Effect of Hydrogen Content for Mechanical Properties of ZIRLO™ tubes

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1. Introduction

Zr-Nb alloys have been used in cladding materials for nuclear power plants because of low neutron absorption, good corrosion resistance and mechanical properties. But, when burn-up is increased, oxidation and hydrogen concentration in fuel cladding increase exponentially by water side corrosion [1]. As a results of high burn-up, massive hydrogen concentration of fuel claddings cause loss of ductility such that the safety margin at normal operation and accident condition [2]. So, understanding effects of hydrogen in Zr alloys is very important to assess the integrity of developing Zr-Nb alloys. Therefore, in order to analyze effect of hydrogen content of Zr-Nb tubes, tensile tests using hydrogen-charged Zr-Nb tubes at room temperature was performed.

2. Experimental Procedure

Materials used in this study are commercial ZIRLO™ tubes. All specimens for the tensile test, OD9.5 x ID8.375 x L200 mm in size, were cut from the ZIRLO™ tubes and were polished by SiC paper to remove surface contaminant and then pickled in a solution of 50 vol.% H_2O, 45 vol.% HNO_3 and 5 vol.% HF.

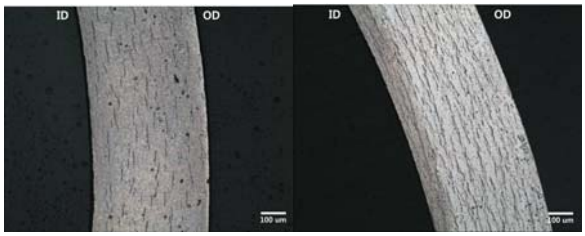
The tensile specimens were charged about 100, 300, 500, 700, 1000 ppms, respectively, with hydrogen using the gas flow charging method. The hydrogen charging apparatus was designed to flow mixed gases of 95%Ar and 5%H_2 into reaction chamber and to create a high vacuum atmosphere (10^{-6} torr) [3].

Tensile test was performed at room temperature with a strain rate of 5 x $10^{-3}s^{-1}$ using the Zwick/Roell's testing machines.

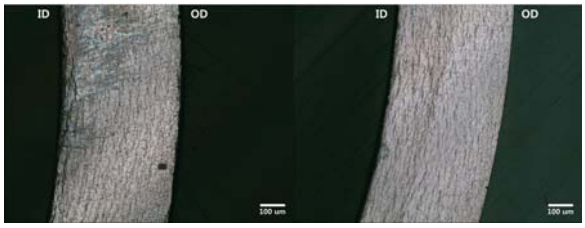
3. Results and discussion

3.1. Microstructure observation

Microstructure and hydride morphology of ZIRLO™ tubes were observed by optical microscope. The samples were mounted and then polished using SiC paper up to 1500 grid. The samples were then etched in acid solution of 40%H_2O, 30%HNO_3, 20%HSO_4, and 10% HF. Fig. 1 shows the micrographs and hydride morphology of ZIRLO™ tubes. As shown Fig. 1, typical circumferential hydride in zirconium matrix has formed. Also, as hydrogen contents are increased, the hydride has formed at tube surface.



a) Z1 (100ppm) b) Z2 (300ppm)



c) Z3 (500ppm) d) Z5 (1000ppm)

Fig. 1 Optical micrographs of circumferential hydride for hydrogen charged samples at 430℃

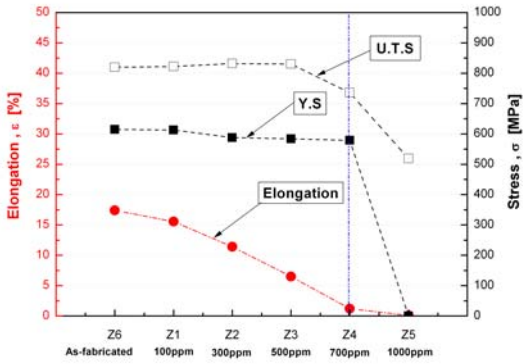


Fig. 2 The effect of hydrogen contents on tensile properties of ZIRLO™ tubes at room temperature

Table 1 The tensile test results of hydrogen charged Samples

ID(hydrogen content)	Y.S (MPa)	U.T.S (MPa)	Elongation (%)
Z1(100ppm)	613	822	16
Z2(300ppm)	588	832	14.5
Z3(500ppm)	584	830	6.5
Z4(700ppm)	579	736	1.4
Z5(1000ppm)	-	519	0.1
Z6(As-fabricated)	615	820	17.1

3.2. Tensile properties of hydride ZIRLO™ tubes

The Table 1 and Fig. 2 are shown tensile properties of ZIRLO™ tubes. Tensile properties of ZIRLO™ tubes up to 500ppm hydrogen contents were similar to Z6(As-fabricated), but the yield stress and ultimate tensile stress of samples was decreased with increasing hydrogen content over 500ppm. Also, the elongation of hydrogen-charged ZIRLO™ tubes over 700ppms was decreased nearly zero. As above results, it is found generally that the effect of increasing hydrogen concentration on tensile strength is less remarkable than the elongation. Also, in terms of ductility, ductile-brittle transition occurs when the hydrogen concentration is higher than a certain threshold at room temperature. Moreover, the results of this work subject to comparison with previous work, effect of hydride concentration on ductile-brittle transition obtains to the same tendency with previous work [4].

4. Conclusion

In order to analyze effect of hydrogen content of Zr-Nb alloy tubes, the present study was performed tensile tests using hydrogen charged ZIRLO™ tubes at room temperature. Based on the results, the following conclusions were below;

(1) Tensile properties of hydrogen charged samples from 100 to 500ppm hydrogen contents were similar to As-fabricated specimen. And the yield stress and ultimate tensile stress of samples were slightly decreased with increasing hydrogen contents over 500ppms.
(2) In terms of integrity, there is a ductile-brittle transition when the hydrogen concentration is higher than a certain threshold (about 700ppm) at room temperature.

Acknowledgements

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