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High Temperature Low Cycle Fatigue Behavior of Alloy 800H Weldments

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1. Introduction

Nowadays, the Korea Atomic Energy Research Institute (KAERI) is developing a nuclear hydrogen development and demonstration project with a capacity of 200 MW_{th} with thermal and core outlet temperature 950℃. The components have a projected plant design service life of 40-60 years operation and 3-8 MPa in He impurities, the most important consideration is the creep-fatigue and fatigue behavior for the materials [1-3].

Alloy 800H is currently the primary candidate material for use a control rod system (CRS), a hot gas duct (HGD), a core barrel, core supports, and a shutdown cooling system (SCS) in the VHTR system. Fatigue behavior is expected to be an important damage mode for the high temperature components.

An analysis of low cycle fatigue behavior can contribute to a deeper understanding of the fatigue fracture mechanisms as well as to improvements in the design and application of VHTR system.

However, the researches associated with low cycle fatigue (LCF) and creep-fatigue (CF) behaviors of Alloy 800H have focused mainly on the base metal, with little attention given to the weldments. Dewa et al studied on uniaxial low cycle fatigue study of alloy 800H weldments at 700℃ [4].

Current research activities at PKNU and KAERI focus on the study of low cycle fatigue properties of Alloy 800H base metal (BM) and weldments (WM) specimens were machined from GTAW butt-welded plates at very high-temperature of 700 ~ 850℃. In the present study, the high temperature low cycle fatigue behavior of Alloy 800H BM and WM are investigated.

2. Experimental Materials and Procedures

2.1 Materials and Specimens

Alloy 800H is an austenitic iron–nickel base superalloy with arranged contents of carbon (0.05–0.10 wt.%), aluminum and titanium (Al + Ti (0.85–1.20 wt.%)), silicon, and manganese. Alloy 800H used in this work was well within the ASTM specifications. LCF tests were performed on specimens machined from a 25 mm thick plate of Alloy 800H. The shape of GTAW butt-welded joint has a single V-groove with an angle of 80 degrees and 10 mm root gap. A filler metal was used for KW-T82 that was prepared according to AWS specifications. Cylindrical LCF specimens were machined from Alloy 800H base metal plate and GTAW butt-welded pad. Fig. 1 shows the schematic diagram showing cutting of specimen with respect to welded plate. The dimension of LCF specimens for both BM and WM is 6.0 mm diameter in the reduced section with a gage length of 12.0 mm.

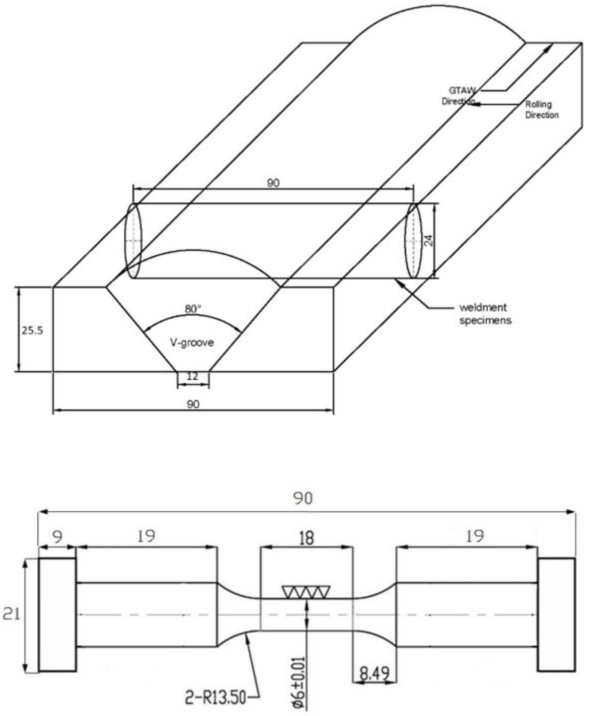

Fig. 1. Schematic diagram showing cutting of specimen with respect to GTAW welded plate, and the LCF specimen.

2.2 Low Cycle Fatigue Test Procedures

A series of LCF tests was performed under fully reversed strain control (R=-1) in the air with different total strain ranges of 0.6, 0.9, 1.2, and 1.5% at temperature of 700, 750 and 800°C. The LCF tests were conducted in servohydraulic fatigue testing equipment (MTS 370 Landmark, USA, 100 kN) with a tube furnace. The target temperature was only allowed to vary about ±2°C. Before the commencement of the test, the target temperature was held at zero stress level for 30 minutes to allow the temperature to stabilize. The LCF tests were carried out under triangular waveform in a constant strain rate of 10^{-3} s^{-1}. The LCF life criterion was defined as 20% drop in the stress ratio (peak tensile over compressive stress).

3. Results and Discussion

Fig. 2 shows the comparison of fatigue life between BM and WM for various total strain ranges at three different temperatures for Alloy 800H. Most of the test results showed that the increase of total strain ranges resulted in a reduction of fatigue life. For BM and WM, the fatigue life decreased with increasing the temperature. Fig. 3 shows the comparison of cyclic stress response behavior for BM and WM at two different temperatures. The figures show the cyclic stress response behavior as a function of temperature and strain amplitude. The same trends were noticed at all test temperatures and total strain ranges. For the BM, in the initial period of cycling, the peak stresses increased, followed by a much longer period where the peak stresses remained constant. Finally, the peak stresses apparently decreased just before specimen failure. The initial tensile and compression stresses for WM specimen showed more a higher value than those of BM specimen. Generally, a material's initial cyclic hardening phenomenon during LCF is known to be work hardening contribution due to dislocation slip band interactions. In this work, the serrated yielding can be observed for both BM and WM materials during initial cycles. This finding also can be found for Alloy 800H BM from existing literatures [4]. This serrated yielding is characterized by fluctuated load level during tension or compression stress, which is one of the manifestations of dynamic strain aging (DSA). In LCF tests, the crack initiation and propagation for both BM and WM materials occurred in a classical transgranular fracture mode.

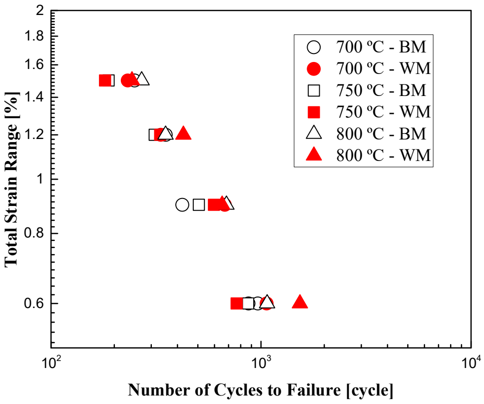

Fig. 2. Comparison of fatigue life between BM and WM.

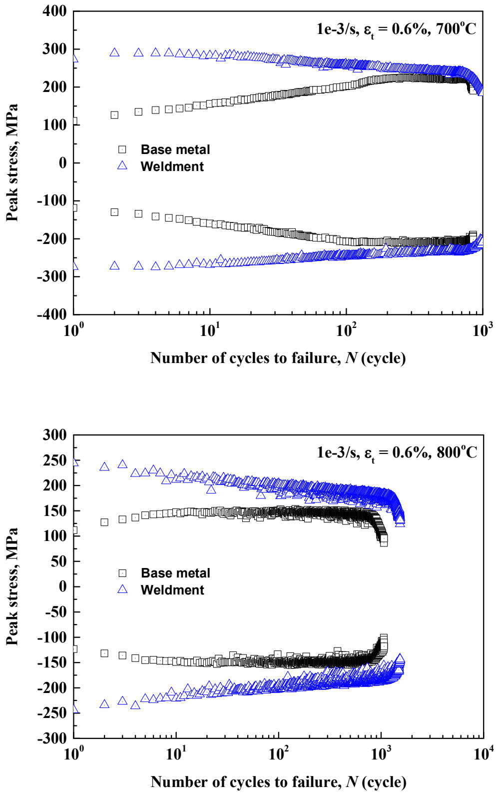

Fig. 3. Cyclic stress response curves for BM and WM.

3. Conclusions

In this paper, high temperature LCF behaviour of Alloy 800H weldments were investigated by means of experimental tests. A series of fully reversed LCF tests were performed with total strain ranges of 0.6, 0.9, 1.2, and 1.5% at 700°C, 550°C and 800°C.

Acknowledgments

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