Use of Alloy 800H as a Heat-Exchanger Material

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INTRODUCTION

Identification and characterization of structural materials for high-temperature heat exchangers to be used in nuclear hydrogen generation pose severe challenge to scientists and engineers. However, Alloy 800H has been widely used for high-temperature applications in the presence of hostile environments in view of its superior metallurgical and corrosion properties documented in the published literature (1-5). The tensile properties of Alloy 800 H have been determined at temperatures ranging from ambient to 600°C. The tensile strength of this alloy was gradually reduced with increasing temperature, as expected. However, some reduction in failure strain was noted at temperatures up to 200°C, which can be attributed to the dynamic stain ageing effect. The results of stress-corrosion-cracking (SCC) testing performed in a simulated acidic solution at constant-load (CL) did not exhibit any failure. The magnitude of true failure stress was gradually reduced in SCC testing under a slow-strain-rate (SSR) condition without showing any significant variation in ductility parameters. The localized corrosion study conducted in a similar environment by a polarization technique revealed more active (negative) critical potentials at elevated temperatures. The fractographic evaluations of the tested specimens showed dimpled microstructures indicating ductile failures.

Keywords: Alloy 800H, corrosion resistance, tensile properties, fractography

WORK DESCRIPTION

The cost of energy has been rising steadily at an alarming rate during this past decade. In order to circumvent the enormous cost associated with the development of energy from fossil fuels, the United States Department of Energy (USDOE) has taken a bold step in developing an alternate source of energy based on the utilization of nuclear power. While many different approaches are currently under consideration, the USDOE has expressed a significant interest on a particular process of hydrogen generation based on a thermochemical cycle involving chemical reactions between sulfuric acid and iodine (S-I) process.

The presence of aggressive chemical species and unusually high operating temperatures associated with the S-I process necessitates the identification and selection of suitable structural materials possessing enhanced corrosion resistance and superior metallurgical properties. While many different metallic materials having the desired properties are available, Alloy 800H was identified as a candidate structural material based on its optimum cost and a combination of superior metallurgical and corrosion properties. The chemical composition and metallurgical microstructure of Alloy 800H under thermally-treated (solution-annealed) condition are given in Table 1 and Figure 1, respectively.

Table 1. Chemical Composition of Alloy 800H

Material/Heat#	Elements (wt%)									
Alloy 800H /	C	Mn	Fe	S	Si	Cu	Ni	Cr	Al	Ti
HH6274AG	0.08	0.75	46.04	0.001	0.24	0.26	31.99	19.67	0.44	0.53

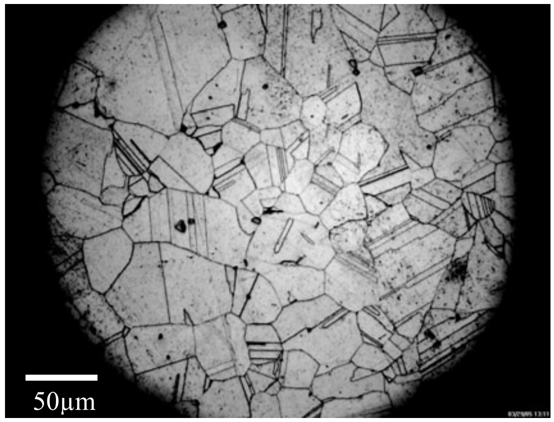

Figure 1. Optical Micrograph, 200X

The tensile properties of Alloy 800H have been determined at ambient and elevated temperatures using smooth cylindrical specimens (Figure 2) in a commercially available testing equipment according to the ASTM designation E 8-04 (6). For elevated temperature testing, a custom-made ceramic chamber containing nitrogen was used to prevent oxidation/contamination of the specimen.

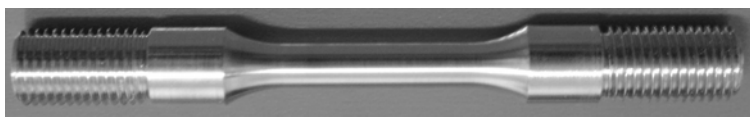

Figure 2. Smooth Cylindrical Tensile Specimen

The susceptibility of Alloy 800H to SCC was determined under CL and SSR conditions. The SCC testing at CL was performed using a calibrated proof-ring, as shown in Figure 3. The specimens were loaded at stresses corresponding to different percentages of the material's yield strength (YS) value and the corresponding time-to-failure (TTF) were recorded. The cracking susceptibility was expressed in terms of TTF for a maximum test duration of 30 days. For SSR testing performed at a strain rate of 3.3×10^{-6} sec^{-1}, the cracking susceptibility was expressed in terms of the ductility parameters (percent elongation-%El, and percent reduction in area-%RA), TTF and the true failure stress ($_f$).

Figure 3. Constant-Load Test Setup

The localized corrosion behavior of Alloy 800H was determined by incorporating a small cylindrical specimen (Figure 4) according to the ASTM designation G 5-04 (7) using a three electrode polarization technique, commonly known as cyclic potentiodynamic polarization (CPP) method. The nature of localized attack was examined visually and by optical microscopy. The extent and morphology of failure of the cylindrical specimens used in tensile testing and corrosion studies were evaluated by scanning electron microscopy (SEM). The comprehensive test results are summarized below.

Figure 4. Polarization Specimen

Results

- The results of tensile testing using smooth cylindrical specimens indicate that the magnitude of both the YS and ultimate tensile strength (UTS) was gradually reduced with increasing temperatures. It is, however, interesting to note that the failure strain was reduced to some extent at temperatures up to 200°C followed by an enhancement up to 500°C. The reduced failure strain at temperatures between ambient and 200°C may be attributed to the dynamic strain ageing effect. A comparison of the engineering stress versus strain (s-e) diagrams at different temperatures is shown in Figure 5. Table 2 shows the different tensile properties derived from this figure and the measured specimen dimensions.

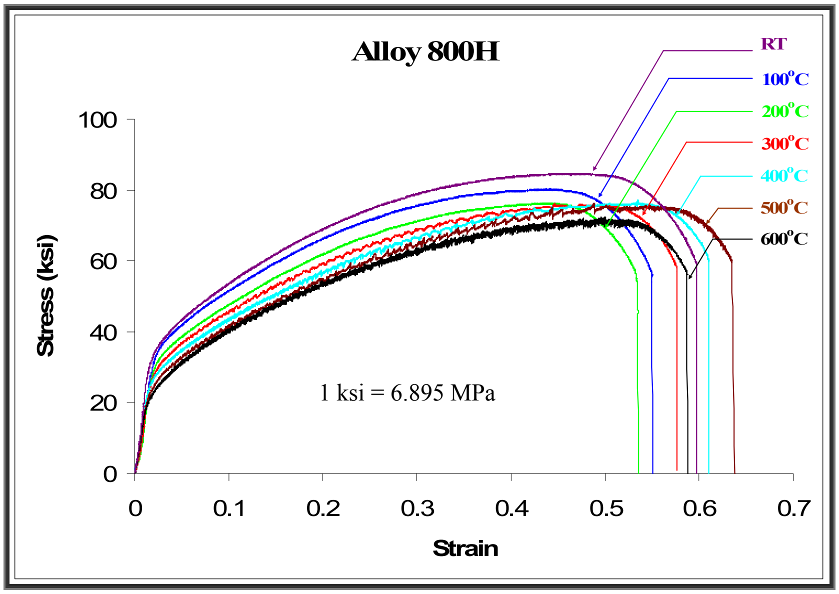

Figure 5. s-e Diagrams vs. Temperature

Table 2. Tensile Properties of Alloy 800H

Temperature, °C	YS, (ksi) MPa	UTS, (ksi) MPa	%El	%RA
RT	(39.34) 271.3	(85.93) 592.6	56.8	67.0
100	(35.99) 248.2	(78.95) 544.5	53.9	66.4
200	(31.78) 219.2	(75.88) 523.3	52.4	64.0
300	(30.77) 212.2	(76.07) 524.6	54.8	61.3
400	(28.81) 198.7	(76.88) 530.2	59.9	59.0
500	(27.52) 189.8	(76.23) 525.7	60.6	57.5
600	(22.36) 168.0	(71.76) 494.9	57.0	61.8

- No failure was onserved in CL SCC testing at 30 and 90°C in the S-I solution even at an applied stress corresponding to 98% of the YS of Alloy 800H.

- The magnitude of %El, %RA, TTF and $_f$ was evaluated in the SSR testing at ambient and elevated temperatures. $_f$ was gradually reduced with increasing temperature. However, very little changes in other three parameters were observed. A comparison of the s-e diagrams at three different testing temperatures is illustrated in Figure 6.

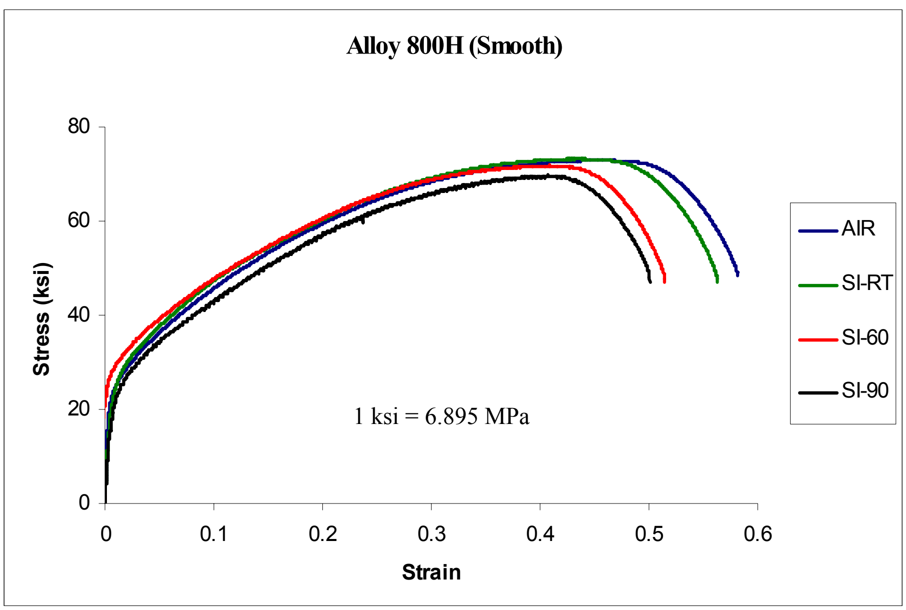

Figure 6. s-e Diagrams vs. Temperature (SSR Testing)

- The results of the localized corrosion study by the CPP technique revealed more anodic (negative) critical potentials (corrosion potential-E_{corr}, critical pitting potential-E_{pit}) with increasing temperature. A similar effect of temperature on the critical potentials has been noted by other investigators (8). The variation of E_{corr} and E_{pit} with temperature is shown in Figure 7.

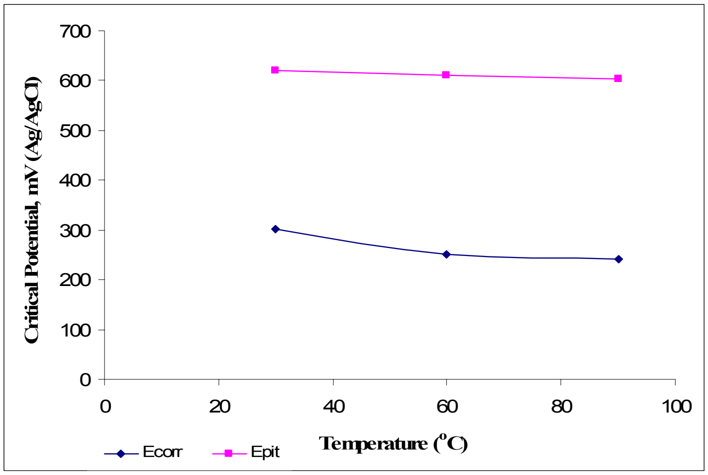

Figure 7. Critical Potential vs. Temperature

- The evaluations of the primary fracture surface of all cylindrical specimens by SEM showed dimpled microstructures indicating ductile failure. The SEM micrographs are shown in Figure 8(a) and 8(b), respectively.

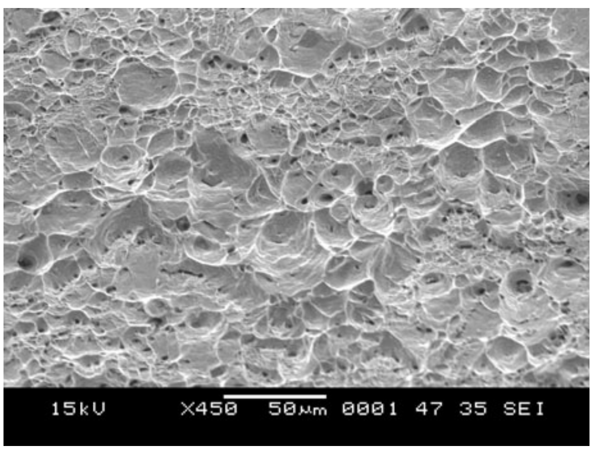

Figure 8(a). Tensile Testing, 500°C

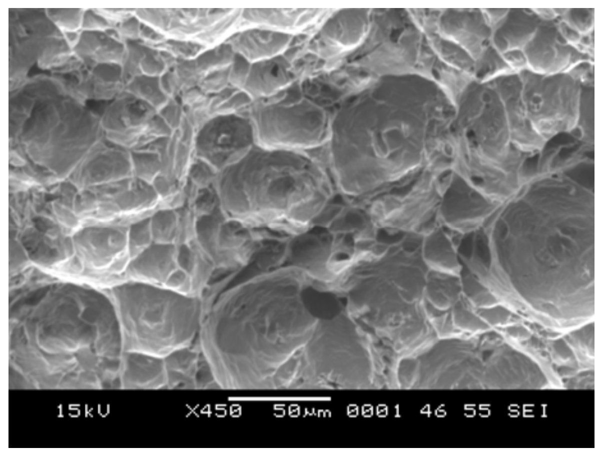

Figure 8(b). SSR Testing, 90°C S-I solution

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