

Zirconium Alloy Guide Thimble Tube Characteristics Made by KNF

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1. Introduction

Korea Nuclear Fuel(KNF) and Westinghouse Electric Co.(WEC) have done a joint development program to develop the nuclear grade zirconium alloy tube manufacturing technology since 2004. As part of program, a joint characterization test program was developed to demonstrate the properties of guide thimble tube products manufactured by KNF and WEC plants [1].

KNF and WEC manufactured four different guide thimble tubes and exchanged for the purpose of performing set of characterization tests each other.

The objective of this study is to compare and evaluate properties of the guide thimble tube products made by KNF and WEC.

2. Methods and Results

One tube shell pair produced from the same ingot and single extrusion was used for producing each tube size. Four different guide thimble tubes were manufactured by the same process in KNF and WEC, respectively. The final recrystallized annealing was applied to K-1/W-1, K-2/W-2 and K-3/W-3. The final stress relieved annealing was applied to K-4/W-4.

Each lot of tubing was inspected and tested according to all the commercially applicable specification and drawing requirements. Some additional tests were also performed including long term corrosion, texture and high temperature mechanical properties etc.

The room temperature tensile test was performed in accordance with ASTM B353 and E8.

The long term corrosion performance tests were conducted at 400°C, 10.3MPa pressurized steam condition and at 360°C, 18.7MPa pressurized 70ppm lithiated water condition in a manner consistent with the ASTM G2/G2M.

Crystallographic texture measurement and Kearns numbers (f_z , f_t , f_r) were determined, using x-ray diffractometer. The x-ray measurement was performed using an x-ray pole figure goniometer. The preferred x-ray radiation is Cu K_α .

2.1 Room temperature tensile properties

Figure 1 shows the room temperature tensile properties of the guide thimble tubes manufactured by both sites. The dotted lines in Fig. 1 represent reference values of the accepted range specified in the guide thimble tubes specification.

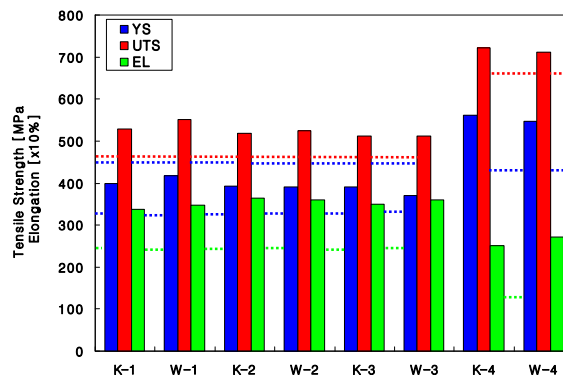


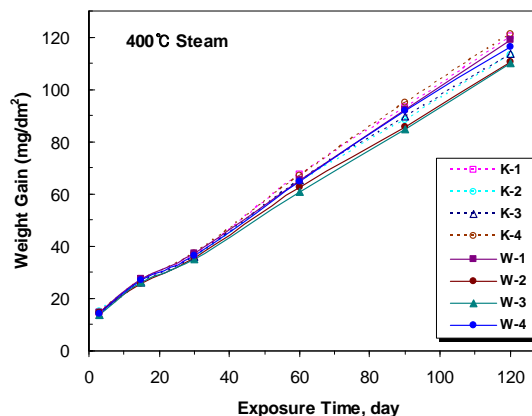
Fig. 1. Tensile properties for the guide thimble tubes manufactured by KNF and WEC

Due to the different final annealing temperature/time, the yield strength and ultimate tensile strength of K-4/W-4 were higher than the others. All tensile test results of the guide thimble tubes met the specification requirements. The guide thimble tubes manufactured in the same process had the equivalent values each other.

2.2 Corrosion behavior

Figure 2 shows the weight gains up to the 120 days of corrosion tests. The corrosion behavior guide thimble tubes produced by the same process in KNF and WEC were nearly same.

The guide thimbles tubes showed lower weight gains in LiOH environment than in steam. In the case of LiOH environment(Fig. 2(b)), the weight gains for K-4/W-4 were higher than others at 90 days but were nearly same at 120 days.



(a) 400°C steam

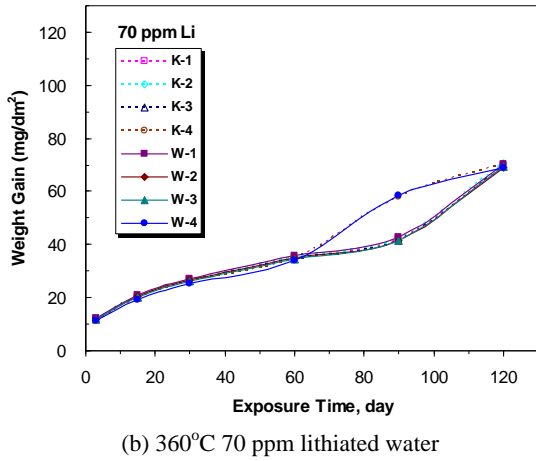


Fig. 2. Corrosion behavior of the guide thimble tubes manufactured by KNF and WEC

2.3 Texture

Figure 3 shows the Kearns number f_r and had the nearly same values each other.

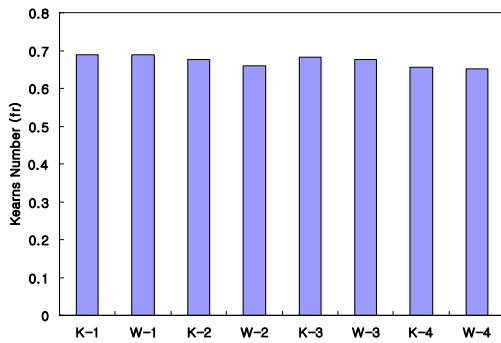


Fig. 3. Kearns number f_r of the guide thimble tubes manufactured by KNF and WEC

The basal (0002) pole figures of K-4/W-4 were showed in Figure 4. The basal pole figure of guide thimble tubes made by KNF was equivalent to WEC's. This is attributed to the same reduction passes and annealing condition.

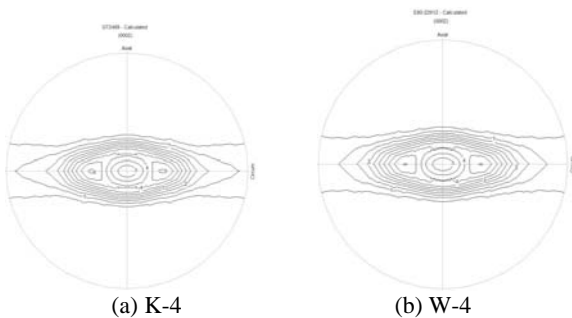


Fig. 4. Basal (0002) pole figures of the guide thimble tubes manufactured by KNF and WEC

3. Conclusions

All test results met the requirements and were considered to be acceptable. The results of each test performed on KNF and WEC guide thimble tubes of a given design were found to be comparable. Based on the results of the tests performed, the guide thimble tubes manufactured by KNF are equivalent to those manufactured by WEC.

Acknowledgement

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REFERENCE

[1] Y.H. Kim, Y.K. Mok and S.J. Lee, Characterization Test Plan Performed at Westinghouse, KTM-CT-08001, 2008.