Hot Tensile Behavior for Alloy 800H Base and Weld Metals

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1. Introduction

A very high temperature reactor (VHTR) is one of the most promising Gen-IV reactors for the economic production of electricity and hydrogen. Its major components are the reactor internals, reactor pressure vessel (RPV), hot gas ducts (HGD), and intermediate heat exchangers (IHX). Alloy 800H is the primary candidate for use a control rod system (CRS), a HGD, a core barrel, core supports, and a shutdown cooling system (SCS) in VHTR system, as shown in Fig. 1 [1]. Alloy 800H, which is a modification of alloy 800, was developed for applications in which additional creep resistance is required. Alloy 800H is approved for use up to 760°C under ASME Code Section III Subsection NH for nuclear applications [2]. Many studies for Alloy 800H base metal (BM) were done and the data for mechanical properties are available in several reported documents [3-6]. However, the data of mechanical properties for its weld metal (WM) are rare and not available in the ASME code as well. Thus, the experimental data for mechanical properties should be provided to establish "the Gen-IV Materials Handbook DB" for design use of Alloy 800H weld components.

In this study, the tensile behavior for Alloy 800H WM, which was fabricated by a gas tungsten arc welding (GTAW) procedure, was investigated through the tensile tests at R.T-900°C. A comparison for the tensile properties between the base metal (BM) and WM was done, and the hot tensile curves for the BM and WM were modeled using the General Atomic (GA) model.

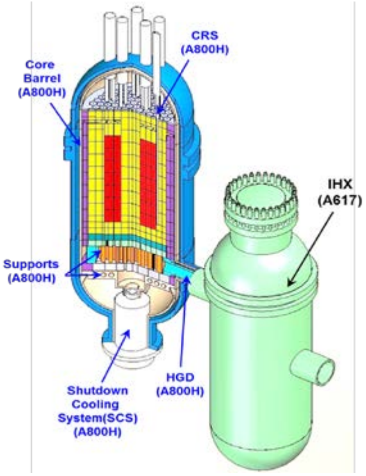

Fig. 1. Application of Alloy 800H in VHTR system.

2. Methods and Results

2.1 Experimental procedures

Commercial grade "Alloy 800H" (Brand name: ATI 800H) stainless steel, which was a hot-rolled plate with a 25 mm thickness made by Allegheny Ludlum Company, was used. In the chemical composition, the amount of each element was identified to be included well within the ASME specifications.

The weld metal for Alloy 800H was fabricated by a GTAW procedure. The shape of the weld joint has a single V-groove with an angle of 80°. A filler metal was used for KW-T82 (brand name), manufactured by KISWEL Co. Alloy 82 (N06082) bare filler metal was prepared according to the American Welding Society (AWS) specifications, AWS SFA 5.14 ERNiCr-3 and its diameter was 2.4 mm. The WM tension specimens were taken in fully weld metal. The WM specimens were machined into the transverse longitudinal direction (TD) against the welding direction. The tension test specimens for the BM and WM were fabricated with a cylindrical form of 30 mm in gauge length and 6 mm in diameter. The tensile tests were conducted under a slow strain rate of 5.55E-4 (1/s) from R.T to 900°C.

2.2 Comparison of tensile properties for base and weld metals

Through a series of the high-temperature tension tests from R.T to 900°C, the hot tensile stress-strain curves for BM and WM of Alloy 800H were obtained, and the tensile properties such as the yield strength (YS), ultimate tensile strength (UTS), and fracture elongation were obtained at each temperature.

Figs. 2 and 3 show the comparisons of the YS and UTS with temperatures for the BM and WM of Alloy 800H. The WM is significantly higher in the YS and UTS than the BM in the all temperature ranges. In the YS values, the different gap between BM and WM is reduced with an increase in a temperature. However, in the uniform elongation presenting for up to the UTS, the WM is reversely lower than the BM, and it is sharply decreased in the temperatures above 600°C, as shown in Fig. 4. Thus, it is clear that the WM was reduced in ductility due to higher tensile strength. Alloy 800H WM fabricated by GTAW process is identified to be lower in ductility and higher in strength than the BM in the hot tensile properties.

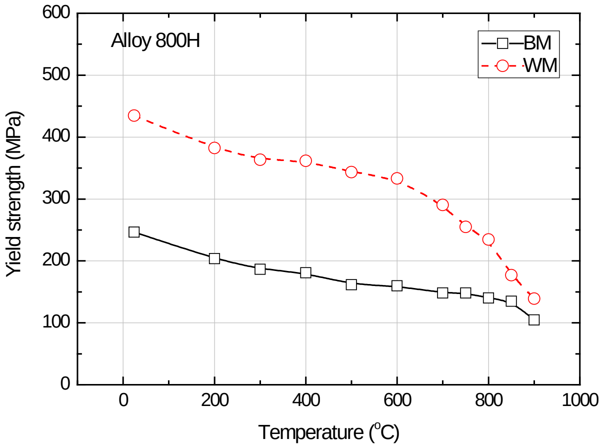

Fig. 2. A comparison of yield strengths for the BM and WM of Alloy 800H.

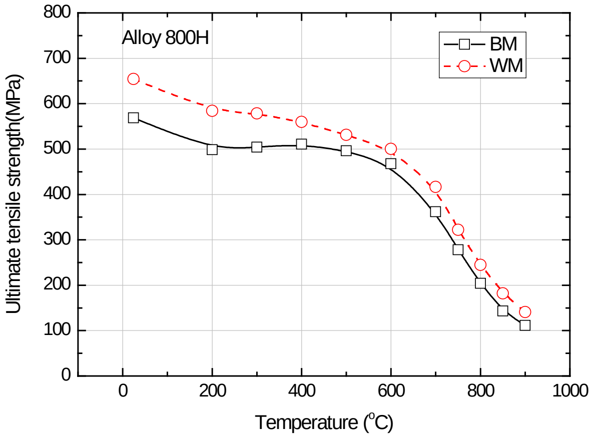

Fig. 3. A comparison of tensile strengths for the BM and WM of Alloy 800H.

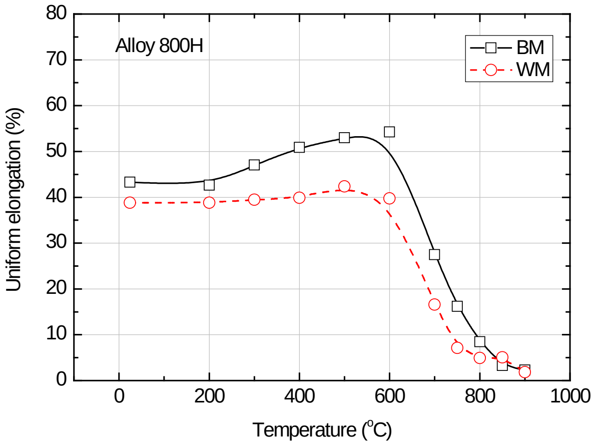

Fig. 4. A comparison of tensile uniform elongation for the BM and WM of Alloy 800H.

2.3 Modeling of hot tensile curves

To describe well the hot tensile curves of Alloy 800H, among various models, the GA model which was developed by Smith at General Atomic Company was considered in the present study. The equation of the GA model can be given, as follows [7]:

$$\text{In } S = B_1 + B_2 \ln e + B_3 (\ln e)^2 + B_4 (\ln (e))^3 \qquad (1)$$

where B_1, B_2, B_3, and B_4 are the coefficients which are determined for each temperature. The hot tensile curves are fitted to third order polynomials in natural log stress (S) and natural log strain(S) for a series of strain up to UTS at each temperature curve. The GA model can model using only an equation for modeling the full range tensile curves from elastic stress to UTS. However, the Ramberg-Osgood (R-O) model has been known as a typically strong tensile model with $S = S_e + D (e_p)^m$. Where Se is the proportional limit stress as an elastic component, and e_p is the plastic strain. The D and m are the coefficients which are determined for each temperature. As given in the R-O equation, we should obtain separately the elastic stress and plastic stress to model the tensile curves up to UTS. Thus, the GA mode is more convenient than the R-O model because the GA model can model the tensile curves of the plastic range up to UTS through calculation of only one equation.

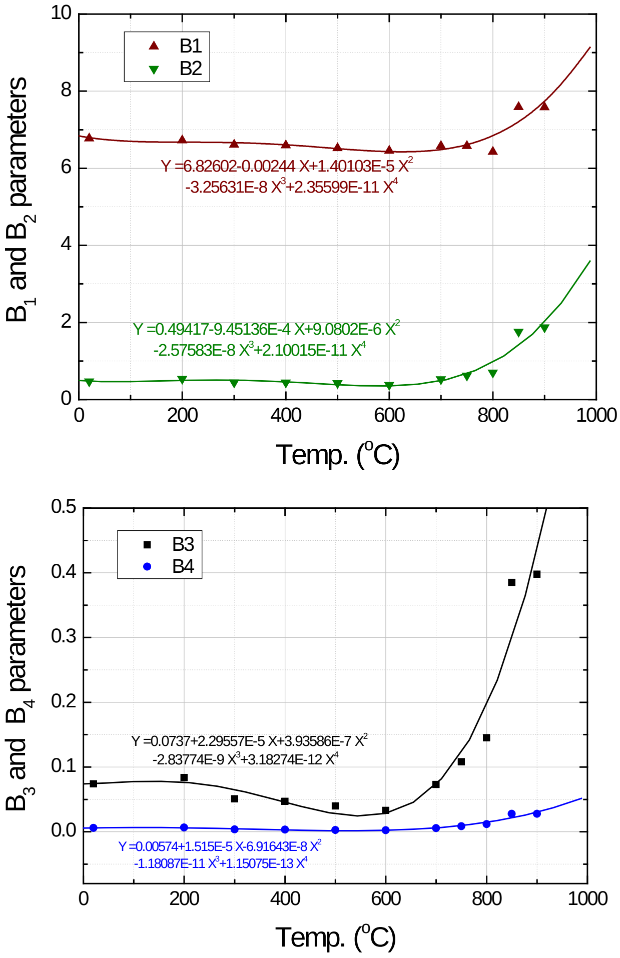

Fig. 5. Temperature dependence of the four coefficients of B_1, B_2, B_3, and B_4 in GA model of Alloy 800H BM.

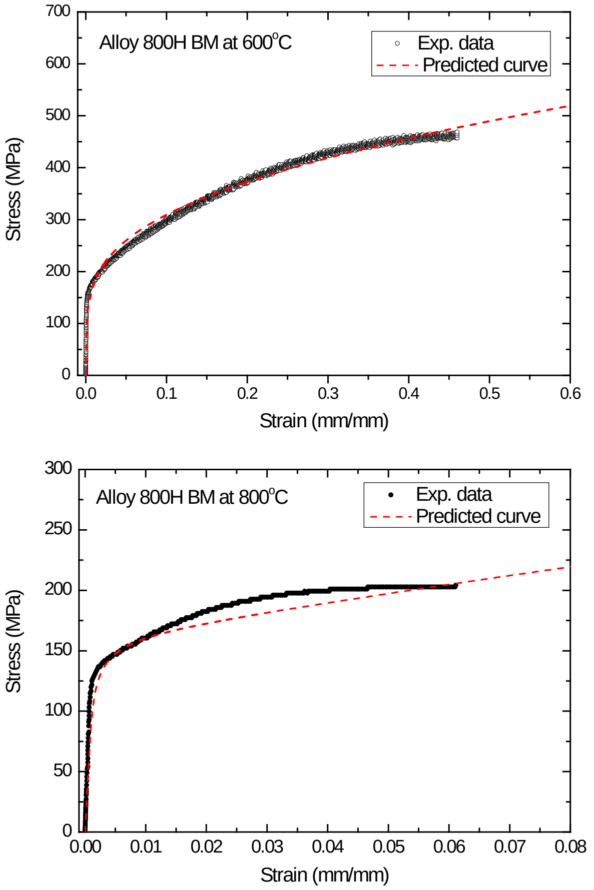

Fig. 6. Typical modeling results of hot tensile curves calculated by the GA model at 600°C and 800°C of Alloy 800H BM.

In the present investigation, the four coefficients were determined using a nonlinear least square fit (NLSF) method to give the best fit to each experimental tensile data. From the obtained each coefficient, the temperature dependence for the four coefficients was investigated, as shown in Fig. 5. Fig. 5 presents the temperature dependence of the four coefficients of B_1, B_2, B_3, and B_4 in GA model for Alloy 800H BM. It appears that the four coefficients follow forth order polynomial well. From the results of temperature dependence, we can generate the hot tensile curves at a specified temperature using Eq. (1).

Fig. 6 shows the modeling results of hot tensile curves calculated by the GA model at 600°C and 800°C of Alloy 800H BM. As shown well in the figures, the modeled curves were in accordance with the experimental data. Accordingly, it is suggested that the GA model is useful to model the hot tensile curves of Alloy 800H.

3. Conclusions

The hot tensile behavior between the BM and WM of Alloy 800H was comparatively investigated. The WM was found to be significantly higher in the YS and UTS than the BM in the all temperature ranges. In the YS values, the different gap between BM and WM was reduced with an increase in a temperature. However, in the uniform elongation presenting for up to the UTS, the WM was reversely lower than the BM, and it is sharply decreased in the temperatures above 600°C. The GA model was found to be in accordance with the experimental data in the tensile curve modeling of Alloy 800H. It is suggested that the GA model was useful to model the hot tensile curves of Alloy 800H.

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