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Creep and Oxidation Behaviors of Alloy 617 in Air and He Environment

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1. Introduction

Alloy 617 is one of the candidate materials to be considered as a structural material for VHTR. It is subject to the high temperature, helium environment containing small amount of impurities for a very long time. The investigation of microstructural stability and creep strength is imperative to design VHTR.

Creep-life is mostly predicted by time-temperature parameter (TTP) method such as Larson-Miller, Orr-Sherby-Dorn that the long-term creep strength is expected from extrapolation of short-term creep strength because of the limitation of test time [1]. Therefore, in the present study, creep behavior and microstructural stability were investigated through the short-term creep test.

2. Experimental

Commercial grade nickel-base superalloy, alloy 617 was used for creep test which was conducted in the high purity helium gas of 99.999 %, containing small amount of impurities (1.8 ppm H_2O, 1.4 ppm O_2, 3.1 ppm N_2) and in air environment. Chemical composition of alloy 617 provided from Haynes International Co. is listed in table 1. Creep strain was measured by extensometer. Helium environment and high temperature up to 1000°C were made possible by the use of closed metal chamber and induction heater. The present creep test was mainly conducted at 800°C up to now.

Table 1. Chemical composition of alloy 617

Cr	Al	C	Co	Fe	Mn	Mo	Ni	Si	Ti
21.8	1.1	.08	12	1.2	.04	9.4	Bal.	.1	.38

3. Results and discussion

3.1.Creep behaviors

Figure 1 shows the creep strain vs. elapsed time curves obtained in air and pure helium environment at 800°C at applied stress of 160 MPa. Little primary creep region was observed for both environments. The elapsed time to creep rupture in helium was longer than air despite of the same applied stress because of the limited damaging elements such as H_2O and O_2. High ductile transgranular fracture was observed in air environment. On the other hand, alloy 617 in pure helium environment was exposed to small amount of damaging elements for a long time that gave enough time to form the cavity on the grain boundary. As a result, low ductile intergranular fracture was observed.

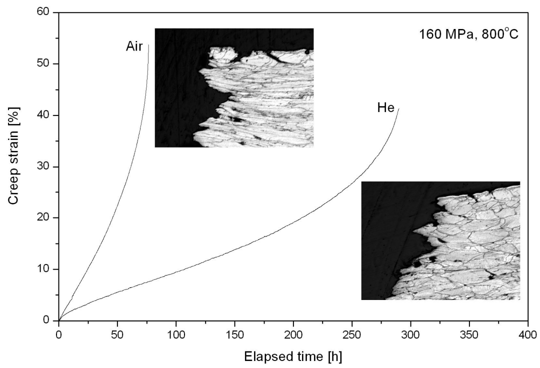


Figure 1. Creep strain vs. time curves for alloy 617 tested at 800°C in air and pure helium environment

The creep behavior of alloy 617 in pure helium and air was compared with ORNL creep data as shown in figure 2 [2]. Creep data obtained from present test was reasonable compared to ORNL creep data. Time to 1% total strain and rupture of alloy 617 exposed to helium environment was longer than air environment because of the limitation of oxygen content.

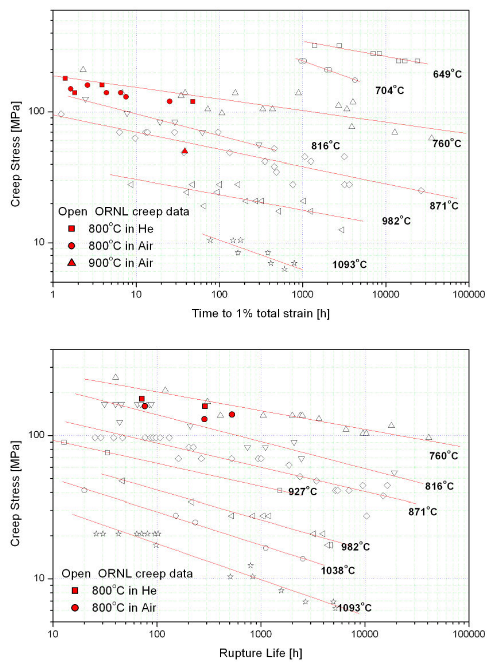


Figure 2. Comparison of creep stress vs. time to 1% total strain and rupture curves with other creep data

3.2.The formation of creep cavities and surface damage

Coarse cubic MC carbide is a major source of carbon during service and $M_{23}C_6$ carbides at grain boundary inhibit grain boundary sliding. They enhance creep strength [3]. Eventually, however, de-cohesion of carbide interface promoted the formation of creep cavities by diffusion of vacancies as shown in figure 3. Creep cavities over critical size enhance crack initiation and propagation so that many intergranular cracks were observed by SEM observation. MCs were identified as Ti-rich or Mo-rich carbides by EDX analysis.

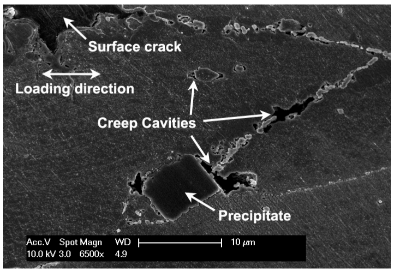
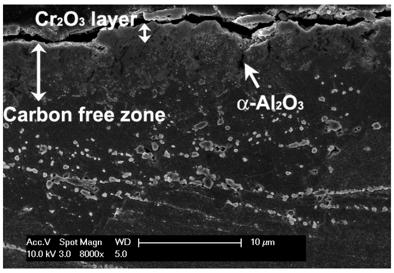
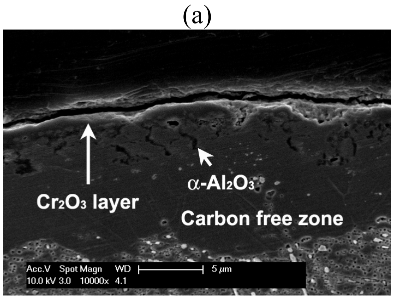


Figure 3. Carbides and creep cavities of alloy 617 tested at 800°C in air environment

Although the exposed time in helium was longer than air environment, surface damage was considerably severe by oxidation in helium as shown in figure 4. Thick carbide free zone was developed around 10 μm despite of pure helium by reaction between chromia and carbide precipitates. Discontinuous internal α-Al_2O_3 oxides were also considerably developed.



(a)



(b)

Figure 4. Internal oxides and carbon free zone of alloy 617 tested at 800°C (a) in air, (b) in helium environment

3.3.Effect of creep stress on oxidation behaviors

Alloy 617 is a chromia-forming alloy on surface. In the case of high temperature oxidation without the applied stress, internal oxide, Al_2O_3 nucleates on the grain boundary near surface. Oxygen diffuses preferentially along the interface between internal Al_2O_3 islands and matrix because grain boundary is one of the most high diffusivity paths [4]. Therefore, extensive internal Al_2O_3 islands are formed in elongated shape [5]. In present study, however, both Cr_2O_3 and small amount of Al_2O_3 along with grain boundary of Cr_2O_3 were observed near surface crack when creep stress was applied as shown in figure 5. Creep stress could be lead to de-cohesion of the Al_2O_3 interface, which provides preferential sites for penetration of damaging elements.

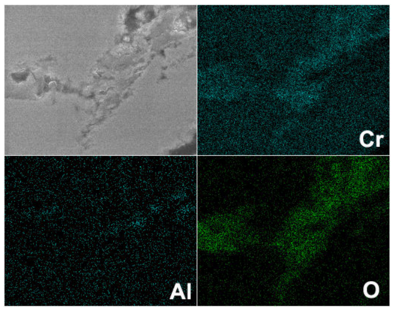


Figure 5. Internal oxide near surface crack of alloy 617 tested at 800°C in pure helium environment

SUMMARY

Creep test was mainly carried out at 800°C in air and pure helium environment. Creep data produced by the induction heating method was considerably accurate compared to ORNL creep data. Creep rupture time was longer in helium than air, but surface damage was considerably severe due to very small amount of impurities despite of pure helium environment. Crack initiation and propagation were strongly related to the de-cohesion of carbides interface and the formation of creep cavities.

ACKNOWLEDGEMENT

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