Crystallographic Orientation of Zirconium TREX Determined by Neutron Scattering

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1. Introduction

Zirconium alloy tubing has been used for many years in chemical and nuclear engineering applications involving severe combinations of temperature and reactive environments [1]. The alloy tubing is generally produced by pilgering process, which is one of plastic deformation techniques for making seamless tube. The pilgering process results in making unique microstructure of the materials such as texture and crystallographic orientation. Since the crystallographic orientation is dependent upon the degree of plastic deformation like the number of deformation process and also changed thermally at a high temperature service condition. Metallurgical point of view, a study of the crystallographic effect on the performance of the alloy is one of important because it influences various mechanical and chemical properties.[2]

Various methods about the texture analysis including crystallographic orientation have been developed based on X-ray, electron and neutron beams. Among these methods, it is known that neutron diffraction technique is more powerful to analyze the texture for large and heavy materials.[3] Hence, in this study, neutron scattering was applied to analyze texture of zirconium alloy tube reduced extrusions (TREX) to know the initial stage of pilgering for the determination of an optimum pilgering condition.

2. Experimental Method

The zirconium alloy TREX was supplied by the Korea Nuclear Fuel Company. The specimen was cut 5x5x5 mm in length, ground with from 320 grit to 600 grit emery papers, rinsed in deionized water, and introduced into electron microscope and neutron scattering facility.

Microstructure of the tube was observed by scanning electron microscopy (Jeol JSM 2400). Crystallographic orientation of the TREX for logitudianal and transverse directions was determined with a four-circle diffractometer using a neutron beam of wavelength 0.99 Å, at the HANARO reactor of the Korea Atomic Energy Research Institute. Three pole figures were measured for each phase. First, the texture was determined by usual complete pole figures. In this procedure, pole figures were scanned on both the radial angle α and azimuth angle β with a constant interval of 5^o.

3. Results and Discussion

Fig. 1 is microstructure of the as-received zirconium TREX with different position. As shown in Fig. 1, the zirconium TREX has similar size of grain in cross section. The TREX has equiaxed shape grains with average grain size of 16.7 μm.

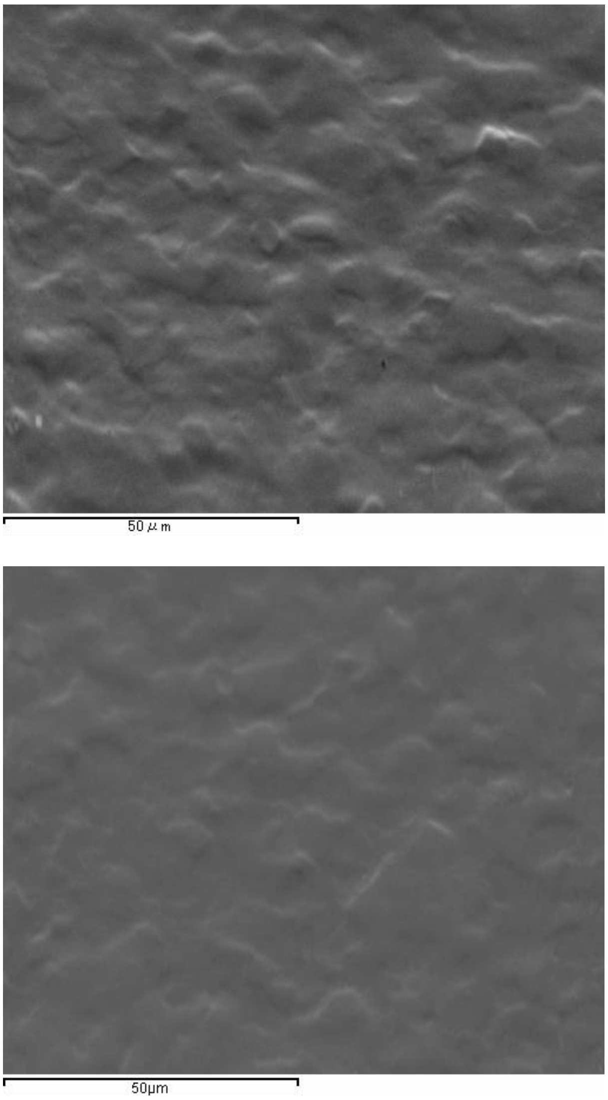

Figure 1. Cross sectional view of zirconium alloy tube prepared reduced extrusion (TREX) observed by scanning electron microscopy : (top) center (bottom) inner areas

In order to study the effect of crystallographic orientation of the TREX, crystallographic orientation was determined by neutron scattering method. Since the most common method for representing crystallographic orientation is through the construction of stereographic pole figures, basal pole (002) or (0001) and prismatic pole (100) or (10$\bar{1}$0) were determined in this study.

Fig. 2 is stereographic pole figures of zirconium TREX. As shown in Fig. 2, the most of (002) poles are oriented along radial direction, whereas, lots of (100) poles are mainly oriented to longitudinal direction and partially oriented to redial direction, respectively. This means that the TREX should have a certain crystallographic orientation to satisfy an initial condition for 1st pilgering process.

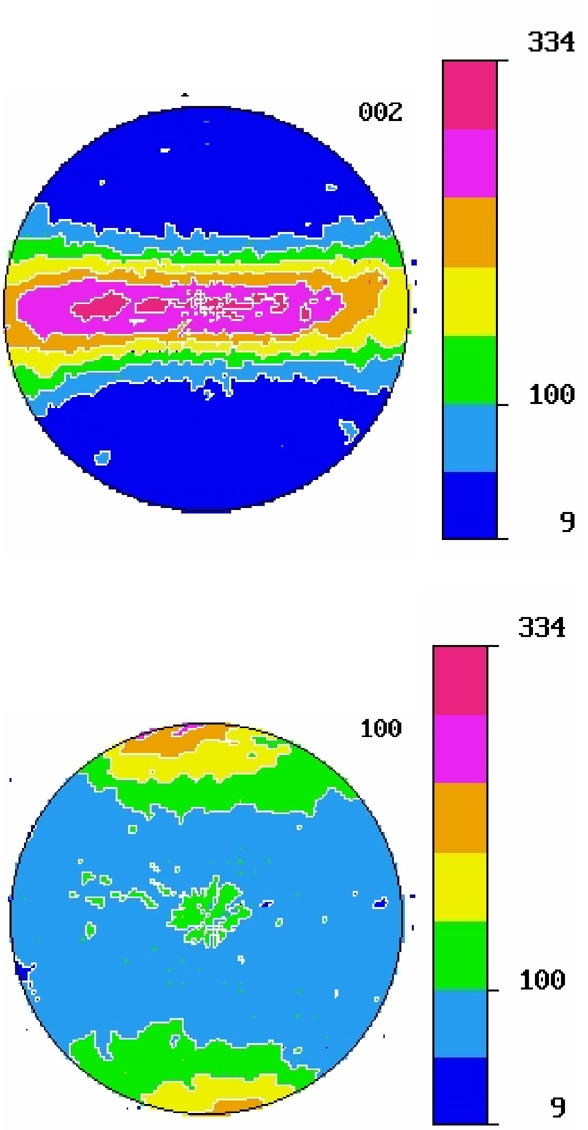

Figure 2. (002) and (100) pole figures of zirconium TREX determined by neutron scattering : (top) (002) (bottom) (100) poles

3. Conclusion

Texture analysis of as-received zirconium TREX was carried by neutron scattering to give a information about initial pilgering condition. From the neutron diffraction analysis, the TREX has the crystallographic orientation such that most of (002) poles are oriented along radial direction, whereas, lots of (100) poles are mainly oriented to longitudinal direction and partially oriented to redial direction, respectively

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