

## A Study on the Microstructure Change of Alloy 617 in Helium Environment at High Temperature

Gyeong-Geun LEE\*, Sujin Jung, Daejong Kim, Dong-Jin Kim

Korea Atomic Energy Research Institute, Daedeok-daero 1045, Yuseong-gu, Daejeon, 305-353, Korea

\*Corresponding author: gglee@kaeri.re.kr

### 1. Introduction

The Very high temperature gas reactor (VHTR) is designed to be a safe, long-life, proliferation-resistant and economical nuclear power plant. The concept of VHTR should produce an outlet gas temperature above 850°C and this high temperature enables the production of hydrogen gas using Sulfur-Iodine process. The heat of the primary loop of a VHTR transfers to the secondary loop through the intermediate heat exchanger (IHX). The primary candidate material for an IHX in Korea is a Ni-base superalloy, Inconel Alloy 617. In this report, the oxidation behavior of the Alloy 617 in Helium environment was observed. In order to compare the microstructure, the microstructure change of Alloy 617 oxidized in air environment was also reported.

### 2. Methods and Results

#### 2.1 Experimental procedures

16 mm thick plate of Alloy 617 was acquired in mill-annealed condition. Its chemical composition from the supplier is listed in Table 1.

The oxidation specimen in the helium environment was a small rectangular coupon with the dimension of 10×10×1 mm. The specimens were tested under impure helium of helium of H<sub>2</sub> 20 Pa, CH<sub>4</sub> 2 Pa, CO 5 Pa and H<sub>2</sub>O below 0.1 Pa at 950°C for 10~250 h with a flow rate of 50 cc/min. the cross-sectional microstructure of the test specimen was observed using SEM back-scattered electron image techniques equipped with energy dispersive X-ray spectroscopy (EDS).

Table I: RPV materials of Korean PWR

Elements	Ni	C	Fe	Si	Mn	Co	Cr
Wt.%	Bal.	0.08	1.49	0.06	0.11	11.58	22.16
Elements	Ti	P	S	Mo	Al	B	Cu
Wt.%	0.35	0.003	0.001	9.8	1.12	0.002	0.08

#### 2.2 Microstructure of as-received specimen

Fig. 1 shows the BSE image of the as-received Alloy 617. The dark and bright particles in the matrix are identified as Cr-rich M<sub>23</sub>C<sub>6</sub> and Mo-rich M<sub>6</sub>C carbides, respectively. They were located mainly along the grain boundaries. Mo-rich M<sub>6</sub>C carbide is brighter than Cr-rich M<sub>23</sub>C<sub>6</sub> because heavy element backscatters electrons more strongly than light element. It seems that

the Cr-rich M<sub>23</sub>C<sub>6</sub> carbides are more abundant in the as-received specimen.

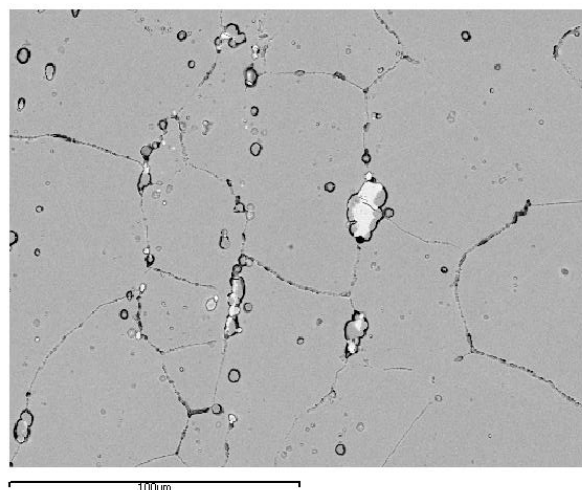


Fig. 1. BSE image for as-receive specimen.

#### 2.3 Microstructural change in helium environment

Fig. 2 shows the cross-sectional views of the specimen which were exposed in the helium environment at 950°C for 250 h. The outer Cr-oxide layer was formed on the surface and the Al-oxide layer protruded inwardly. The carbide-free region was shown between the Al-oxide layer and matrix in the specimen. This result is similar to other reports [1-5]. The carbide precipitates in the matrix shows a bright color.

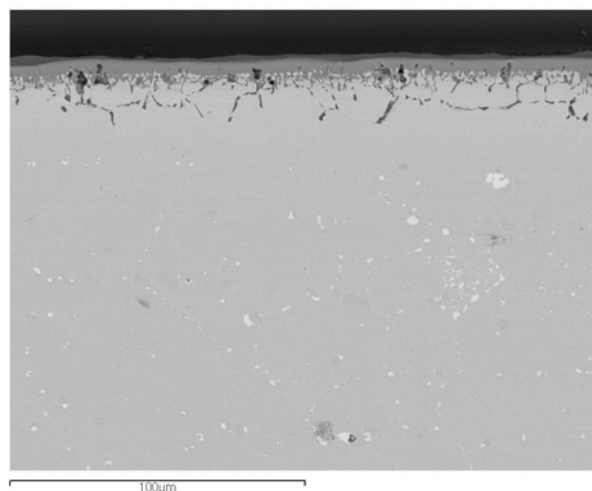


Fig. 2. BSE image for the cross-section of the specimen under impure helium environment at 950°C after 250 h.

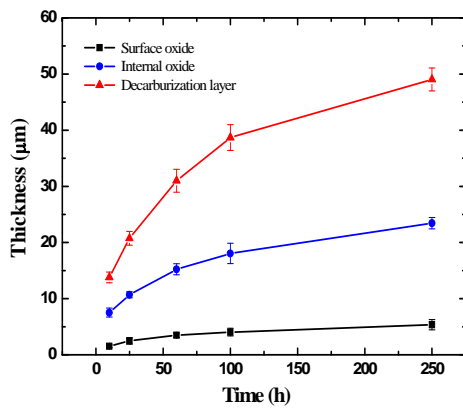


Fig. 3. Thickness change as a function of the test duration under controlled impure helium environment at 950°C.

Fig. 3 shows the change in the thickness of surface Cr-oxide, internal Al-oxide and decarburization layer of Alloy 617 specimens as a function of the test duration. The thicknesses increased with the test time, and the increase rate of the thickness was decreased with the time. The behavior seems to follow a parabolic rate law. It is expected that the surface oxide was protective to prevent the further surface reaction. The thickness would increase linearly with the time if the surface layer were not protective. The Cr-oxide in the air specimens shows a rather rough surface compared to helium specimens. In the case of the air specimens, the outer oxide layer thickness was thick in the early stage of rupture time, but the thickness increased slightly with duration time. It seems that the oxide layer of the air specimens was dense and the diffusion of the oxygen was inhibited.

### 3. Summaries

The microstructures of the Alloy 617 specimens which are oxidized in helium environment at 950°C were observed. The outer Cr-oxide layer and inwardly protruded Al-oxide layer increased with the duration time. The thickness of outer oxide layer in helium environment specimens slowly increased with the duration time. The increase in oxide layers and decarburization thickness seems to show a parabolic curve. The difference of Cr-oxide layer between the air and helium specimen affected the oxidation kinetics.

### REFERENCES

- [1] C. Cabet, F. Rouillard, Corrosion of High Temperature Metallic Materials in VHTR, *J. Nuclear Materials*, 392 (2009) 235.
- [2] W. J. Quadackers, Corrosion of High Temperature Alloys in the Primary Circuit Helium of High Temperature Gas Cooled Reactors. Part II: Experimental Results, *Werkstoffe und Korrosion*, 36 (1985) 335.

- [3] M. R. Warren, Rapid Decarburization and Carburization in High Temperature Alloys in Impure Helium Environments, *High Temperature Technology*, 4 (1986) 119.
- [4] C. Cabet, J. Chapovaloff, F. Rouillard, G. Girardin, D. Kaczorowski, K. Wolski, M. Pijolat, High temperature reactivity of two chromium-containing alloys in impure helium, *J. Nuclear Materials*, 375 (2008) 173.
- [5] T. S. Jo, S. Lee, G.-S. Kim, S.-H. Kim, Y.D. Kim, Effect of High Temperature Degradation on Microstructure and High Temperature Mechanical Properties of Inconel 617, *Kor. J. Mater. Res.*, 17 (2007) 268.