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The Tensile and Stress Relaxation Behaviors of Solution Annealed 316L Stainless Steel in High Temperature Conditions

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1. Introduction

Type 316L austenitic stainless steel has been widely used in the high temperature components of a liquid metal reactor [1]. These components are subjected to a mechanical load and exposed to a high temperature condition during a plant life time. Thus, it is necessary to know its mechanical properties and time-dependent creep data during the design stage and a damage assessment.

In this paper, a tensile and a stress relaxation test (SRT) were carried out in a high temperature range from 300 to 600℃. The tensile tests were accomplished at various strain rates of 0.2 – 0.002 %/s to investigate the effect of the strain rate of 316L, especially its dynamic strain aging (DSA) and strain rate sensitivity [2-3]. The most common techniques for gathering high temperature creep data are "creep tests" done under a load control. However, it would be extremely time consuming and laborious to archive the available data. Hence, in order to identify a creep behavior of 316L efficiently, stress relaxation tests (SRT) in a high temperature were accomplished as an alternate technique. The SRT offers a particularly simple and attractive way to study creep behavior and, the correlation between a creep behavior and a relaxation behavior needs to be studied further.

2. Experiments and Results

2.1 Material and Testing Methods

The material used in this study was SA (Solution Annealed) 316L stainless steel and its chemical compositions are shown in Table 1. Tensile test and SRT specimens were aligned in the rolling direction and machined into a cylinder with a 7mm diameter and a 12.5mm gauge length according to ASTM standard E606-92[4].

Table 1 Chemical composition of specimen (wt%)

C	Si	Mn	P	S	Cr	Ni	Mo	N
0.02	0.58	1.26	0.032	0.001	16.77	10.75	2.06	0.026

Tensile tests were conducted in air at a constant cross head speed in temperature conditions of 300℃, 500℃ and 600℃, respectively. The test temperature was maintained constant within ±2℃ during the whole period of the test. All the specimens were held at the test temperature for 100 minutes before a testing. Tensile tests were performed at the three fixed strain rates of 0.2, 0.02 and 0.002 %/s, respectively. An extensometer (gauge length: 12.5mm) was directly attached to the narrow part of the specimen to measure a uni-directional elongation which can be converted directly to a strain.

Stress relaxation experiments were carried out in high temperatures of 500℃, and 600℃ after imposing different extents of uni-axial strains of 1%, and 2% for about 100 hrs. An INSTRON 8516, servo hydraulic testing system equipped with a 3-zone resistance type furnace was used.

2.2 Dynamic Strain Aging (DSA) and negative strain rate sensitivity

DSA is the phenomenon of interactions between solute atoms and movable dislocations for a plastic deformation of materials [2]. DSA is manifested by a serrated flow in the stress-strain curve and negative strain rate sensitivity. The importance of a DSA effect on a material behavior has been reported in various types of materials [5-6]. Especially, Mannan et al. have investigated a DSA in a 316 stainless steel [7].

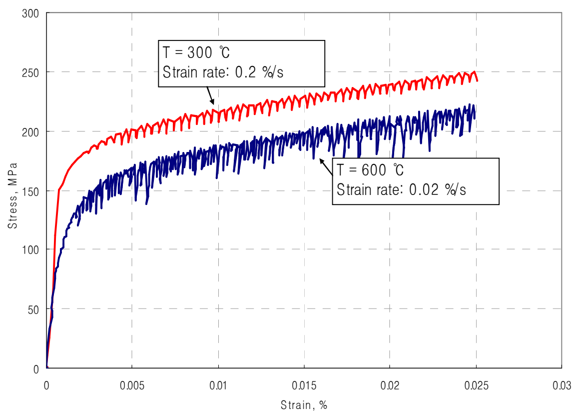
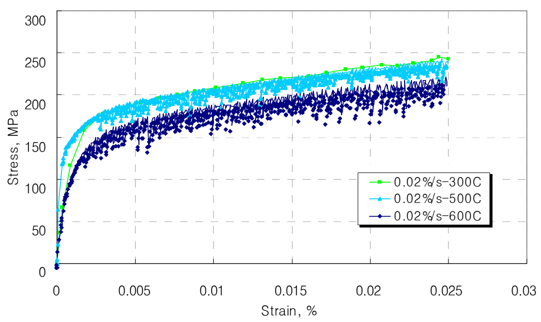


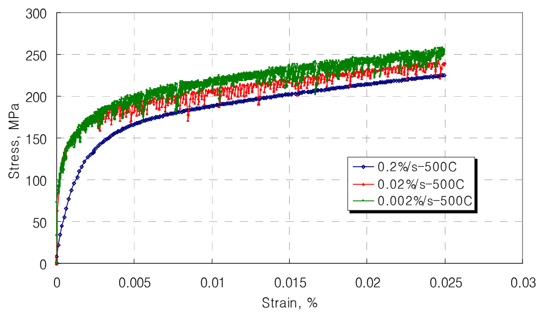
Figure 1. Stress-stain curve in tension test

In general, the regime of a serrated flow depends on the temperature and strain rate and it occurs easily in a higher temperature region and at a lower strain rate. In Fig. 1, a serrated flow occurred at both temperature conditions of 300℃ and 600℃ with different strain rate conditions. But, the magnitude of the load drop due to the serrated flow as evidence of a DSA is much higher at 600℃, and a lower strain rate than at 300℃.

The variation of the tensile curves with a temperature of 500℃ at each strain rate, and 600℃ for a given strain rate are shown in Fig. 2. It is known that the maximum stress level of most materials increases with an increasing strain rate. But, in Fig. 2(b), negative strain rate sensitivity (SRS) was observed which means that the strain hardening decreases as the strain rate increases.



(a)



(b)

Figure 2. Stress-strain curves from the tensile tests at (a) 500℃ (b) 0.002 %/s for given various conditions.

2.3 Stress Relaxation Test Results

The relaxation stress versus hold time resulting from a 100 hrs tensile hold with an initial strain range of 1% and 2% for a temperature of 500℃ and 600℃, respectively, are shown in Fig. 3

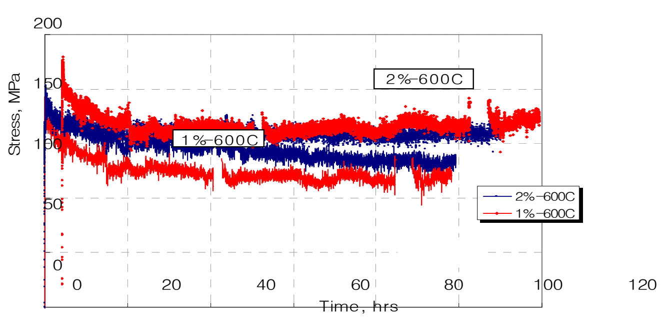


Figure 3. Stress relaxation curves at 600℃ in a 1% and 2% strain range

The relaxation stress depends on the temperature and initial strain range. The amount of relaxation stress is relatively higher in the temperature of 600℃, init strain range of 2%, respectively. It is noted that the da acquisition by using an extensometer under a hi temperature was not easy especially for a stra controlled testing.

3. Discussions

Tension tests were carried out at various temperatur in order to construct the basic material test data of t solution annealed 316L SS. In addition, stress relaxati tests were performed under strain controlled conditic Findings are as follows:

(1) A dynamic strain aging and negative SI behavior were exhibited in the giv temperature range of 300-600℃.

(2) A sharp reduction in the relaxation stre occurred in the early periods of a holding tir and then approached to saturation at 100 hrs.

(3) The relaxation stress is increases with increase of the initial holding strain range f the temperatures of 500℃ and 600℃.

(4) This stress relaxation data will be used predict a creep behavior.

Acknowledgement

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