
Hasegawa A., Abe K., Satou M., Kudoh Y., Briyatmoko B., and Masuda N.
Faculty of Engineering, Tohoku University

Introduction

Type 316 austenitic stainless steels have been used for fuel cladding materials of fast breeder reactor such as Monju, a Japanese prototype fast breeder reactor. Maximum irradiation damage of cladding material in Monju will be about 115dpa and maximum temperature is 773K\(^1\). In a future power reactor, total amount of damage will be higher than 150dpa and helium contents will be higher than about 200appm\(^2\), therefore, further improvement of void swelling resistance, creep strength, high temperature strength and corrosion resistance will be required. The PNC1520, which is a Fe-15Cr-20Ni base alloy, is one of the candidate alloys for the power reactor\(^1\).

The purpose of this work is to study the helium effect on high temperature tensile behavior of Fe-15Cr-20Ni model alloy from the stand point of view of basic study to apply the alloy development by clarifying temperature dependence of tensile behavior of solution annealed specimen.

Experimental

The chemical compositions of Fe-15Cr-20Ni austenitic stainless steel is given in table 1. The Fe-15Cr-20Ni alloy was supplied by PNC (Power Reactor and Nuclear Fuel Development Corporation). The specimens were annealed at 1293K for 120sec in avacuum-shield quartz tube for solution annealed treatment.

Helium implantation was carried out using 36MeV helium ion beam of the cyclotron in CYRIC. A tandem-type energy degrader system was used to obtain uniform helium distribution along the implanted direction. The total amount of helium in a specimen was evaluated to be approximately 100appm for 12h irradiation and the level of displacement damage was 0.04dpa. The He concentrations of 5 and 30appm specimens were also prepared. Maximum specimen temperature during the implantation was kept below 429K.

After implantation, tensile tests were conducted from room temperature to 1123K in a vacuum furnace (1x10\(^{-4}\)Pa) with an Instron-type testing machine. Fracture surfaces of
ruptured specimen were examined in a scanning electron microscope(SEM). The detail of the experimental condition has been described elsewhere\(^3\).

**Results**

Results of 0.2% proof stress (yield stress: \(\sigma_y\)) of unimplanted and helium implanted specimens are shown in figure 1. Yield stress increase by the 100apppm helium implantation is observed at room temperature and the \(\sigma_y\) decreased with increasing test temperature but it did not fully recover even at 1123K. Figure 2 shows temperature dependence of total elongation of helium implanted and unimplanted specimens. Reduction of total elongation by helium implantation is observed at all test temperatures, but remarkable decrease of elongation is observed above 723K. Temperature dependence of uniform elongation is almost the same as that of total elongation.

Figure 3-a shows fractograph of the 100apppm helium implanted specimen tested at 698K. Fracture mode of figure 3-a is transgranular mode and it shows ductile behavior. Fracture mode of unimplanted specimen was transgranular and had large reduction-of- area at all the test conditions. Figure 3-b shows the fractograph of 100apppm helium implanted specimen tested at 923K. Fracture mode of Figure 3-b is intergranular mode. It is a typical fractograph of brittle specimen. Intergranular fracture surface was observed in the implanted specimen tested above 723K. The results show that significant reduction of elongation above 723K is caused by the grain boundary fracture. Therefore, the fraction of grain boundary fracture surface to the total fracture surface can be considered a indication of the extent of helium embrittlement under each testing conditions\(^3,4\).

Figure 4 shows the relationship between fraction of intergranular fracture and helium concentration at various temperatures. It shows the helium embrittlement strongly depends on helium concentration and testing temperature. The results and estimation method of this work will contribute to estimate the effects of alloying elements or heat treatment on suppression of helium embrittlement.

**Acknowledgement**

The authors would like to thank to the staffs of the CYRIC cyclotron for their cyclotron operation and beam transport.

**References**

Table 1. Chemical compositions of Fe-15Cr-20Ni (wt%).

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Fig. 1. Helium effects on proof stress.

Fig. 2. Helium effects on total elongation.
Fig. 3. SEM micrographs of 100appm He implanted and tensile tested specimens.

Fig. 4. Relationship between helium concentration and fraction of intergranular fracture at various test temperatures.