Effect of Crystallographic Texture on Corrosion Behavior of Zircaloy Cladding Tube

J. J. Lee*, D. J. Kim, H. J. Jung, H. J. Cho, Y. W. Moon, J. M. Jang, N. I. Baik, Y. Choi
Materials and Metal Eng., Sunmoon Univ., Asan Chungnam 336-840, Korea
**Corresponding author: ferrite2@sunmoon.ac.kr*

1. Introduction

Zircaloy cladding tube produced by pilgering process has been used for many years in chemical and nuclear engineering [1]. The zirconium alloy is hexagonal structure which crystallographic texture is formed by pilgering process [2]. Since the crystallographic texture influences durability of the tube, texture control is very important technique in industry [3]. Corrosion resistance generally depends on grain size, texture, precipitation, and crystallographic orientation. In this study, neutron scattering was applied to analysis crystallographic texture of zircaloy cladding tube and corrosion behavior with the crystallographic texture was observed by electrochemical method.

2. Experimental methods

Zirconium alloy tube supplied by the Korea Nuclear Fuel Co. The tube was sectioned to several pieces with 10x10x10 mm and 5x5x10 mm, 1.8x2x20 mm, respectively. Microstructure of the tube was observed by polarizing microscope (Nikon Epithot 200). Micro-hardness of the tube was determined by Buehler micro Vickers. Texture of the tube was analyzed by neutron diffraction (ND, HANARO). Corrosion resistance was determined (Gamry 100) in 3.5% NaCl with SCE as a reference electrode and Pt counter electrode at room temperature.

3. Results and Discussion

The hardness of TREX (tube reduced extrusion), 1st and 2nd pilgered tubes for longitudinal and cross-sectional directions were 180, 172, 233, 218 and 252, 246 [Hv], respectively.

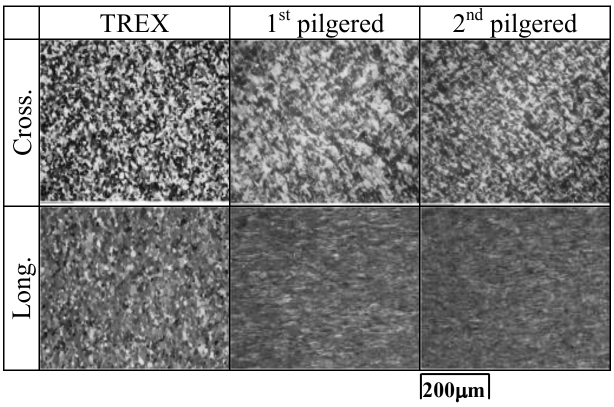

Fig. 1. The microstructures of TREX, 1st, 2nd pilgered tubes for longitudinal and cross-sectional directions.

Fig. 1 is microstructures of the zirconium alloys observed by cross-sectional and longitudinal directions. As shown in Fig. 1, average grain sizes of them for the cross-sectional direction were 28, 11, 8 μm, respectively. As 1st and 2nd pilgered, aspect ratio of them for the longitudinal direction were 6, 12, respectively. The hardness increment is related to work hardening and grain size refinement.

Fig. 2 shows geometry direction on the tube respective neutron diffraction spectra. Comparing Fig. 2 and Fig. 3, most of (001) poles of TREX were 45° tilted to longitudinal direction of the tube

They tended to be parallel to the direction by 1st pilgering. 2nd pilgering made the (001) poles tilt 45° to the longitudinal direction again, where most of (100) poles tended to be parallel to radial direction of the tube Fig 1. The microstructures of TREX, 1st, 2nd pilgered tubes for longitudinal and cross-sectional directions.

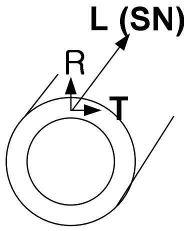

Fig. 2. Mark of geometric direction on zircaloy cladding tube.

Table 1 is corrosion potential and rates in aqueous 3.5%-NaCl solution at room temperature, in which they changed in the range of -0.53 ~ -0.18V_{SCE} and 0.52x10^{-8} ~ 1.04x10^{-6}A/cm^2, respectively. In general corrosion resistance depends on grain size, texture, precipitation, and crystallographic orientation. Since the tube has equal content of pilgering, their corrosion behavior should be related to grain size and crystallographic texture.

Table 1. Corrosion potential and rate with direction and working rate of pilgering

		TREX	1st pilger	2nd pilger
Long.	**C.P.[V_{SCE}]**	**-0.300**	**-0.409**	**-0.535**
	C.R.[A/cm^2]	**3.56**	**11.01**	**0.52**
Cross.	**C.P.[V_{SCE}]**	**-0.327**	**-0.260**	**-0.184**
	C. Rate [10^{-8}A/cm^2]	**1.88**	**104.40**	**3.40**

Since average grain size was decreased by pilgering, grain boundary area should be increased. Accordingly, pilgering process tends to reduce corrosion potential. As shown in Table 1, the corrosion potential decreases in longitudinal direction of the tube, whereas, increases in cross-sectional direction. This means that the corrosion potential behavior is influenced by different factors. There are several metallurgical factors influencing corrosion behaviors such as precipitates and texture. Considering crystallographic texture changes with pilgering, the corrosion potential at the longitudinal direction, which has relatively low grain boundary area, is related to the (001) and (100) planes after 1st and 2nd pilgering, respectively.

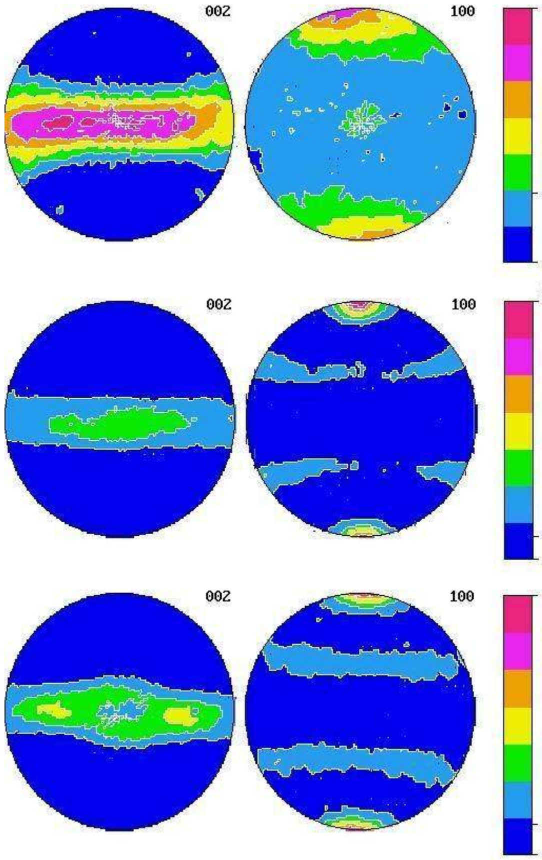

Fig. 3. Neutron diffraction was used to analysis crystallographic texture for (top) TREX, (middle) 1st, (bottom) 2nd pilgerling tube.

4. Summary

Effect of crystallographic texture of zirconium alloys on their corrosion behavior was studied by neutron beam analysis and electrochemical technique. The hardness increases in the order of TREX, 1st and 2nd pilgerd tubes. Grain size refinement was observed after the pilgering process. Comparing microstructure and corrosion resistance at metallurgical point of view, the crystallographic texture of the zirconium alloys clearly influences corrosion.

5. Acknowledgements

The authors would like to thank Korea Science and Engineering Foundation (KOSEF) though National Research Laboratory (NRL) Program, Neutron Beam Application Lab. They also would like to thank Dr. Y.H. Chung and his team at KAERI for valuable help to observe microstructure and Korea Nuclear Fuel Co. LTD (KNFC) for valuable sample preparation and support.

References

[1] D. R. Knittel and R. T. Webster, "Industrial Application of Titanium and Zirconium", ASTM Special Technical Publication 728, ASTM. Philadelphia, p. 191, (1979)
[2] Deformation Twinning, R.E. Reed-Hill, J. P. Rosi, and H. C. Rogers, Eds., Gordon and Breach, Science Publishers, New York and London, vol. 25, 1964.
[3] Christian, J. W., Theory of Transformations in Metals and alloys, Pergamon Press, Oxpord, 1965