Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Thermal creep of hydride Zircaloy-4 plates under dry storage conditions

Ho-A Kim, Ju-Seong Kim, Tae-Hoon Kim, Yong-Soo Kim*
Department of Nuclear Engineering, Hanyang University,
222 Wangsimni-ro, Seongdong-gu, Seoul, 133-791, Republic, of Korea
Corresponding author: yongskim@hanyang.ac.kr

1. Introduction

As the capacity of spent nuclear fuel storage pool at reactor sites becomes saturated, the Korean government needs other spent nuclear fuel storage methods. Dry storage is one of the most realistic options for interim storage until fuel reprocessing or final disposal[1]. During dry storage, the fuel cladding temperature rises up around 400 ℃ due to poor heat conductivity of inert gases surrounding the cladding tubes as compared to water in wet storage[2]. Under these conditions, creep and hydride effects are important degradation mechanisms for spent nuclear fuel cladding. However, in Korea, there are few experimental results on not only in-pile but also out-of-pile spent nuclear fuel cladding to understand degradation mechanisms and to determine the domestic safety criteria. Therefore, experimental researches for creep and hydrogen effects in dry storage conditions are required[3].

2. Methods and Results

2.1 Material

The cold-rolled and recrystallized Zircaloy-4 sheets were used in this work. Tensile specimens were manufactured in a smaller size than ASTM E8[4] from Zircaoy-4 sheets by using wire cut electric discharge processing. The schematic illustration of the specimen is shown in Fig. 1. Hydrogen was charged into the specimen by using the Sievert method.

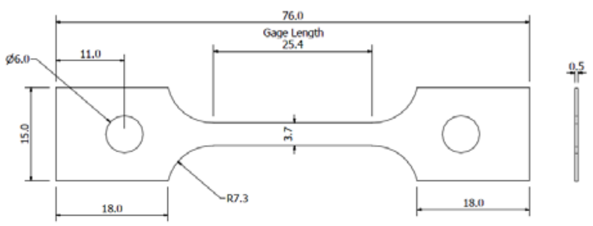


Fig. 1. Schematic illustration of the specimen for the plate creep test.

2.2 Plate creep tests

Plate creep tests were carried out using creep test apparatus under the stresses 140 MPa and 160 MPa at 400 ℃ (Fig. 3). The creep test apparatus consists of an electric furnace, a direct load applying system and LVDT (Linear Variable Differential Transformer) for measuring linear displacement (position). The creep tests were performed following the procedure shown in Fig. 3 until the specimens reached creep rupture. During the tests, temperature, load and displacement were recorded by the data acquisition system.

Fig. 2. Picture of the creep test apparatus and the data acquisition system.

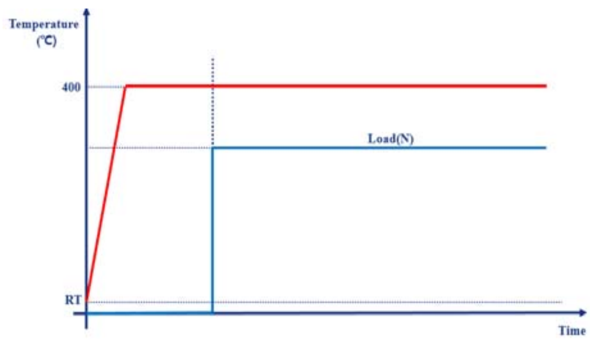
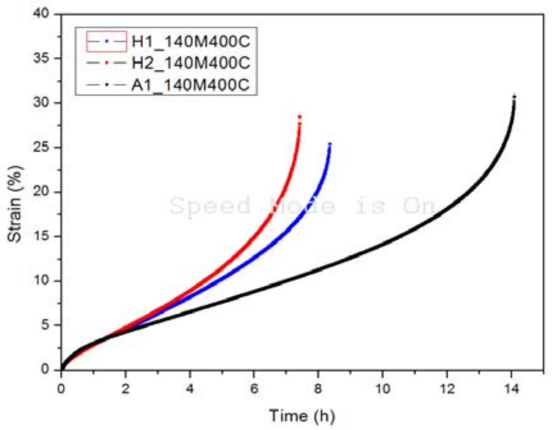


Fig. 3. Schematic diagram of the creep test procedure applied temperature and load.

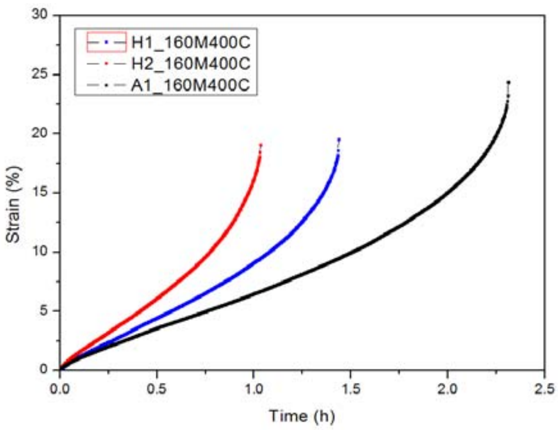
2.3 Results and discussion

Fig. 4 displays the strain versus time curve obtained from the results of plate creep tests under stresses 140 MPa and 160 MPa at 400 ℃. At the beginning of the experiments, the creep curve shows a transient region (creep rate decreases with time) and after a certain time, the creep curve shows a steady state creep region (creep rate is constant). At the end of experiments, the creep curves shows a tertiary creep region (creep rate is increases with time).

Secondary creep rates of the specimens calculated by using linear least squares fitting in secondary creep regions are shown in Table I.



(a)



(b)

Fig. 4. Results of the plate creep tests under (a) 140 MPa stress at 400 ℃, (b) 160 MPa stress at 400 ℃.

Table I. Secondary creep rate.

	Secondary creep rate (sec^{-1})	Standard Error
H1_140M400C	5.41E-4	4.74E-7
H2_140M400C	5.69E-4	8.40E-7
A1_140M400C	3.34E-4	2.34E-7
H1_160M400C	2.37E-3	5.64E-6
H2_160M400C	3.37E-3	1.08E-5
A1_160M400C	1.80E-3	4.25E-6

Fig. 4 and Table I depict that for both creep tests at 140 MPa and 160 MPa, secondary creep rates of hydride specimens are higher than those of as-received specimens and creep rupture time of hydride specimens is shorter than that of as-received specimens. There is no creep data using Zircaloy-4 plate tensile specimen, so it is hard to compare the results.

3. Conclusions

Plate creep tests were carried out up to rupture on Zircaloy-4 tensile specimen under the stresses 140 MPa and 160 MPa at 400 ℃. The results obtained were as follows:

(1) The more stress applied, the shorter creep rupture time was and the smaller secondary creep rates were.
(2) Secondary creep rates of hydride specimens were higher than those of as-received specimens.
(3) Creep rupture time of hydride specimens was shorter than that of as-received specimens.

REFERENCES

[1] M. Mayuzumi, T. Onchi, Creep deformation of an unirradiated zircaloy nuclear fuel cladding tube under dry storage conditions, Journal of Nuclear Materials, 171 (1990) 381-388.
[2] V. Mallipudi, S. Valance, J. Bertsch, Meso-scale analysis of the creep behavior of hydrogenated Zircaloy-4, Mechanics of Materials, 51 (2012) 15-28.
[3] J. KIM, H. YOON, D. KOOK, Y. KIM, A STUDY ON THE INITIAL CHARACTERISTICS OF DOMESTIC SPENT NUCLEAR FUELS FOR LONG TERM DRY STORAGE, Journal of Nuclear Engineering and Technology, 45 (2003).
[4] ASTM E8/E8-09, Standard Test Methods for Tension Testing of Metallic Materials, in: ASTM International.