2007 International LWR Fuel Performance Meeting
September 30 – October 3, 2007, San Francisco, California

Track 2 – LWR Fuel Performance and Operational Experience

The Effects of Cladding Chemical Composition on Corrosion Behavior of High Burnup BWR Fuel (Corrosion Properties of Low Iron and Low Silicon Content Cladding)

OTSUKA Yasuyuki[1*], ABE Moriyasu[1]
KAKIUCHI Kazuo[2], FUKUDA Takuji[2], OHIRA Koichi[2], ITAGAKI Noboru[2]

[1] Tokyo Electric Power Company (TEPCO),
1-3, Uchisaiwai-cho 1-chome, Chiyoda-ku, Tokyo 100-0011, Japan
[2] Nuclear Fuel Industries, Ltd. (NFI),
3135-41, Muramatsu, Tokai-mura, Naka-gun, Ibaraki 319-1196, Japan

[*] Corresponding author, Email: Otsuka.Yasuyuki@tepco.co.jp,
Tel: +81-3-4216-4937, Fax: +81-3-4216-4919

1. Introduction

Hotcell PIEs for 9×9 BWR fuels, which were irradiated as LUA in a Japanese commercial BWR for five cycles from 1996 to 2002, were performed [1]. The results showed that the oxide thickness was higher locally on the fuel rods in the corner positions of 9×9 fuel type B (burnup is 53.5 GWd/t, irradiated period is 2000 days) fabricated by NFI.

In order to study the phenomenon, oxide thickness was measured by poolside examination for a number of high burnup fuels in some commercial BWRs. This paper describes the results of a joint study by TEPCO and NFI.

The cladding material which showed higher oxide thickness had low iron and low silicon content, compared with the cladding used as standard material today. The examination focused on this aspect.

2. Poolside examination and results

The oxide thickness was measured by the eddy current technique without disassembling the fuels at the reactor poolsides. The fuel rods located in peripheral positions of the fuel assemblies were measured at plural axial positions.

The fuel assemblies for oxide thickness measurements were selected from some commercial BWRs, according to irradiation period and cladding chemical composition (iron and silicon content), and a total of 117 fuel rods of 20 fuel assemblies, which contain three different types of fuel design, were selected.

The measurement results showed that the oxide thickness of almost all fuel rods ranged from 10 to 40 μm and axial profiles were flat. The oxide thickness was found to increase slightly with irradiation period as shown by previous data. The maximum irradiation period of examined fuels was 2300 days.

Only two fuel assemblies of all examined fuel assemblies showed higher oxide thickness, i.e. from 50 to 60 μm, compared with normal data. The claddings of these two fuel assemblies were low in iron and silicon content, and had been made from the same material ingot. The irradiated periods of the two fuel assemblies were 2000 days and 2300 days. In the case of an irradiation period of less than 2000 days, higher oxide thickness was not observed, even if the cladding was low in silicon and iron content.

Higher oxide thickness was not observed for high iron content claddings, even if the silicon content of the cladding was low, and higher oxide thickness was also not observed for high silicon content claddings, even if the iron content of the cladding was low.

From these results, the following conditions caused the higher oxide thickness of fuel rods:

- Both the iron content and silicon content of cladding chemical composition were low.

- Irradiated period was over 2000 days.

3. Discussion

While it is well known that the Zry corrosion resistance increases with iron content, the effect of the silicon content of cladding on the corrosion mechanism is not clear. We performed an out-pile corrosion test, and found that Zry material with low silicon content showed large deviations of corrosion property under severe corrosion environments.

We checked the power history and core loading positions for the fuel assemblies which had the higher oxide thickness. They were loaded in core periphery positions in their latter irradiation cycles. In the periphery of a core, the thermal power of the fuel is suppressed and the coolant mass flow rate is also suppressed. Consequently, it is thought that a coolant environment of lower flow rate and lower void fraction, which is severe in terms of cladding corrosion, was formed in the fuel.

4. Conclusion

Extensive data on the oxide thickness of high burnup fuels could be obtained successfully by the poolside examination. The results confirmed that iron and silicon content of cladding material, long irradiation period and severe coolant environment affected the corrosion property of fuel cladding, and caused a higher oxide thickness.

Cladding with low iron and low silicon content is no longer used for the fuel assemblies of Japanese BWRs, so higher oxide thickness which could have an adverse effect on plant operation should not occur.

[1] Y. Hirano, et. al., “IRRADIATION CHARACTERISTICS OF BWR HIGH BURNUP 9×9 LEAD USE ASSEMBLIES,” 2005 Water Reactor Fuel Performance Meeting, Kyoto