Microstructures, Corrosion and Tensile Properties of Ti-Al-Zr (PT-7M) Alloy

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1. Introduction

The primary circuit with the primary coolant of SMART (System integrated Modular Advanced ReacTor) is much different from that of commercial PWRs, i.e., an ammonia is used as a pH raising agent. To be used and have long term sustainability from this coarser environment, the titanium alloys should be proved they are good to hydrogen embrittlement. Thus, excellent mechanical properties and hydriding resistance is required for the safe operation during the reactor lifetime.

The effects of hydrogen on the microstructure, mechanical properties and corrosion behavior of the Ti-Al-Zr (so-called PT-7M) alloy were studied.

2. Experimental

The Ti-Al-Zr alloy for the heat exchanger tubes in SMART steam generator is annealed in a high vacuum at the temperatures from 600 to 1050°C for 1h and then water quenched. To hydrogenate the specimens, high purity hydrogen gas (99.9999%) was used in the high vacuum quartz tube with charging temperature 500°C. The hydrogenated tensile specimens were homogenized at 500°C for 15 hrs and examined at a strain rate (constant crosshead speed) of 0.5mm/min at 25°C and 300°C, respectively.

Optical microscope and transmission electron microscope (TEM) were used for microstructural characterization and analyzing the precipitates and hydrides. A mixture of 80ml H_2O, 20ml HNO_3, and 1ml HF was used as a OM etchant.

The Ti-Al-Zr alloy annealed with different heat-treatment were evaluated in the SMART simulated loop in an ammonia aqueous solution adjusted to pH 9.98 at 360 °C under a pressure of 18 MPa over 250 days. The water chemistries in the inlet of heating zone were constantly controlled and the corrosion kinetics was periodically determined by the weight gain method.

3. Results and Discussion

3.1 Microstructures

The bright field TEM image of the longitudinal section of the as-received PT-7M is shown in Fig. 1. The as-received alloy was analyzed as a hexagonal close-packed (hcp, a=0.2950 nm, c=0.4686 nm) with an average grain size of about 20 ㎛. As the alloy is quickly water quenched, the α, α+β, and β phases are formed with the crystallographic characteristics with the heat treatments. Water quenching from α-phase annealing temperatures leads to the formation of the equiaxed grain structure which its grain size increases with increasing temperature. And after water quenching from β region, martensite structure dominates in the microstructure, but quenching from 940 °C makes a mixture of α and β structures with α plates formed inside and at prior β grain boundaries. Some α' martensite is present inside the β phase (Fig. 1(c)).

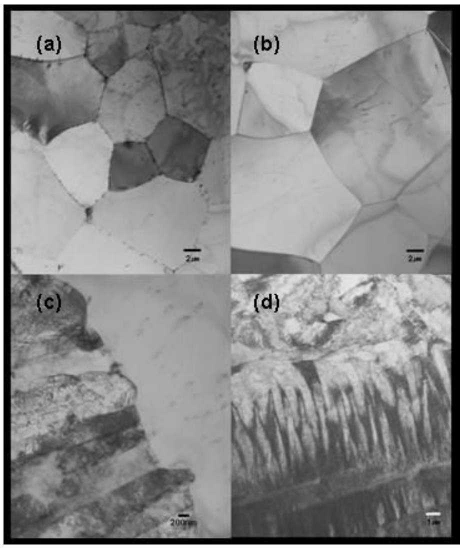

Fig. 1 TEM for the PT-7M alloy after annealing at (a) as-received, (b) 800, (c) 940, and (d) 1050 °C

3.2 Corrosion behaviors

Fig. 2 shows the corrosion behavior of the Ti-Al-Zr alloy in the simulated SMART loop system. The initial corrosion rate of the 1050 °C heat-treated specimens was much increased rapidly, and then the rate is reduced and saturated after 100 days. The heat-treatment with α-region induced more corrosion rate than as-received. These results showed that the excellent corrosion resistance would be correlated with the thickness of a protective oxide layer [1].

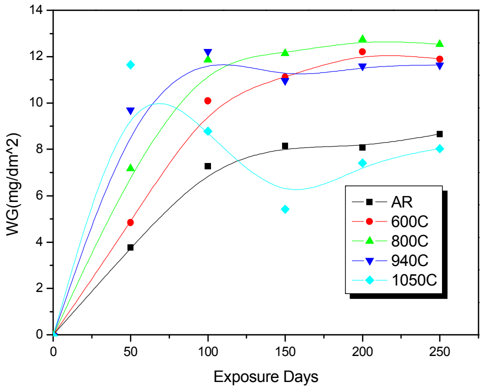

Fig 2. The effect of heat-treatment on the corrosion behavior of PT-7M

3.3 Tensile properties

An as-received PT-7M specimen has hydrogen contents originally about 47ppm [2]. The solubility of hydrogen in a pure titanium at room temperature is tens ppm, but in the 300 °C temperature, the solubility of hydrogen increases to the approximately 1800 ppm [3]. Thus it is well matched with that no other hydride effect could be found in the tensile test at high temperature (Fig. 3). But for the result of room temperature tensile test should be re-considered and as a future work hydrogen contents over the solubility will be charged.

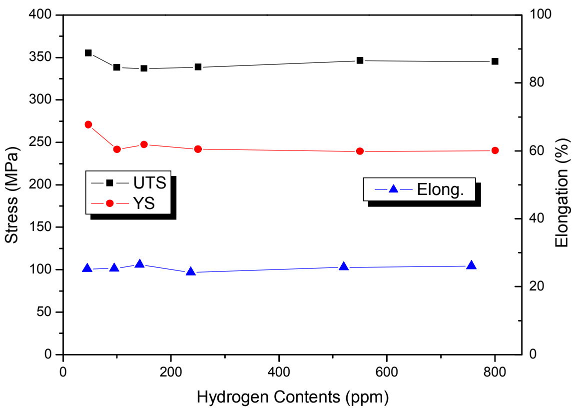

Fig 3. The hydrogen effect on the tensile test at 300 °C

4. Conclusion

In this study, the effect of the heat-treatment and hydrogen on the corrosion behavior and mechanical properties of Ti-Al-Zr alloy were evaluated, respectively. The bright TEM images for the heat-treated specimens showed the transformation of phase and the growth of grain size with the increased heat-treatment temperature. The corrosion behavior of the alloy depended on the heat-treatment region, and the corrosion rates usually increased with increasing heat-treatment temperatures. The tensile properties were almost independent to the hydrogen contents up to somewhere.

ACKNOWLEDGEMENT

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