A Comparative Study of Deformation Behavior of Zr-1.8Nb Cladding Tube Under Axial and Hoop Stress

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Abstract

The uniaxial tension (UT) tests and advanced expansion due to compression (A-EDC) test have been applied to examine the deformation behavior of Zr-1.8Nb cladding tubes, respectively. The differences of mechanical properties and microstructure evolution between UT test and A-EDC test have been compared and discussed.

Keywords: anisotropy, deformation, texture, microstructure, twinning, EBSD

1. Introduction

Zr-Nb alloys have been applied as nuclear fuel tubes on benefit of the excellent properties such as corrosion resistance. Due to pilgering process, preferred orientations or textures in zirconium (Zr) alloys are feasibly formed, leading to anisotropic mechanical properties and further affecting the in-service behavior in light water reactors [1]. In the case of reactivity-initiated accident, cladding tubes will be subjected to compression because of the expansion of inner fuel pellets, and sometimes it even causes fracture of cladding tubes. The α-Zirconium has hexagonal close-packed crystal structure, therefore, the deformation systems are very limited. Twin deformation is greatly important for the plastic deformation along <c> directions [2]. In this research, Zr-1.8Nb alloy has been mechanically tested under UT and A-EDC tests, respectively. The mechanical properties in axial and hoop directions have been studied. Finally, the microstructural evolution will be comparatively discussed as well.

2. Experimental Procedure

For UT along tube axial direction, Zr-1.8Nb was fabricated into SSJ type tensile specimen by electron discharge machining. Then, the SSJ specimen has been loaded by a Shimadzu AG-100KNX plus machine at room temperature. The strain rate was maintained at ~3.3×10^{-4} s^{-1}. For the A-EDC test [3], it has also been conducted at room temperature under a strain rate of $2.0\sim4.5\times10^{-4}$ s^{-1}. Samples reached different total elongations of 5%, 10%, 15%, 20% and 30% by UT and A-EDC tests, respectively. The X-ray diffraction (XRD) technique and EBSD method have been employed for sample examination and analysis. The axial and hoop stress-strain curves have been derived based on the raw experimental data.

3. Conclusion

It has been found that the tube hoop direction presents higher mechanical strength than the axial direction because the microstructure evolution shows different behaviors under these two tests. In A-EDC tests, twin deformation played significant role in plastic deformation than the case of UT tests, and the $\{10\bar{1}2\}\langle1\bar{0}11\rangle$ tensile twins have been mostly examined in the deformed specimen. When total strains continually increase, the crystallographic orientation shows different tendency between UT and A-EDC tests, which has been investigated by EBSD and XRD methods.

References

[1] B. Cheadle, et al., J. Nucl. Mater., 1967. 23(2): p. 199-208.

[2] R. McCabe, et al., Philos. Mag., 2006. 86(23): p. 3595-3611.

[3] H. Abe, et al., J. Nucl. Sci. Technol. 2015. 52(10): p. 1232-1239.