Creep Properties of Alloy 617 at 900°C in Helium Environments with Various Oxygen Concentrations

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1. Introduction

A very high temperature gas-cooled reactor (VHTR) is one of the most promising reactor types of the generation-IV reactors. The components of VHTR, such as intermediate heat exchanger (IHX) and hot gas duct (HGD), will be in the temperature range of 850-950°C and helium environment to achieve higher performance. Alloy 617 is a nickel-base wrought superalloy having exceptional creep strength above 800°C. Currently, Alloy 617 is considered for the use of structural materials for IHX and HGD utilizing the excellent high temperature corrosion resistance in VHTR helium environments [1].

Helium by itself is inert gas. However, the helium coolant in a VHTR is expected to contain small amounts (of the order ppms) of contaminants such as H_2, H_2O, CH_4, CO_2 and O_2. These contaminants can significantly corrode the materials at high temperatures, thereby affecting critical long-term mechanical properties like creep and tensile elongation [2,3]. There are considerable literatures [1,4,5] on the creep rupture properties of Alloy 617 in a helium environment with various impurities such as H_2, H_2O, CH_4, CO_2 and O_2. The effects of such impurities on creep and tensile properties are complex and inter-related, thus it is not easy to isolate the effects of any specific impurity.

In this study, the effects of oxygen in the environments on the high temperature creep properties of Alloy 617 were investigated. The evolution of oxide layer during the creep test in various oxygen contents was discussed and correlated with creep resistance of Alloy 617.

2. Experimental

The chemical composition of the Alloy 617 is shown in Table 1. The gage length of the creep specimen is 19.05mm. A hole is made below the gage length section for a thermocouple to control induction coil heater. The temperature was monitored and controlled by pyrometer within 900°C ± 5°C during the tests. The pressure in the environmental chamber was maintained at 1.1 atm to prevent in-leakage of impurities. The flow rate of mixed gas was 200cc/min with various oxygen concentrations: 99.999% pure He (< 2 ppm O_2), He + 200 ppm O_2, and air. The creep tests were performed at constant load of 50 MPa and 70 MPa.

In addition, a coupon type specimen, 12mm diameter and 1mm thickness, was also oxidized in the same environments with creep specimen for 200 hours in order to investigate the potential effects of oxidation on creep behavior of Alloy 617.

Table 1. Chemical composition (wt%) of Alloy 617.

Ni	Cr	Fe	C	Si	Mn	Ti	Al	Co	Mo
Bal	22.1	1.58	0.09	0.42	0.12	0.35	1.41	11.6	9.57

3. Results and Discussion

3.1. Creep resistance

The results of creep rupture tests at 900°C in helium environment with various oxygen concentrations at 50MPa are summarized in Fig. 1. It shows the creep curves conducted in flowing He, He + 200 ppm O_2 and air environment at 900°C and 50MPa. The creep rate of Alloy 617 in flowing He is the highest. And the rupture life is also the shortest in flowing He environment due to poor oxidation resistance in moderate oxygen concentrations.

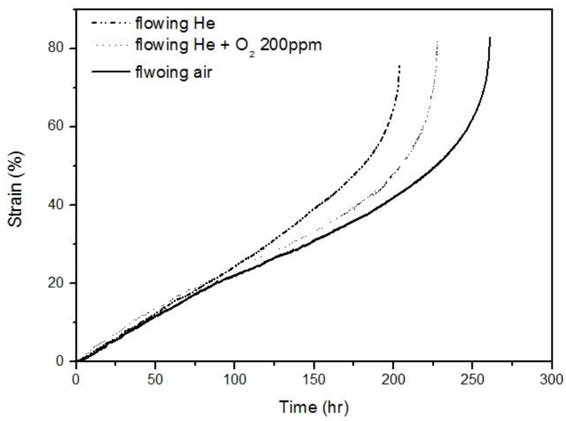
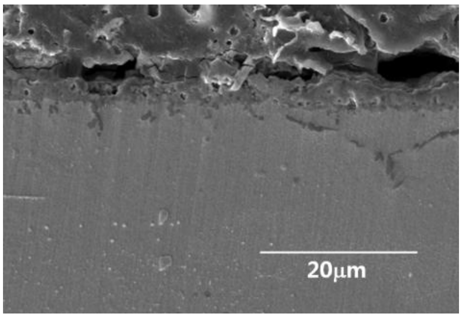


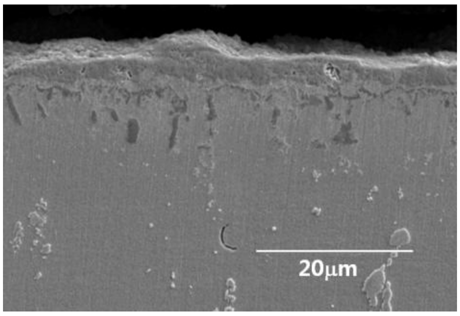
Fig. 1 Creep curve of Alloy 617 with various oxygen concentration at 900°C and 50MPa

3.2. Oxide layer characteristics

The SEM images of Alloy 617 oxidized in flowing air and flowing He are shown in Fig. 2. Fig. 2(a) shows stable and thick outer Cr_2O_3 oxide layer result in large weight gain in air environment. In addition, there are well developed Al_2O_3 internal oxides in a short range under oxide layer. It is commonly observed in oxidizing environments [3,6]. Similarly, Fig. 2(b) also shows Cr_2O_3 outer oxide layer and deeper Al_2O_3 internal oxides in the pure helium environment than air environment. Even if pure helium is used in this study, the pure helium includes about 2 ppm of oxygen. The small amount of oxygen is continuously supplied to surface. And it helps to make a severe oxidation of Alloy 617 specimen. Furthermore, the small amount of oxygen helps to form unstable stochiometry of chromium oxide layers. Thus more oxygen penetrate oxide layer and the formation of internal oxide such as Al_2O_3 is promoted in the pure helium environment.



(a)



(b)

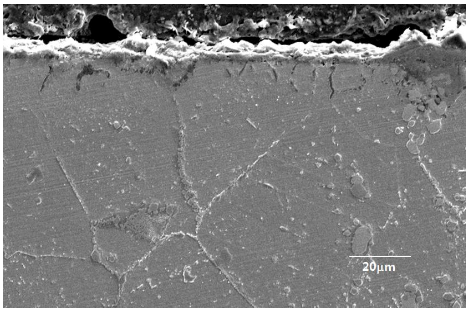
Fig. 2 SEM image of the Alloy 617 samples oxidized at 900°C for 200 hours: (a) in flowing air, (b) in flowing He

3.3. Decarburization Depth

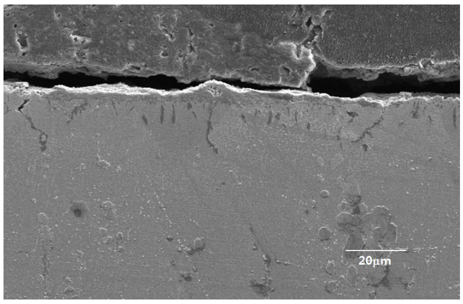
Fig. 3 shows the comparison of decarburization depth of Alloy 617 oxidized in flowing air and in flowing helium environment. The decarburization depth of Alloy 617 oxidized in flowing helium environment was deeper than in flowing air environment. In flowing helium environment, the unstable stochiometry of chromium oxide layers allows the oxygen penetration through the oxide layers easily.

4. Conclusions

The oxidation resistance and creep rupture life of Alloy 617 in flowing He, He + 200 ppm O_2 and air environment at 900°C. The results showed that the worst oxidation resistance corresponded to the lowest creep rupture life of Alloy 617. The oxidation resistance affected creep property because formation of stable oxide layer prevented decarburization which is known to have significant effects on creep resistance. Further tests at lower stress would provide more information to understand the relation between the environment and creep resistance of Alloy 617.



(a)



(b)

Fig.3 SEM image of the Alloy 617 samples oxidized at 900°C for 200 hours: (a) in flowing air, (b) in flowing He

REFERENCES

[1] P. S. Shankar and K. Natesan, "Effect of Trace Impurities in Helium on the Creep Behavior of Alloy 617 for Very High Temperature Reactor Applications", Journal of Nuclear Materials, Vol. 366, No. 1-2, pp. 28-36, 2007.

[2] C. Jang, D. Lee and D. Kim, "Oxidation Behavior of an Alloy 617 in Very High-Temperature Air and Helium Environments", Int. J. of PVP, Vol. 85, No. 6, pp. 368-377, 2008.

[3] D. Kim, I. Sah and C. Jang, "Effects of High Temperature Aging in an Impure Helium Environment on Low Temperature Embrittlement of Alloy 617 and Haynes 230," Journal of Nuclear Materials, Vol. 405, No. 1, pp. 9-16, 2010.

[4] Y. Hosoi and S. Abe, "The Effect of Helium Environment on the Creep Rupture Properties of Inconel 617 at 1000C," Metallurgical Transactions, Vol. 6A, pp. 1171-1178, 1975.

[5] B. Huchtemann, "The Effect of Alloy Chemistry on Creep Behaviour in a Helium Environment with Low Oxygen Partial Pressure," Materials Science and Engineering, Vol. A121, pp.623-626, 1989.

[6] A. Duval, F. Miserque, M. Tabarant, J. P. Nogier and A. Gedeon, "Influence of the Oxygen Partial Pressure on the Oxidation of Inconel 617 Alloy at High Temperature", Oxid Met, Vol. 74, pp.215-238, 2010.