Spent Fuel Behaviors under Loss of Cooling/Coolant Accident in A Spent Fuel Pool

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1. Introduction

It is well known that one of the primary considerations for the feasibility of dry storage of spent fuel is the creep deformation due to internal rod pressure. Although during wet storage, the temperature of the fuel rods is relatively at low levels due to the contact with the pool water, during dry storage the cladding temperature initially increases due to the relatively poor decay heat removal by inert gases [1]. Under dry storage conditions for spent nuclear fuels, creep deformation/rupture is the most probable degradation mechanism for the cladding material [2], because internal pressure of the fuel rod also becomes higher with storage temperature. Thus the integrity of spent fuel during dry storage has been evaluated by predicting creep deformation of Zr alloy claddings [3, 4]. In particular, the hoop-directional creep behavior of high burn-up fuel cladding is concern due to the difference of pressure between fuel-cladding gap and storage environment. Many investigations have been performed in order to validate the hydrogen effect on creep behavior of fuel cladding, because high burn-up fuel cladding contains high concentration of hydrogen absorbed during waterside corrosion during normal operation. But there is no consensus regarding hydrogen effect on creep behavior. Accordingly, it is essential to clarify hydrogen effect on creep behavior of the high burn-up fuel cladding. In this paper, some experimental results on hydrogen effect on the hoop-directional creep properties of nuclear fuel cladding are presented.

2. Experimental Methods and Results

2.1 Experimental Method

The hoop directional creep test specimens used in this study are as-received unhydrided Zircaloy-4 cladding, hydrided Nb-containing cladding, and high burn-up Zirclaoy-4 cladding. The dimensions and shape of the hoop-directional creep specimen were designed in order to ensure that any deformation is limited to the gage section of the specimen, so that the uniform uniaxial hoop strain in the gage section could be at its maximal [5]. The gage sections of the specimens were oriented at the top and bottom of the half cylinder of the grip, such that a constant curvature of the specimen can be maintained during a creep deformation. The interface was lubricated with a graphite-containing vacuum grease lubricant at the beginning of each test to minimize a loss of the applied load. The hoop directional creep tests were performed at 500℃ and 550 ℃ with the Instron Servohydraulic System, Model 8562.

2.2. Experimental Results

Hoop directional creep tests for unhydrided, hydride (~500 ppm H), and high burn-up claddings (~500 ppm H) were performed at 500ºC and 550ºC. Fig. 1 and Fig. 2 shows creep deformation behaviors of un-hydrided and hydrided cladding at 500ºC and 550ºC, respectively. As shown in Fig. 1 and Fig. 2, it was revealed that there is a significant difference in the steady-state creep rate among them. The steady-state creep rate of high burn-up fuel cladding (~500 ppm H) is the highest, compared with un-hydrided cladding and hydrided cladding (~500 ppm H). The creep rate was in order of high burn-up cladding > hydrided cladding > un-hydrided cladding.

3. Conclusion

The experimental results on hydrogen effect on the hoop-directional creep properties of Ziraloy-4 and Nb-containing nuclear fuel cladding at 500ºC and 550ºC showed the following main results. First, it was revealed that hydrogen in the Zr alloy plays a role to increase secondary creep rate. Second, the creep rate of irradiated(high burn-up) cladding is highest, and hydrided cladding > un-hydrided cladding.

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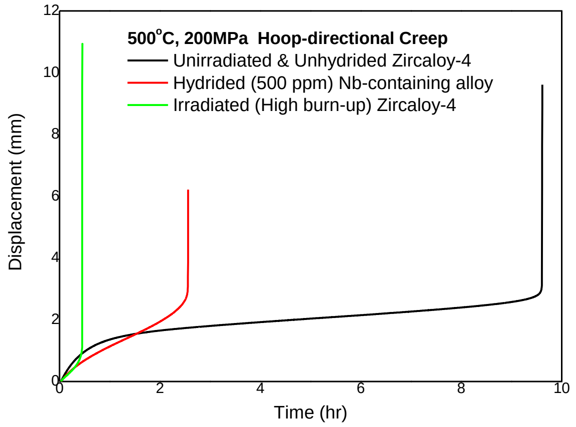

Fig. 1. Creep deformation behaviors of un-hydrided, hydrided, and high burn-up cladding at 500°C (H = ~500 ppm)

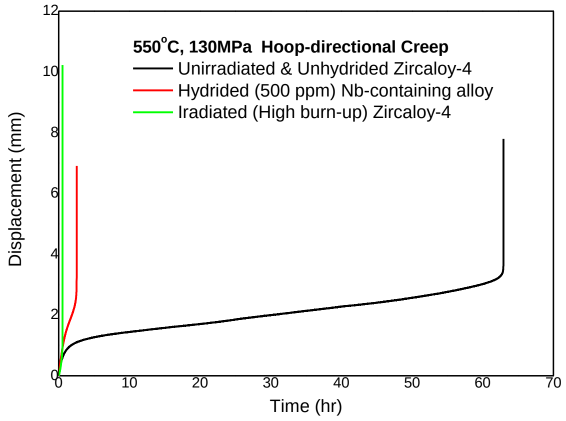

Fig. 2. Creep deformation behaviors of un-hydrided, hydrided, and high burn-up cladding at 550°C (H = ~500 ppm)