Comparative Study of Deformation Process in the Axial and Hoop Directions of Zr-2.5Nb Cladding Tubes

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Abstract

Uniaxial tension and advanced expansion due to expression tests were applied to prepare different deformed Zr-2.5Nb cladding samples. The total elongation has reached to a maximum value of 20% in tube axial and hoop direction, respectively. The microstructure and texture evolution during each deformation process will be comparatively investigated by electron backscatter diffraction (EBSD) technique.

Keywords: anisotropy, deformation, texture, EBSD

1. Introduction

Preferred orientations or textures in zirconium (Zr) alloys are feasibly produced by pilgering fabrication, which result in anisotropic mechanical properties and further affect the in-service behavior in light water reactors [1]. Due to the hexagonal close-packed crystal structure, deformation systems are very limited in α-Zr. Plastic shear deformation on the first or the second prismatic planes can be easily realized along the <a> directions. In addition, the plastic deformation along <c> directions can be mostly attained by the pyramidal planes slip along <a+c> directions, $\{10\bar{1}2\}$ tensile twinning, or $\{11\bar{2}2\}$ compression twinning [2]. In this research, Zr-2.5Nb cladding tube has been examined under axial tension and hoop tension, respectively. Through this work, the microstructural and crystallographic evolution will be studied, and the differences in slip and/or twin deformation of the above two tests will be comparatively discussed as well.

2. Experimental Procedure

For uniaxial tension (UT) along tube axial direction, Zr-2.5Nb 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 $\sim 3.3 \times 10^{-4}$ s^{-1}. For the hoop tension test, advanced expansion due to compression (A-EDC) method [3] has been utilized at room temperature under a strain rate of $2.0 \sim 4.5 \times 10^{-4}$ s^{-1}. Samples reached different total elongations of 6%, 10%, 15%, and 20% by UT and A-EDC tests, respectively. Then, EBSD method has been employed for sample examination and analysis.

3. Conclusion

In this work, it has been found that Schimid factors (SFs) of primary slip systems were different under UT and A-EDC tests. The prismatic slip system $\{10\bar{1}0\}\langle 1\bar{2}10\rangle$ as the most favorable slip system, seems much easier to activate under UT than A-EDC. Apart from slip deformation, in A-EDC tests twin deformation played significant role in plastic deformation, and the $\{10\bar{1}2\}\langle\bar{1}011\rangle$ twins have been mostly examined in the deformed specimen. With respect to the UT tests, slip deformation is the main attributor to plastic deformation, and very few twins have been detected. This implies that twinning deformation seems more significant for specimen plastic deformation under hoop stress in A-EDC tests. When total strains continually increase, the change of crystallographic orientation appears to be different between UT and A-EDC tests, which will be further discussed.

References

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