Effects of Heat-treatment on the Tensile Properties of Ti-Al-Zr Alloy

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1. Introduction

Ti-Al-Zr, titanium alloy, has been well known material as one of the candidates for heat-exchange tubes in steam generators in SMART (System integrated Modular Advanced ReacTor). But the primary circuit with the primary coolant is much different from that of commercial PWRs, i.e., an ammonia is used as a pH raising agent and the heat-exchange tubes are exposed to the primary coolant water at high temperatures and in high-pressure environments. Thus, excellent mechanical properties and corrosion resistance are required for the safe operation during the lifetime [1].

A lot of tests were done to examine the mechanical properties of the Ti-Al-Zr alloy in the room temperature [2]. But the test of this work is done in the more realistic condition from the viewpoint of the system characteristics for SMART design concept. Therefore, the purpose of this study is to evaluate the effects of annealing and cooling rate on the tensile properties of Ti-Al-Zr alloy at the operation temperature.

2. Experimental

2.1 Determination of heat-treatment temperature

The DSC (Differential Scanning Calorimeter) is commonly used to detect the temperature of phase changes and melting points. From the DSC test of the Ti-Al-Zr alloy, the each phase change temperature was evaluated as the temperatures between 914 ^{o}C and 950 ^{o}C were $\alpha+\beta$ phase. Thus, the heat-treatment temperatures were decided among the α phase, $\alpha+\beta$ phase, and β phase region to show the annealing temperature effects on the tensile properties.

Fig. 1 shows the optical microstructures of the Ti-Al-Zr alloy after annealed at each phase temperature. The analysis and examination for the microstructures will be done for the further study by using of Transmission Electron Microscope (TEM) and other equipments.

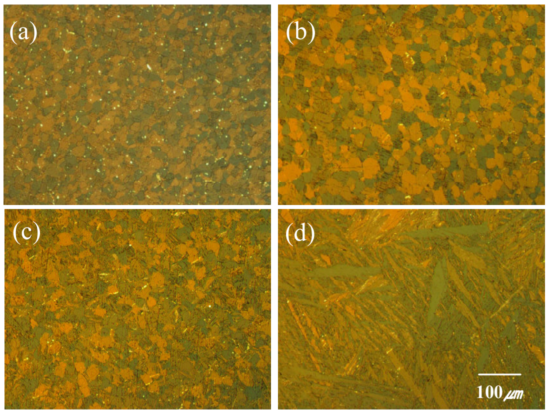

Figure 1. OM for the Ti-Al-Zr alloy after annealing at (a) 600, (b) 900, (c) 940, and (d)970^{o}C

2.2 Test condition

The Ti-Al-Zr alloy tensile specimens were annealed in a high vacuum in the temperature range from 600 to 1050 ^{o}C for 1h, and then cooled in some different ways, water quenching, air cooling, and furnace cooling.

Sub-sized specimens with a gauge length of 10mm were prepared from the tube specimen by splitting to lengthways. And then, the tensile tests were performed at a constant crosshead speed of 0.5mm/min at 25^{o}C and 300^{o}C, respectively.

3. Results and discussion

3.1 The effects of annealing on the tensile properties

Fig. 2 shows that the tensile strengths are almost independent of the annealing temperature up to 900 ^{o}C [2]. But as the temperature increases above the $\alpha+\beta$ transition temperature (940^{o}C), the tensile strengths assume a different aspects at both temperatures. In the room temperature, the UTS and YS were increased gently, but the UTS and YS in the high temperature were increased up to the $\alpha+\beta$ transition temperature (940^{o}C) then decreased at β transition temperature (970 and 1050^{o}C).

Fig. 3 shows that the effects of annealing temperature on the ductility of Ti-Al-Zr alloy in the room and high temperatures. Ductility is not much dependent on the annealing temperature up to the 900°C. But after α+β transition temperature, the values were drop down sharply and then increased from the β transition temperature. By comparing tensile properties of both temperature regions, although the overall values of high temperature condition were decreased, the effects of heat-treatment are as same as those of room temperatures.

3.2 The effects of cooling rate on the tensile properties

To evaluate the effects of cooling rate, Ti-Al-Zr alloy tensile specimens were annealed in a high vacuum at 1050°C for 1h, and then cooled by various cooling ways. As the 1050°C temperature is absolutely in the range of beta phase, the phase transformation is much dependent on the cooling rate. Usually, the cooling rate decides strength and ductility. As the cooling rate increase, the tensile strength increase but the ductility in normal. Most of the tensile properties in this test follow the general tendency, but the UTS in the high temperature test have little reverse tendency in this result.

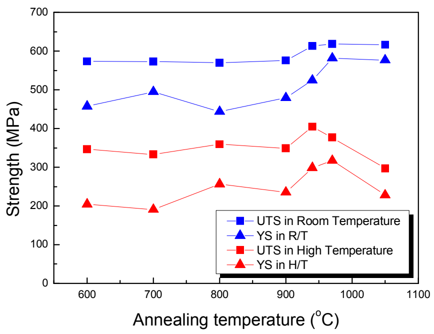

Figure 2. Effects of annealing temperature on the tensile strength

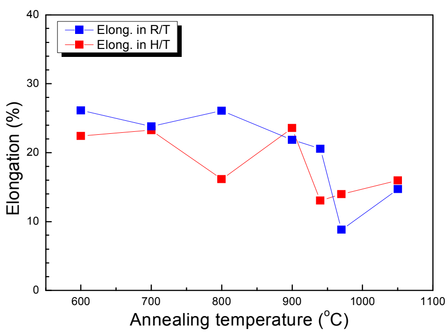

Figure 3. Effects of annealing temperature on the ductility

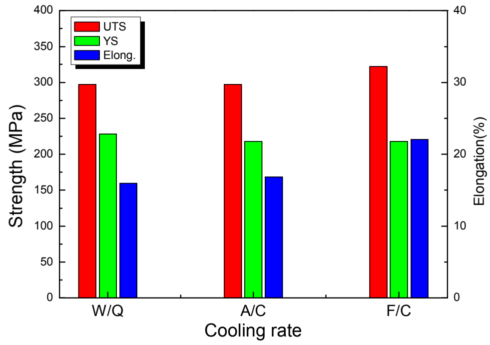

Figure 4. Effects of cooling rate on the tensile properties in the high temperature

4. Conclusion

In this study, the effects of heat-treatment on the tensile properties were evaluated in the room and high temperature, respectively. The tensile properties were almost independent to the annealing temperature up to the 900°C at both experimental temperatures. But in the high temperature test, the tensile strength was decreased after α+β transition temperature comparing to the room temperature results. The effects of cooling rate follow the general tendency except few properties. For the further analysis, microstructure study is needed to verify this phenomenon for the future study.

ACKNOWLEDGEMENT

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