Effect of Hydrogen on Axial and Tangential Creep of a Zr-2.5Nb Pressure Tube

Tae Wook Oh, Young Suk Kim, Sang Bok Ahn, Kyung Soo Im, Yong Moo Cheong
Korea Atomic Energy Research Institute, 150 Dukjin-dong, Daejeon 305-353, Korea, yskim1@kaeri.re.kr

1. Introduction

Zr-2.5Nb pressure tubes are one of the main components of CANDU nuclear reactors to carry fuel bundles and coolant inside. Diametral creep of pressure tubes is an important factor in establishing a maximum allowable channel power due to a concern that non-uniform coolant flow due to an excessive creep increases coolant channel temperatures over a safety criterion [1]. However, it is yet to be clearly understood if the creep of the Zr-2.5Nb tubes is affected by hydrogen which is picked up during their reactor operation.

This study has investigated the effect of hydrogen on anisotropic creep of unirradiated Zr-2.5Nb pressure tube which has a strong tangential texture with most of (0001) poles oriented in the tangential direction. Small creep specimens were taken from the axial and tangential directions of a Zr-2.5Nb tube and they were charged using an electrolytic charging method to 60 and 180 ppm of hydrogen, respectively. The creep tests were conducted at two different temperatures to figure out the effect of plastic deformation twins on the creep anisotropy in zirconium alloys: one is 250 ^{o}C where deformation twins are actively working and the other is 325 ^{o}C where little deformation twins are effective.

2. Experimental Procedures

Uniaxial creep tests were performed at temperatures ranging from 250 to 350 ^{o}C, using creep test machines equipped with a lever arm to apply a load with the 10 to 1 ratio. The tensile specimens as shown in Fig. 1 were cut from the axial and tangential direction of a CANDU Zr-2.5Nb tube. Applied stresses ranged from 130 to 350 MPa. The specimens were hydrided by an electrolytical charging method in 0.1M H_2SO_4 followed by homogenization treatments at 303 ^{o}C for 30 h and 391 ^{o}C for 9 h to charge hydrogen to 60 ppm and 180 ppm, respectively.

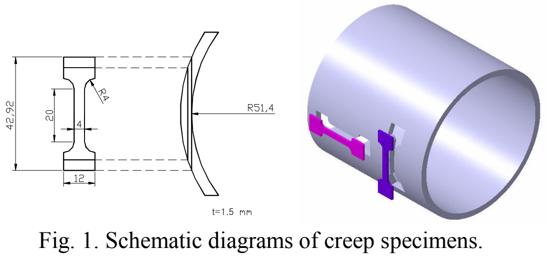

Fig. 1. Schematic diagrams of creep specimens.

A small fraction (10%) of the applied force was applied before and during a heating to the test temperatures to align the loading axis to be parallel.

3. Results

3.1. Hydrogen effect on creep

Fig. 2 shows the axial creep strains of the Zr-2.5Nb tube with hydrogen. Since the terminal solid solubility of hydrogen in zirconium is around 31 ppm [2] at 250 ^{o}C, the actual concentration of the hydrides precipitated in the Zr-2.5Nb specimens would be 28 ppm and 148 ppm, respectively. The axial creep of the Zr-2.5Nb tube increased with an increasing concentration of the hydrides. The results shown in Fig. 2 are in contrast with the reported results that precipitated hydrides have an suppressing effect on the longitudinal creep of Zircaloy-4 [3]. Additional work is underway to figure out the effect of dissolved hydrogen on the creep of the Zr-2.5Nb tube.

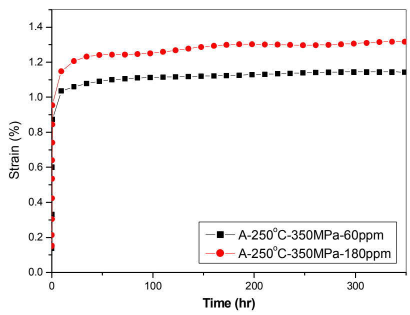

Fig. 2. Axial creep strains of the Zr-2.5Nb tube with hydrogen at 250 ^{o}C and 350 MPa.

3.2. Creep anisotropy with temperature

Fig. 3 shows the creep strains in the axial and tangential directions of the Zr-2.5Nb tube at 250 ^{o}C and 325 ^{o}C, respectively. At 250 ^{o}C where deformation twins are actively working[4], the tangential creep strains were considerably lower than the axial ones. The same trend was observed at 325 ^{o}C as shown in Fig. 4, where the effect of the deformation twins still remains [4], leading to a decreased tangential creep. However, at 350 ^{o}C with the absence of deformation twining[4], the tangential creep becomes faster, leading to higher creep strains than the axial creep as shown in Fig. 4.

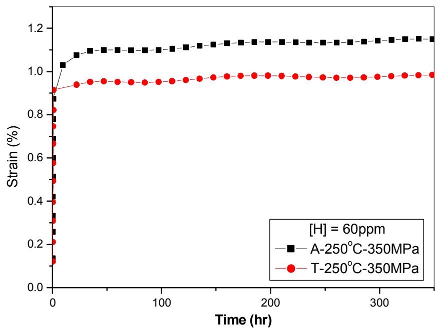

Fig. 3. Axial and Tangential creep strains at 250℃ of the Zr-2.5Nb specimens with 60 ppm H specimens

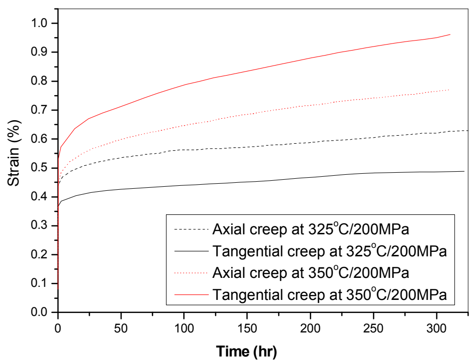

Fig. 4. Creep anisotropy of the Zr-2.5Nb specimens with no additional charged hydrogen at 325 and 350 oC, respectively.

4. Conclusion

When the charged hydrogen was present as hydride precipitates in the Zr-2.5Nb tube, the hydrides enhanced the axial creep of the Zr-2.5Nb. Further work is underway to understand the enhanced creep of zirconium by the hydrides. The tangential creep of the Zr-2.5Nb tube was lower at 250 °C than the axial creep because of a strong tangential texture causing the suppressing effect of twins on creep. However, this creep anisotropic effect due to a texture became weaker at 325 °C and finally disappeared at 350 °C, leading the tangential creep to become faster than the axial creep.

REFERENCES

[1] G. J. C. Garpenter and J. F. Watters, Irradiation Damage Recovery in Some Zirconium Alloy, Zirconium in Nuclear Applications, ASTM STP 551, pp. 400, 1974.
[2] J. J Kearns, J. Nucl. Mat., 22, p. 28, 1967.
[3] N. Rupa, M. Clavel, P. Bouffioux, C. Domain and A.Legris, About the Mechanism Governing the Hydrogen Effect on Viscoplasticity of Unirradiated Fully Annealed Zircaloy-4 Sheet, *Zirconium in the Nuclear Industry:Thirteenth International Symposium*, ASTM STP 1423.
[4] Y. S. Kim, D. J. Oh and S. B. Ahn, JOM, 56(2), p.219, 2006.