The Difference of Creep Behavior of Zr-2.5Nb Pressure Tubes According to the Longitudinal and Transverse Direction

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1. Introduction

Zr-2.5Nb alloys are widely used for a pressure tube for CANDU nuclear reactors. Creep and growth of pressure tubes due to irradiation, temperature and stress etc. are important property that may limit the lifetime of the tubes [1].

This work aims at providing experimental creep data and developing steady-state creep rate(axial/transverse) equation over a wide stress and temperature range according to the axial and transverse direction for Zr-2.5Nb pressure tubes prior to considering effect of irradiation.

2. Methods

2.1 Materials and Specimen

The material used in this work was cold-worked Zr-2.5Nb pressure tube. The uniaxial creep tests were performed on pressure tubes at a large range of temperatures(325℃, 350℃, 375℃ and 400℃) and stresses(130 MPa, 165MPa, 180MPa and 200MPa).

The miniature creep specimen drawn in Fig. 1 was used to test specimens cut from a pressure tube in the longitudinal and transverse direction.

The creep specimens were dog-bone shape which has 42mm length, 4mm width, 20mm parallel length and 1.5 mm thickness. A small fraction(10%) of the test force was applied before and during heating of the specimen to improve the axiality of loading.

The initial strain(ε_0) at zero force was obtained by extrapolating the linear portion of the load-strain curve [2]. The test time was equally applied to all specimens for 300 hours.

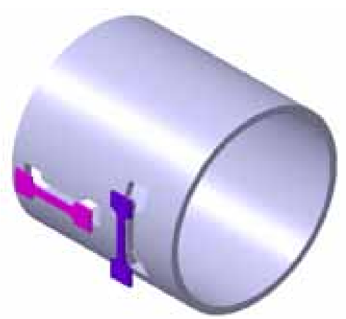


Figure 1. Schematic of uniaxial creep specimens.

3. Results

As a result of creep test, the creep strain and steady-state creep rate for the transverse specimens are more bigger and faster than those of longitudinal specimen. The higher test temperature and stress rise, the quicker steady-state creep rate arrives at the steady-state stage.

At the constant stresses, the creep strains are more changeable as changing temperature. On the other hand, the steady-state creep stains are small relatively as changing stress at the constant temperature. Especially, the creep strains are nearly constant though stresses change at the lowest test temperature, 325℃.

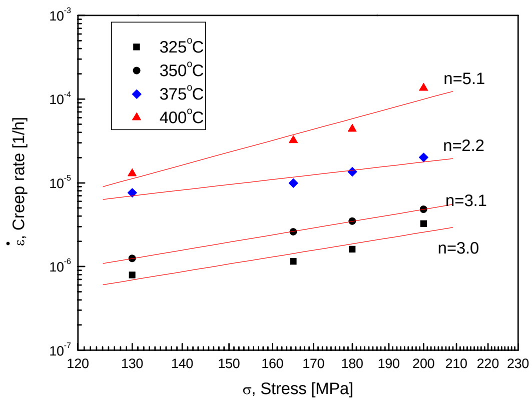
The stress and temperature dependence of thermal creep are generally described by an equation of form below, respectively.

$$\dot{\varepsilon} = A\sigma^n \tag{1}$$

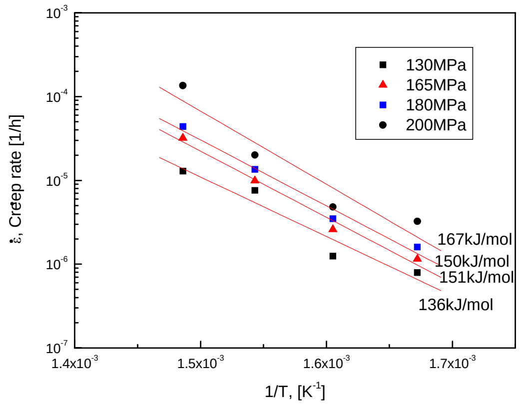
$$Q/R = \left(\frac{\partial \ln \dot{\varepsilon}}{\partial(-1/T)} \right)_\sigma \tag{2}$$

where, $\dot{\varepsilon}$ is steady-state creep rate, σ is applied stress, A is material constant, Q is activation energy and R is gas constant.

Fig. 1 and Fig. 2 show the result of the stress and temperature dependence of thermal creep for longitudinal and transverse direction, respectively.

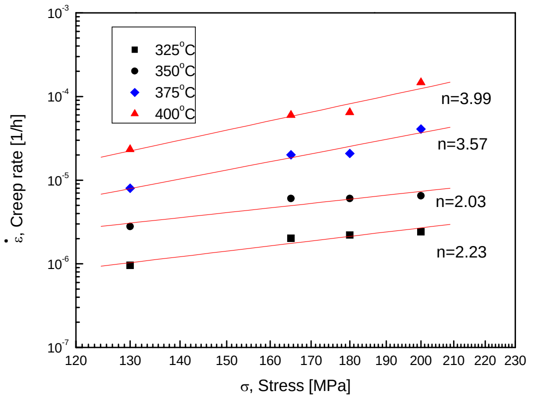


(a) Creep rates vs. stresses.

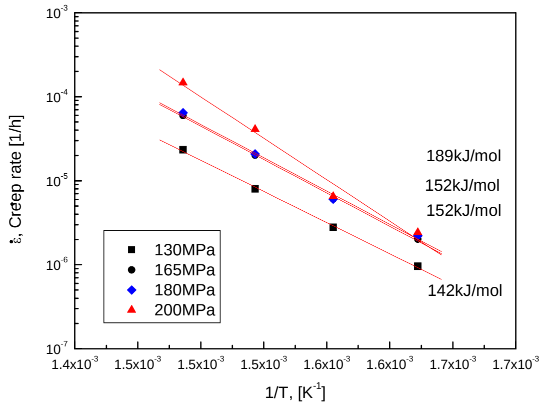


(b) Creep rate vs. absolute temperature.

Figure 1. Relations between steady-state creep rate, stresses and absolute temperature for the longitudinal direction.



(a) Creep rates vs. stresses



(b) Creep rate vs. absolute temperature.

Figure 2. Relations between steady-state creep rate, stresses and absolute temperature for the transverse direction.

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] ASTM Standard E 139, Standard Test Methods for Conducting Creep, Creep-Rupture and Stress Rupture Tests of Metallic Materials, American Society for Testing and Materials, Philadelphia, 2003.