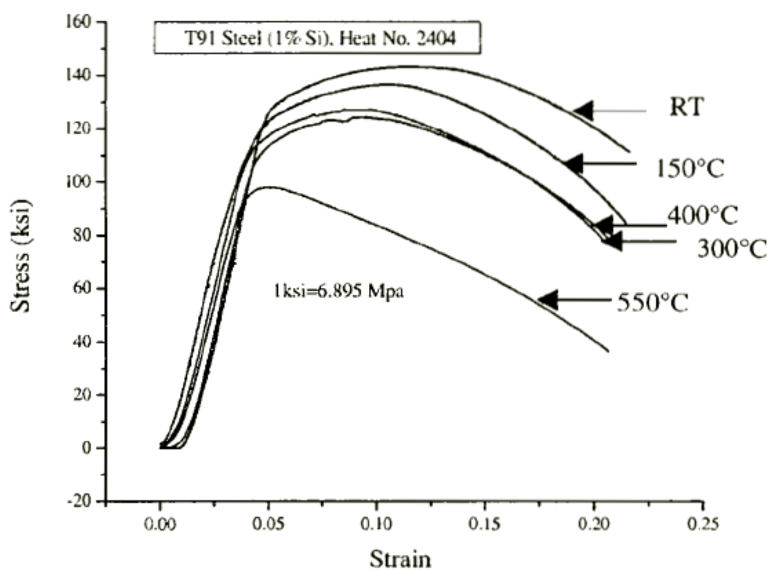

Figure 2. s-e Diagram versus Temperature

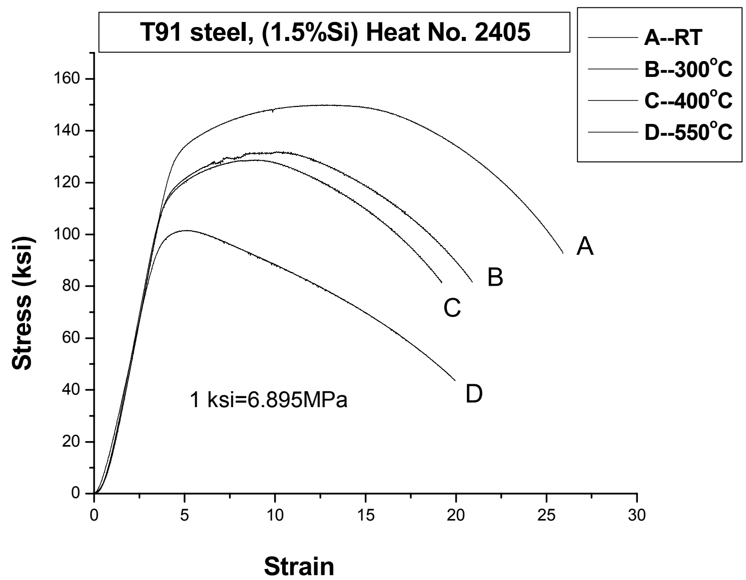

Figure 3. s-e Diagram versus Temperature

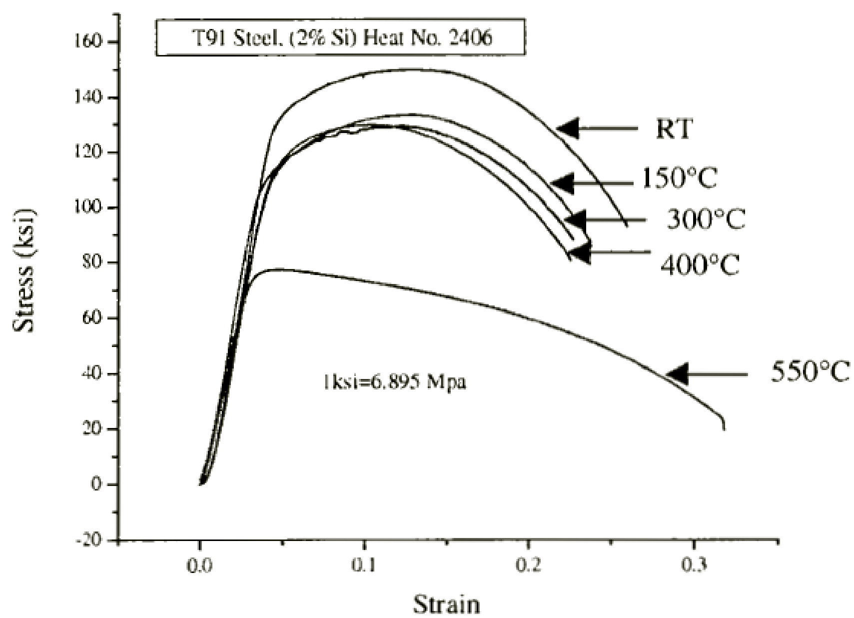

Figure 4. s-e Diagram versus Temperature

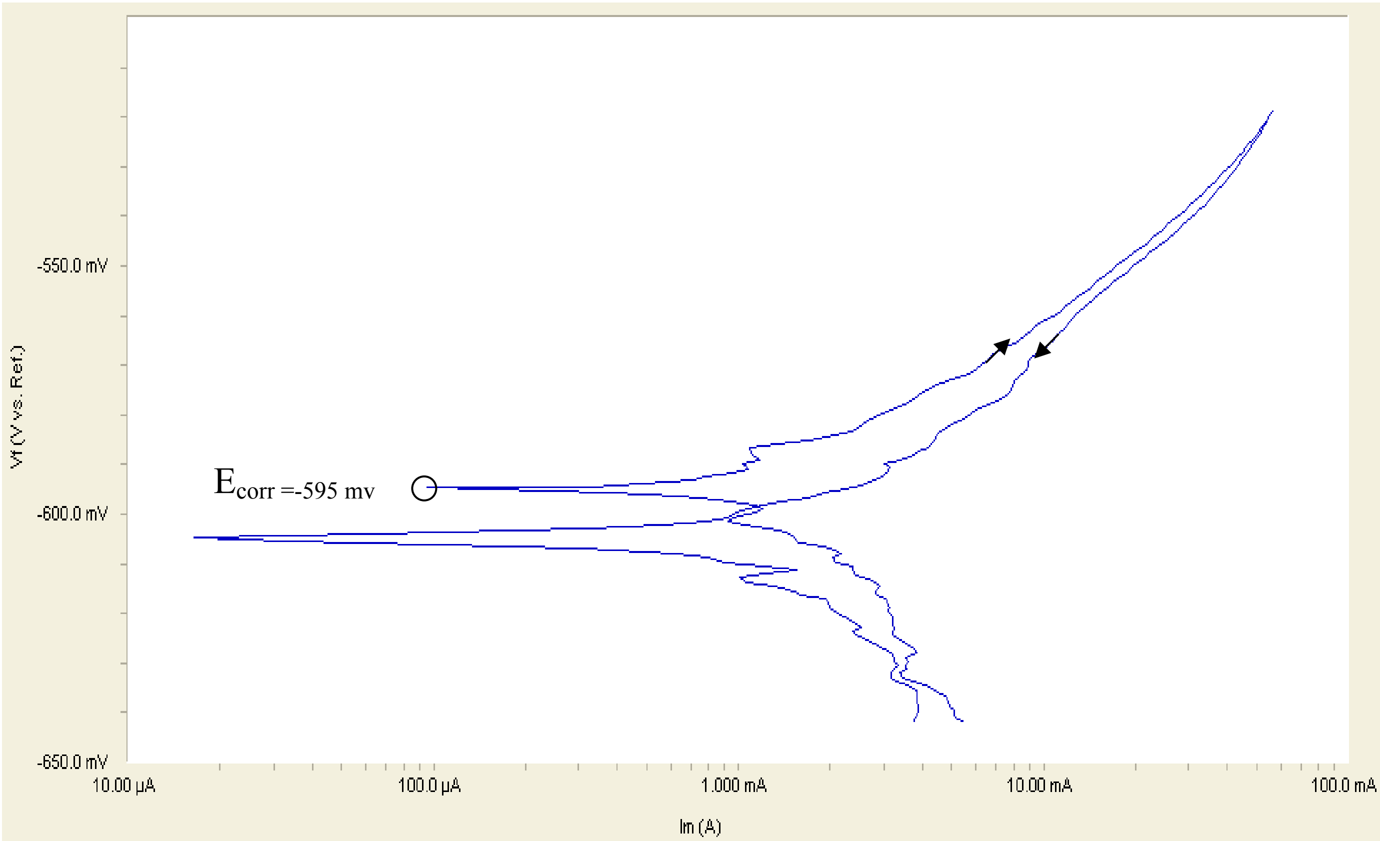

Figure 5. CPP Diagram of T91 Grade Steel Containing 0.5 wt% Si at 60°C