Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

An evaluation of mechanical and high-temperature corrosion properties of Ni-Cr alloy with composition of alloying elements

Sujin Jung , Dong-Jin Kim
Nuclear Materials Safety Research Division, Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353,
**Corresponding author: sjjung921@kaeri.re.kr*

1. Introduction

Alloy 617 is considered as a candidate Ni-based superalloy for the intermediate heat exchanger (IHX) of a very high-temperature gas reactor (VHTR) because of its good creep strength and corrosion resistance at high temperature.

Helium is used as a coolant in a VHTR owing to its high thermal conductivity, inertness, and low neutron absorption. However, helium inevitably includes impurities that create an imbalance in the surface reactivity at the interface of the coolant and the exposed materials.

As the Alloy 617 has been exposed to high temperatures at 950℃ in the impure helium environment of a VHTR, degradation of material is accelerated and mechanical properties decreased. The high-temperature strength, creep, and corrosion properties of the structural material for an IHX are highly important to maintain the integrity in a harsh environment for a 60 year period.

Therefore, an alloy superior to alloy 617 should be developed. In this study, the mechanical and high-temperature corrosion properties for Ni-Cr alloys fabricated in laboratory were evaluated as a function of the grain boundary strengthening and alloying element composition.

2. Experimental

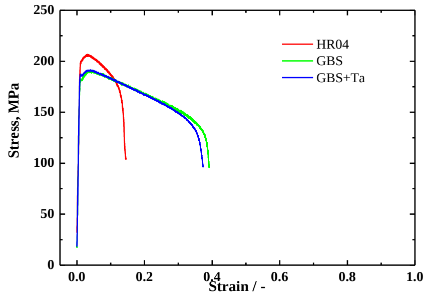
The specimen used in the experiments was produced by varying the Cr, Co, and Mo composition. A mechanical property test was carried out in air and 950^{o}C with a tension speed of 1 mm/min using a 50N tensile tester. After the experiment, the side fracture and the fracture surface of the specimen were observed.

The high-temperature corrosion tests of the Alloy 617 specimens were carried out at 950^{o}C in an air environment. The specimens were heated at a rate of 10℃/min and the duration of the holding period at a test temperature was up to 250 h. The weight change of the specimen was measured using a precision balance with a 1×10^{-5} g accuracy. A scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectroscope (EDS) was used to analyze the microstructures and the composition of the specimens.

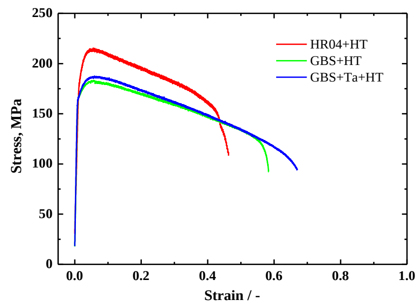
3. Results and Discussion

Fig. 1 presents the tensile test results for the solution annealed (SA) specimen, SA + grain boundary strengthener (GBS) and SA + GBS + Ta specimen at 950℃ in an air environment. In the case of the SA+GBS specimen, elongation is significantly improved compared with the SA specimen. From the results, Zr and Hf elements strengthen the grain boundary.

Mo was beneficial to the high-temperature ductility, while Cr was detrimental. This is differentiated from the carbide composition. Co seems to modify carbide leading to a mechanical property change at 950^{o}C. A high-temperature ductility of 76% was achieved by a combination of alloying elements and heat treatment without a significant loss of yield strength or tensile strength, which is comparable to a commercial Ni-based superalloy.



(a)



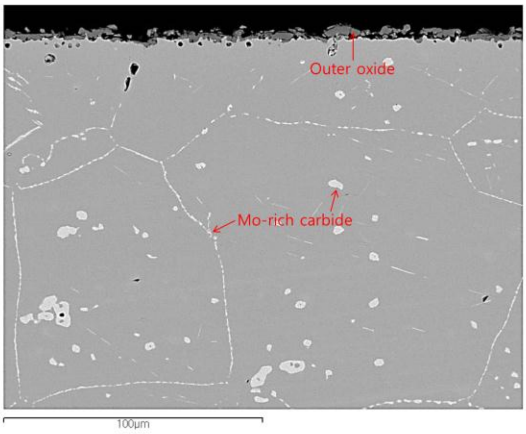
(b)

Fig. 1. Stress-strain curves at 950^{o}C in air obtained for (a) SA specimen, SA + GBS and SA + GBS + Ta and (b) heat treatment.

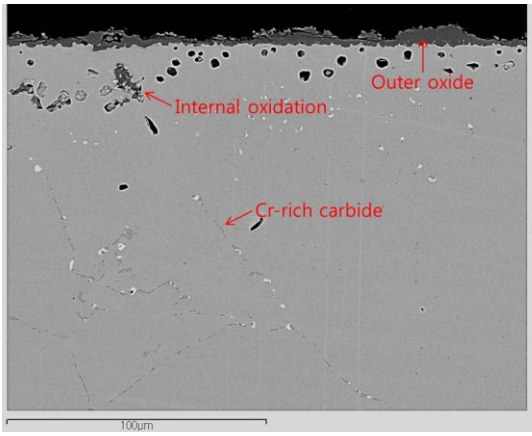
Fig. 2 shows a cross-sectional image of a corroded specimen in an air environment at 950^{o}C.

As the result of a high-temperature corrosion test, an unstable outer oxide layer was formed, and the internal oxidation was almost not observed in the case of a Mo increased specimen. The coarse Mo-rich carbides are shown along the grain boundary, and in the grain Cr-rich carbides are difficult to be observed.

On the other hand, the case of higher Cr specimen, a Cr content of unstable outer oxide layer was higher and discontinuous internal oxidation occurred near the surface. Cr-rich carbides were dominantly observed rather than Mo-rich carbides along the grain boundary and in the gain.



(a)



(b)

Fig. 2. Back - scattered SEM micrograph of the corroded specimens in an air environment at 950^{o}C: (a) Mo increased specimen and (b) Cr increased specimen.

4. Conclusions

The mechanical property and corrosion property for Ni-Cr alloys fabricated in a laboratory were evaluated as a function of the main element composition. The ductility was increased and decreased by increasing the amount of Mo and Cr, respectively.

Surface oxide was detached during the corrosion test, because there was not aluminum element in the alloy. Aluminum seems to act as an anti-corrosive role in Ni-based alloy. In conclusion, the addition of Al into the alloy is required to improvement of high temperature corrosion resistance.

REFERENCES

[1] W.R. Corwin et al., Generation IV Reactors Integrated Materials Technology Program Plan: Focus on Very High Temperature Reactor Materials, ORNL/TM-2008/129, 2008.

[2] R. N. Wright, Kinetics of Gas Reactions and Environmental Degradation in NGNP Helium, INL/EXT-06-11494, 2006.

[3] D.-J. Kim, G.-G. Lee, S. J. Jeong, W. G. Kim and J. Y. Park: *Nucl. Eng. Tech. 2011, vol. 43, pp. 429-436.*

[4] G.-G. Lee, S.-J. Jung, D. Kim, Y.-H. Jeong and D.-J. Kim, *Kor. J. Met. Mater. 2012, vol. 50, pp. 659-667.*