Correlation Between Hydrogen Contents and Stiffness of Oxidized Spacer Grid for Calculating Spent Fuel Rod Response to Impacting Force

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1. Introduction

Discharged spent fuels from light water reactors are temporarily stored in spent fuel storage pools of each plant site, but it reaches saturation in the near future. So, dry storage method is regarded as one of the most practical and alternative solutions for resolving the spent fuel accumulation problems in Korea [1]. However, domestic technologies and industrial know-how for operating dry storage facilities are in the beginning stage while the first dry storage installation in the US was licensed by the Nuclear Regulatory Commission (NRC) in 1986 at the Surry Nuclear Power Plant in Virginia. The spent fuels are safely stored by applying the dry storage methods of various concepts such as Vaults, Silos, metal and concrete cask.

The final objectives of spent fuel dry storage are to prevent a gross rupture of the spent fuel during operation and to keep its retrievability until transportation because dry storage means an intermediate method before a permanent decision [2]. In other words, integrities of spent fuel rods and their structural supporting parts should be maintained against temperature-induced failures (i.e., creep, hydrogen reorientation, etc.) and interaction between fuel rod and spacer grid during handling and transportation, respectively. This study focus on the later issue that external force to spent fuel rods mainly exerted by spacer grid springs and dimples. It is well known that Zr-based claddings of spent fuel rods show brittle characteristics due to the formation of hydrides and oxidation in high temperature pressurized water. In addition, it is expected that structural parts of fuel assembly also degraded by the same environment. During the transportation and handling, external force on spent fuel rod exerted by spacer grids that their stiffness values are increased by thermal relaxation and irradiation embrittlement. In this study, the variation of spring stiffness of spacer grid with increasing oxidation time in high temperature pressurized water were examined focusing on effect of hydrogen contents and oxide thickness for calculating spent fuel rod response during the transportation and handling.

2. Experiments and Results

2.1 Oxidation tests

The spacer grid specimens were prepared with 10.9 mm in width and 40 mm in length and oxidized in an autoclave up to 360 days and then examined their stiffness values, oxide thickness and hydrogen contents.

2.2 Specimen analysis

The stiffness of oxidized spacer grids were measured by a simplified p-δ (force-displacement) tester with 10 N of maximum applied force. The oxide thickness and hydrogen contents were also measured by SEM and a hydrogen determinator, respectively.

2.3 Variation of stiffness & oxide thickness

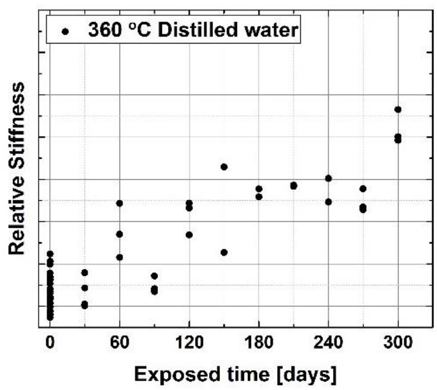

Fig. 1. Variation of stiffness with exposed time.

Fig. 1 shows the variation of stiffness with increasing oxidation time. When compared with as-received specimen (i.e., before oxidation), stiffness of oxidized grid spring gradually increased. However, oxide thickness rapidly increased at 60~90 days and then gradually increased as shown in Fig. 2. This means that thin oxide did not affect the variation of thickness.

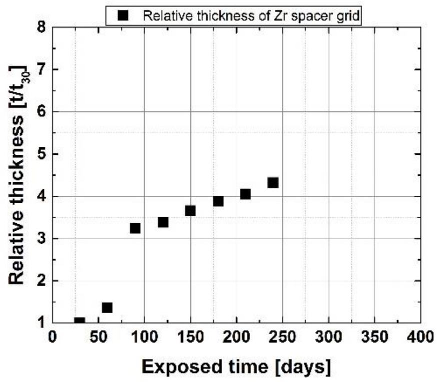

Fig. 2. Measurement results of oxide thickness.

2.4 Hydrogen contents

Fig. 3 shows the variation of hydrogen contents with increasing oxidation time. As expected, amount of hydrogen increased with oxide thickness and oxidation time. However, these amount seem to be small rather than conventional Zr cladding because of different microstructures.

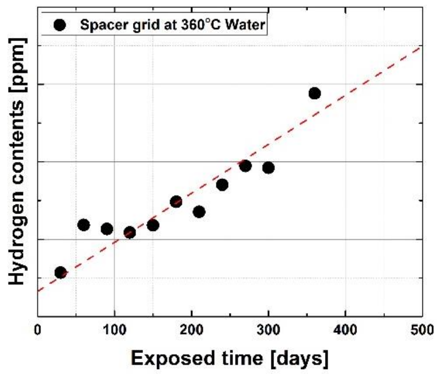

Fig. 3. Measurement results of hydrogen contents.

3. Summary

In this study, the stiffness of spacer grid gradually increased with oxide thickness and hydrogen contents (i.e., oxidation time). Previous results [3] indicated that average cell size of spacer grid enlarged rather than as-built condition. So, increased stiffness of spacer grid should be examined for calculating the spent fuel rod response to impact force during the transportation and handling. However, the key factor affecting the stiffness variation is not apparent and further studies focus on the effect of hydrogen contents without surface oxidation.

ACKNOWLEGEMENTS

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