Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Comparison of Creep Rupture Properties in Air and Helium Environments at 800°C of Alloy 617

Woo-Gon Kim[a*], Jae-Young Park[a], I.M.W. Ekaputra[b], Seon-Jin Kim[b], Eung-Seon Kim[a], Min-Hwan Kim[a]
[a] *Korea Atomic Energy Research Institute, 989-111 Daedeokdaero, Yuseong, Daejeon, Korea, 305-353,*
[b]*Pukyong National University, 100 Yongdang-dong, Nam-gu, Busan, 608-739*
[*]*Corresponding author: wgkim@kaeri.re.kr*

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. It has been 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 environment drastically affected the rupture time. In addition, the creep data for Alloy 617 in the air and He environments 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, a comparison of creep rupture properties in the air and He environments of Alloy 617 was carried out based on a series of experimental data obtained from the creep tests, which were conducted with different applied stress levels at 800°C. Creep fractured microstructures in the air and He environments were investigated, and their features were discussed.

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 at 800°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 creep testing in the He environment, 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 $20 cm^3/min$.

2.2 Creep rupture properties

The creep rupture data such as the rupture time, minimum creep rate, rupture elongation and reduction of area were investigated in the air and He environments at 800°C. Their properties were compared using various creep plots.

Fig. 1 shows the comparison result of the log stress vs. log time to rupture in the air and He environments at 800°C. It can be seen that there were some differences in the creep rupture time between the air and He environments. Creep stress in the He environment was reduced compared with that in the air one. The different gap is larger with an increase in rupture time. Thus, it is expected that the He environment is more decreased in creep stress than the air one in the longer time of 10^5 h. The reason for this is that the creep rate in the He was faster than that in the air one.

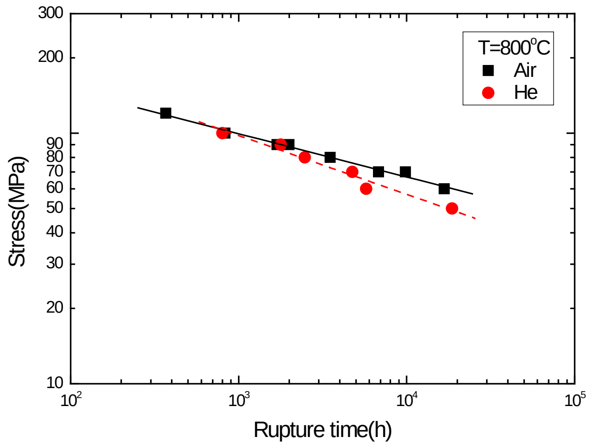

Fig. 1. Comparison of the log stress vs. log time to rupture in the air and He environments at 800°C

As shown in Fig. 2, Alloy 617 followed well Norton's power rule at this creep condition. The minimum creep rate in the He environment was faster than that in the air one, as shown in Fig. 2. It can be seen that the relationships between the minimum creep rate and stress present a good linearity regardless of the air and He environments. In the comparison of the Monkman-Grant (M-G) relationships between creep rupture time and minimum creep rate, it was investigated that no difference was for the air and He environments. At this creep condition for Alloy 617, it is assumed that creep deformation corresponds to power-law creep region, and its mechanism is governed by a climb of dislocation. The *A* and *n* values of Norton's power-law constants, in the air and He environments for Alloy 617 can be obtained using Fig. 2.

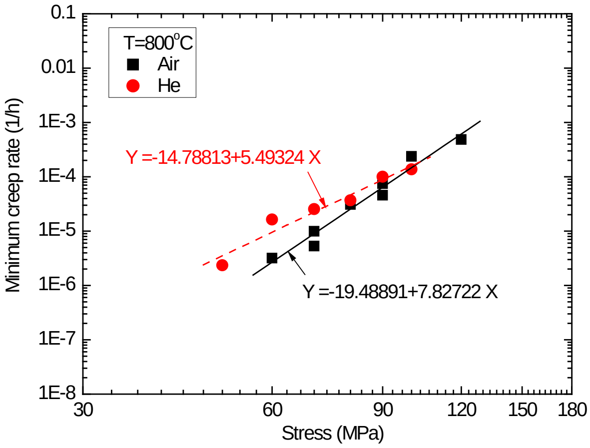

Fig. 2. Comparison of minimum creep rate vs. stress in the air and He environments at 800°C

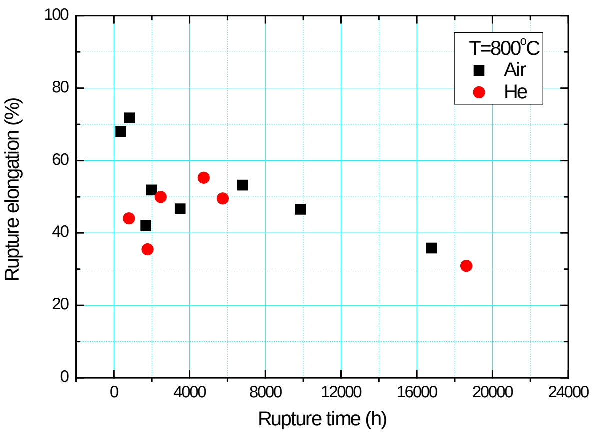

Fig. 3. Comparison of creep rupture elongation vs. rupture time in the air and He environments at 800°C

In addition, creep rupture elongation increased with an increase in stress. On the contrary, it decreased with an increase in rupture time. No difference was for the rupture elongation between the air and He environments at 800°C, as shown in Fig. 3. In the author's previous study at 950°C and 900°C, the creep ductility in the air was higher than that in the He [6]. In the present investigation at 800°C, it is assumed that there was no effect regardless of the air and He environments.

Fig. 4 shows SEM photos for the precipitates formed in crept specimens under 60MPa in the air and He environments at 800°C. It can be seen that the He specimen remains more coarsening precipitates in the grain boundary than the air one. It is analyzed that more coarsening precipitates in the He deteriorated the rupture time or strength.

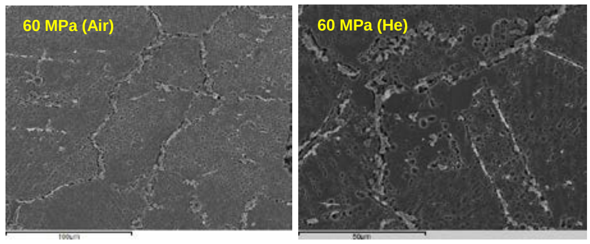

Fig. 4. SEM photos showing the precipitates formed in crept specimens under 60MPa in the air and He environments at 800°C

3. Conclusions

The He environment showed more reduction in creep rupture time (or stress) than the air. The reduction gap was larger with an increase in rupture time. The reason for this is that the creep rate in the He was faster than that in the air one. Rupture elongation increased with an increase in stress, but it decreased contrarily with an increase in rupture time. No difference was for the rupture elongation between the air and He environments at 800°C. The He specimen remained more coarsening of the precipitates in the grain boundary than the air one.

Acknowledgements

This study was supported by the Korean Ministry of Education, Science & Technology through its National Nuclear Technology Program.

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