

## Effects of Impurity on the Corrosion Behavior of Alloy 617 in the Helium Environment

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### 1. Introduction

Nickel-based superalloy such as Alloy 617, is being considered as a candidate for the intermediate heat exchanger (IHX) of a very high-temperature gas reactor (VHTR) operated at the temperature of up to 950°C and gas pressure difference of up to 8 MPa. Alloy 617 has superior mechanical properties in air but many researchers have reported its properties decrease at high temperatures above 900°C in the impure helium environment of a VHTR. The helium coolant in the primary circuit inevitably includes minor impurities such as H<sub>2</sub>, CO, CH<sub>4</sub>, and H<sub>2</sub>O under operating condition. Material degradation is aggravated through oxidation, carburization, and decarburization under the impure helium environment.

In this study, high-temperature corrosion tests were carried out at 850-950°C in the impure helium environment. The mass changes of the specimens were measured and the microstructures were analyzed quantitatively. In addition, all corrosion tests were conducted in the pure helium environment and the results were compared to the results under the impure helium.

### 2. Experimental

The tested material was a commercial Alloy 617 plate purchased from Special Metals (Huntington, West Virginia, US). The chemical composition of Alloy 617 is shown in Table 1. The plate was cut into small coupons of ~10×11×1 mm<sup>3</sup> in size using a wire cutting technique. No thermal treatment was carried out before machining. The surface of the specimen was polished mechanically using 1500 SiC paper and cleaned using ultrasonic a for in acetone and ethyl alcohol for removal impurities.

Table 1 Chemical composition of the commercial Alloy 617 used in this study (in wt%)

Ni	Cr	Co	Mo	C	Mn	S
53.16	22.16	11.58	9.80	0.08	0.11	0.001
Si	Cu	Al	Ti	Fe	P	B
0.06	0.08	1.12	0.35	1.49	0.08	0.002

The high-temperature corrosion tests of Alloy 617 specimens were carried out at 850, 900, and 950°C in the impure helium and pure helium environments, respectively.

The impure helium composition was fixed by 200 ppm H<sub>2</sub>, 50 ppm CO, 20 ppm CH<sub>4</sub>, and H<sub>2</sub>O < 2 ppm, and the gas flow rate was 50 cm<sup>3</sup>/min. The specimens were heated at a rate of 10°C/min and the duration of the holding period at a test temperature was up to 250 h. The helium gas with 99.999-% purity was used for the pure helium test include the H<sub>2</sub>O content of a few ppm.

The weight change of the specimen was measured using a precision balance with 1×10<sup>-5</sup> g accuracy. A scanning electron microscope (SEM) equipped with energy-dispersive X-ray spectroscopy (EDS) was used to analyze the microstructures and the composition of the specimens. A transmission electron microscope (TEM) analysis was performed on the JEOL JEM-2100F (HR).

### 3. Results and Discussion

#### 3.1 Weight changes

High-temperature corrosion tests were performed in the impure helium environment, to measure the weight change. The specimen weight increases as a function of the exposure time and temperature, and the rate of weight change decreased with an increase in time. The square of the weight change and time clearly shows the linear relationships indicating a parabolic oxidation of metals. Alloy 617 specimens show a parabolic oxidation behavior for all temperatures.

Fig. 1 plots the weight changes from corrosion in the pure helium and the impure helium environment at 950°C. The weight increase of the corroded specimens in the pure helium was relatively reduced than the weight increase in the impure helium environment. The oxidation rate was drastically reduced to 1.6-% of the impure helium result.

#### 3.2. Microstructure

Fig. 2 shows the cross-sectional image of a corroded specimen in the impure helium and pure helium environment at 950°C. The corroded specimen in the impure helium environment in which the outer oxide layer, internal oxides and carbide depleted zone

thicknesses increased with the test time. On the other side, the corroded specimen under the pure helium, the outer oxide layer could not be identified, and the internal oxide was not developed heavily along the grain boundaries. The carbide-depleted zone was found, but the depth decreased compared to that of the impure helium environment.

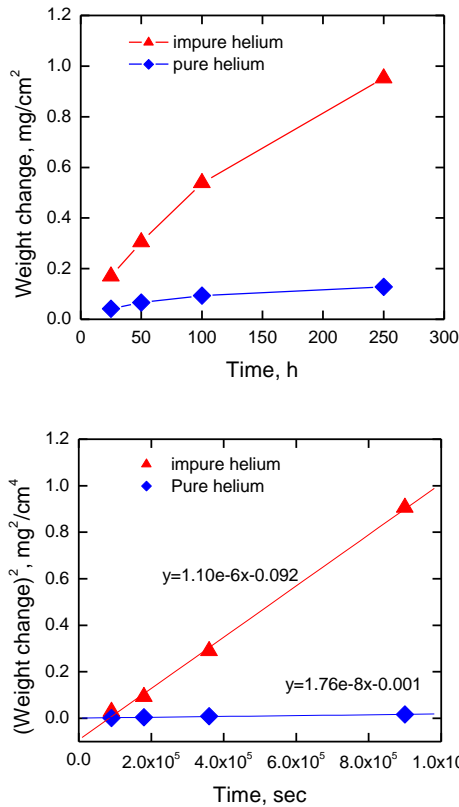


Fig. 1 Comparison of mass change between the impure helium environment and the pure helium environment at 950°C: (a) mass change vs. time and (b) (mass change)² vs. time (sec).

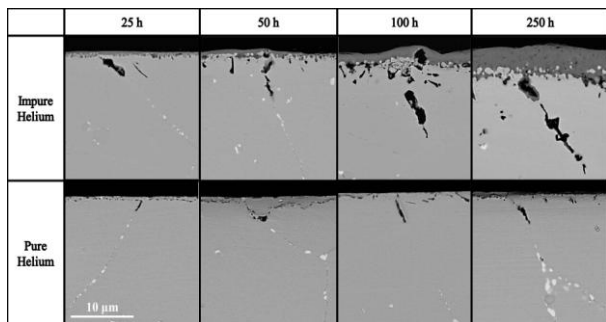


Fig. 1 Back - Scattered SEM micrograph of the corroded specimens in the helium environment at 950°C.

#### 4. Conclusions

Alloy 617 specimens showed a parabolic oxidation behavior at all temperatures under the impure helium environment. All specimens had similar microstructure in the outer Cr-oxide layers, internal Al-oxides, and carbide-depleted zone. The weight increase of the corroded specimens in the pure helium was relatively reduced. Microstructure result, oxide layer and carbide-depleted zone were hardly ever observed. The impurity in helium affected the corrosion behavior of Alloy 617 and may cause a decrease in the mechanical properties. Therefore, the control of minor impurities in VHTR helium is necessary for the application of Alloy 617 to the IHX material of a VHTR.

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