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Creep Behavior in Air and Helium Environments of Alloy 617

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1. Introduction

A very high temperature gas reactor (VHTR) is one of Generation-IV reactors which aim at the safe, long-lived, proliferation-resistant and economical nuclear power plants. Its high operating temperature of over 800°C enables high energy efficiency and the production of hydrogen gas using Sulfur-Iodine process. The heat of the primary helium (He) circuit transfers to the secondary helium loop through the intermediate heat exchanger (IHX). The IHX component needs high-temperature creep resistance in He environment, and also it requires good oxidation resistance, corrosion resistance, and phase stability at high temperatures [1-4].

Currently, Alloy 617 is a prime candidate material because of its excellent mechanical properties at high temperature [5]. Its superiority originates from solid-solution strengthening by various additional components such as Co and Mo. Some researchers reported that the creep rupture time varied widely at high-temperature He environments. However, it has not been well established that the test temperature and minor impure gases in the He drastically affected the rupture time. Also, the creep data for Alloy 617 in the He environment are still insufficient for design application, and it is not yet well understood enough about the creep mechanism of the He effect.

In this study, to provide creep data for Alloy 617 in the air and He environments, a series of creep tests was conducted with different applied stress levels at 850°C. Creep behaviour in the air and He environments was investigated, and the results for 850°C were compared with those of 950°C and 900°C, which were obtained through author's previous study.

2. Methods and Results

2.1 Experimental procedures

Commercial grade nickel-based superalloy, Alloy 617 (Inconel 617) of a hot-rolled plate with a thickness of 15.875mm (5/8 inch) was used for this study. Creep specimens in the air and He environments were a cylindrical form of a 30 mm gauge length and a 6 mm diameter. Creep tests were conducted under different applied stress levels of 90MPa-32MPa at 850°C. Creep strain data with elapsed times was taken automatically by a personal computer through an extensometer attached to the creep specimens. Creep curves with variations were obtained, and the value of a minimum creep rate was obtained by calculating the secondary creep stage from the strain–time creep curves.

Before the creep tests, a vacuum chamber made for the quartz tube was purged with three or four times by a vacuum pump to remove some impurities in the chamber. During the creep tests, pure He with 99.9995% was supplied on the creep specimens attached in the quartz tube. Impurity concentration in pure He gas was $O_2 < 1.0$, $N_2 < 5.0$ and $H_2O < 1.0$. Flow rate of the He gas was controlled under $20cm^3/min$.

2.2 Comparison of creep behavior in the air and He environments

The creep rupture data such as the rupture time, minimum creep rate, rupture elongation and reduction of area were investigated for Alloy 617 in the air and He environments at 850°C. Their properties were compared.

Fig. 1 shows the comparison result of the log stress vs. log time to rupture in the air and He environments at 850°C. Creep rupture time between the air and He environments was almost similar. In previous study at 950°C and 900°C, there were some differences in the creep rupture time between the air and He environments. It is thus believed that a He effect disappeared down at 850°C. Currently, long-term creep tests for two samples are ongoing under 35MPa and 30MPa in the air, and the creep test for one sample is running under 32MPa in the He environment.

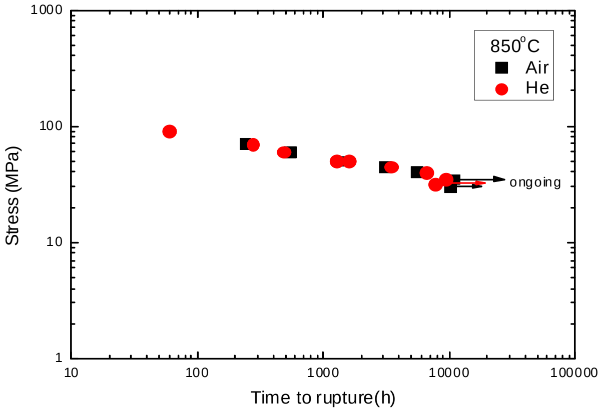

Fig. 1. Comparison of the log stress vs. log time to rupture in the air and He environments at 850°C

In addition, the relationship between a steady state creep rate and stress showed a good linearity in the air and He environments. Alloy 617 followed well Norton's power rule at this creep condition. The creep rate in the He environment was closely similar that of the air one.

Fig. 2 shows the comparison result of the Monkman-Grant (M-G) relationship between creep rupture time and minimum creep rate. As shown in this figure, creep rupture time between the air and He environments was almost similar. However, in previous study at 950°C and 900°C, Kim et. al.[6], reported that there were some differences in creep rupture time between the air and the He environments, that is, creep rupture time in the air was longer than that in the He environment.

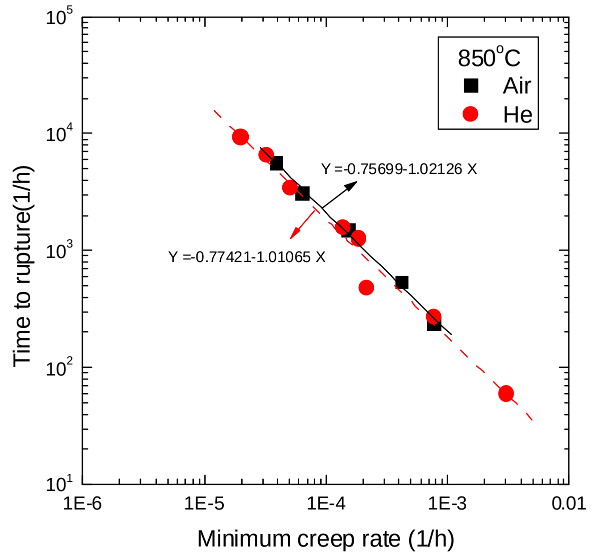

Fig. 2. Comparison of Monkman-Grant(M-G) relationship in the air and He environments at 850°C

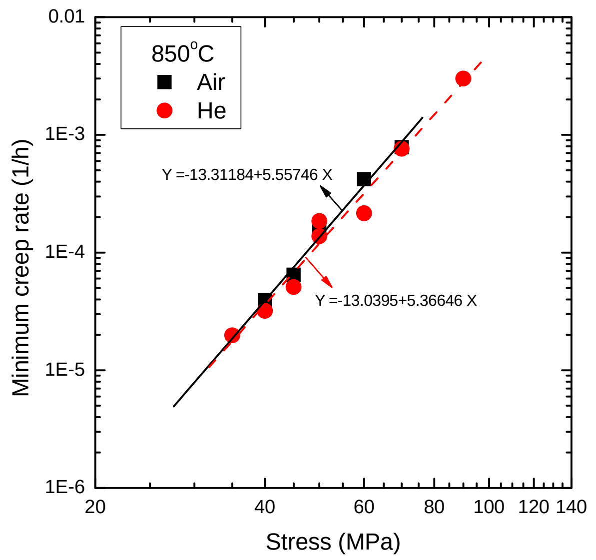

Fig. 3. Minimum creep rate vs. stress in the air and He environments at 850°C

Fig. 3 shows the power-law relationships between a minimum creep rate and stress. At this creep condition for Alloy 617, since creep deformation corresponds to power-law creep region, the mechanism of creep deformation is governed by a climb of dislocation. Thus, the relationships showed a good linearity. The constants of Norton's power law, $\dot{\varepsilon}_m = A\sigma^n$ can be obtained. It is supported well that creep rupture time between the air and He environments was almost same at 850°C. However, in previous study obtained at the temperatures of 950°C and 900°C, it appeared that the minimum creep rate in the He was a little faster than that in the air.

In addition, we investigated creep ductility between the air and He environments. As the stress increased, the creep ductility increased significantly. But, there was no difference in the creep ductility between the air and He environments at 850°C. It was reported well at 950°C and 900°C that the creep ductility in the air was higher than that of the He environment [6]. This reason is because the He effect disappeared during creep at 850°C.

3. Conclusions

Alloy 617 followed Norton's power law and the Monkman-Grant relationship well. It appeared that there was no difference in creep behavior between the air and He environments at 850°C. The minimum creep rate in the He environment was closely similar that in air. Also, creep rupture time in the He environment was almost same that in the air. As the stress increased, the creep ductility increased significantly. Similar behavior of creep properties at 850°C is because the He effect disappeared down during creep.

Acknowledgements

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