Effect of Hydrogen on Creep Anisotropy of a Zr-2.5Nb Pressure Tube

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1. Introduction

Zr-2.5Nb pressure tubes are one of the main components of CANDU nuclear reactors to carry fuel bundles and coolant inside. An excessive diametral creep of pressure tubes increases coolant channel temperatures over a safety criterion. So diametral creep of pressure tubes is an important factor in establishing a maximum allowable channel power[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 180ppm of hydrogen, respectively. The creep tests were conducted at two different temperatures to figure out the effect of deformation twins on the creep anisotropy in zirconium alloys: one is 250℃ where deformation twins are actively working and the other is 325℃ where little deformation twins are effective.

2. Experimental Procedures

Uniaxial creep tests were performed at temperatures ranging from 250 to 350℃, using creep test machines equipped with a lever arm to apply a load with the 20 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 350MPa. The specimens were hydrided by an electrolytical charging method in 0.1M H_2SO_4 followed by homogenization treatments at 303℃ for 30hour and 391℃ for 9hour to charge hydrogen to 60ppm and 180ppm, respectively.

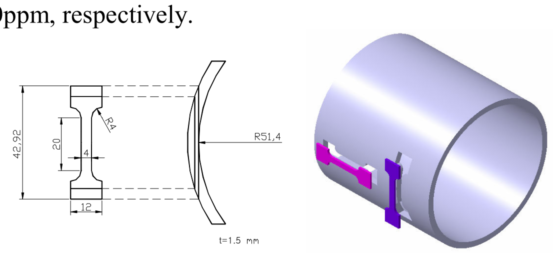

Fig. 1. Schematic diagrams of creep specimens.

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 at 325 ℃ and 350MPa. Since the terminal solid solubility of hydrogen in zirconium is around 88ppm [2] at 325℃, the actual concentration of the hydrides precipitated in the Zr-2.5Nb specimens would be zero ppm (all in solution) and 92ppm, respectively. The axial creep of the Zr-2.5Nb tube decreased with an increasing concentration of the hydrides. The results shown in Fig. 2 turn out to be similar to the reported results that precipitated hydrides have an suppressing effect on the longitudinal creep of Zircaloy-4 [3].

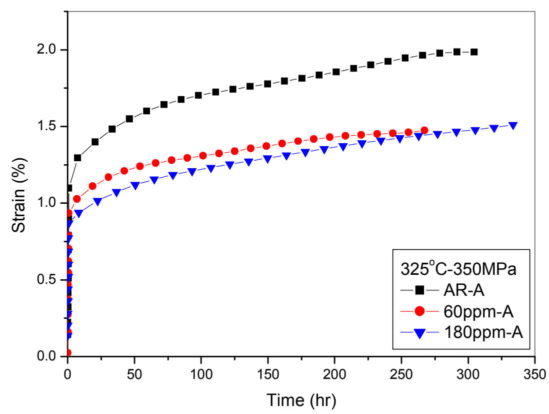

Fig. 2. Axial creep strains of the Zr-2.5Nb tube with hydrogen at 325℃ and 350MPa.

3.2. Creep anisotropy with temperature

Fig. 3 and 4 show the creep strains in the axial and tangential directions of the Zr-2.5Nb tube at 250℃. At 250℃ 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℃ as shown in Fig. 5, where the effect of the deformation twins still remains [4], leading to a decreased tangential creep. However, at 350 ℃ 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. 5.

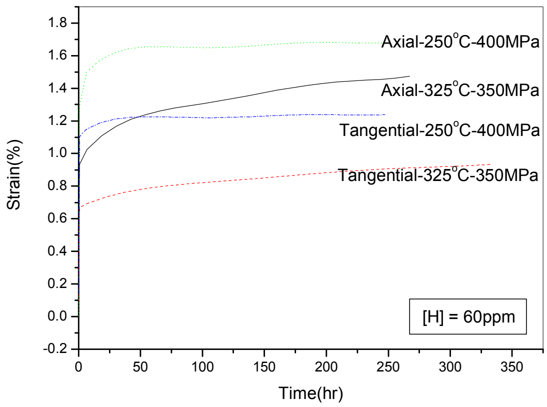

Fig. 3. Axial and Tangential creep strains at 250℃ of the Zr-2.5Nb specimens with 60ppm H specimens.

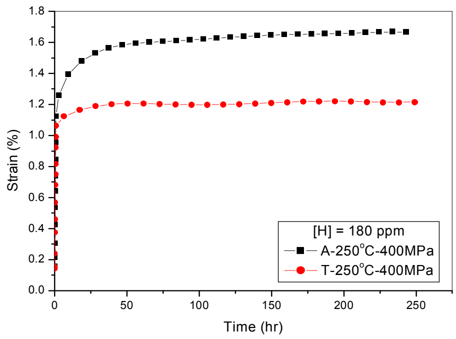

Fig. 4. Axial and Tangential creep strains at 250℃ of the Zr-2.5Nb specimens with 180ppm H specimens.

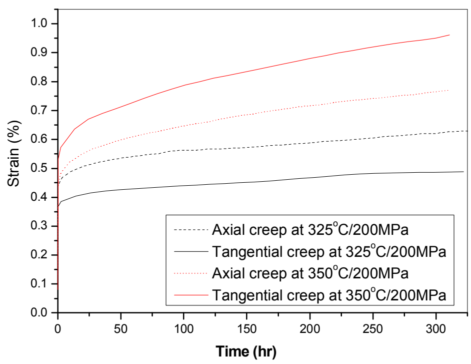

Fig. 5. Creep anisotropy of the Zr-2.5Nb specimens with no additional charged hydrogen at 325 and 350 ℃, respectively.

4. Conclusion

When the charged hydrogen was present as solid solutions and as hydride precipitates in the Zr-2.5Nb tube, the hydrides decreased the creep strain of the Zr-2.5Nb. The tangential creep of the Zr-2.5Nb tube was lower at 250℃ 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℃ and finally disappeared at 350℃, leading the tangential creep to become faster than the axial creep.

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