The Evaluation of IFPE Database by FRAPCON-3 Code – IFA-432, AECL Bundle NR

Yeonseung Kim [a*], Hyoungju Yoon[a], Jungsoo Kim[a], Hyonggun Shim[a], Kwangheon Park[a]
a Green Nuclear Research Lab., Kyunghee University, 449-701, Korea,
[*]*Corresponding author :* specialkys@nate.com

1. Introduction

Since 1990, improving fuel cycle economy has required an extension of the fuel cycle and higher burn up operations. Modern reactors tend to operate under severe operating conditions [1]. Therefore, it is important to maintain the integrity of fuel in severe conditions.

This report deals with a paper from a research laboratory located in Halden, Norway, where it is possible to determine the location of the thermocouple that is most efficiently able to analyze nuclear fuel rod performance compared to results of the IFPED (International Fuel Performance Database), to the IFA-432 experiment, and to the FRAPCON-3 Code, which is a program for the analytical simulation of nuclear fuel rod performance. In addition, research was conducted as to whether it is possible to simulate the performance of AECL Bundle – NR fuels irradiated in a CANDU-type NRU reactor.

2. Methods and Results

2.1 FRAPCON 3 Code

The FRAPCON-3 Code forms a part of the reactor safety research program being conducted by the NRC (U.S. Nuclear Regulatory Commission) and is a useful tool to simulate the performance of LWR (Light Water Reactor) fuel rods under long-term burnup conditions. It calculates the variation with time of all significant fuel rod variables, including fuel and cladding temperature, cladding oxidation, fuel irradiation swelling, fuel densification, fission gas release, and rod internal gas pressure.

2.2 IFPE Database

The aim of the project is to provide a comprehensive and well-qualified database on Zr clad UO2 fuel for model development. The data include prototypic commercial irradiations, as well as experiments performed in Material Testing Reactors. This work is carried out with the close cooperation and coordination of the NEA (Nuclear Energy Agency) and the IAEA (International Atomic Energy Agency) [2].

2.2.1 IFA-432 Experiment

The IFA-432 experiment was irradiated under a research program on fuel rod steady-state performance in the Halden heavy boiling water reactor (BWR). The experiment was to test the long-term steady-state performance of BWR-6 type fuel rods, operated at power levels that were at the upper bound for full-length commercial fuel rods. The main objectives of the experiment were to obtain measurements of fuel temperature response, fission gas release and mechanical interaction on BWR-type fuel rods up to high burnup [3].

2.2.2 AECL Bundle - NR

This consists of 37 prototype fuel bundles for CANCU600. The center of the fuel bundle was removed. It is a pressurized heavy water reactor (PHWR) using heavy water for the coolant. Bundle – NR had been burned out over 160 days, and it had approximately 58 ~ 62 KW/m of power distribution [3].

2.3 The Result of IFA-432 Experiment

The measured and predicted fuel center temperatures for pre-compensation are plotted as a function of irradiation time in Figure 1. From approximately 75 days onward, the measured temperature was overpredicted by 100 to 150 ℃ by the FRAPCON-3 Code.

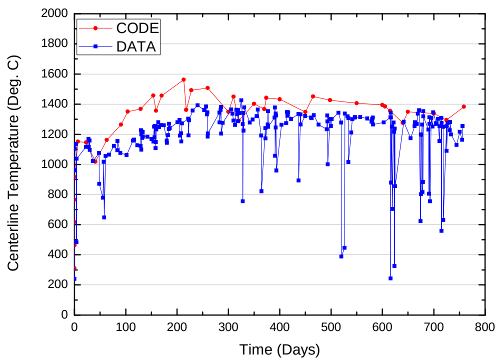

Fig. 1. Match between predicted and measured temperature versus time for pre-compensation.

The Heating-7.2 Code which is the analytical program of Heat Transfer was used in order to reduce the difference of temperature between the FRAPCON-3 Code and the IFPE Data. Figure 2 shows the temperature distribution depending on the difference of the gap size from the tip of the thermocouple to the pellet. It should be noticed that the location of the thermocouple which was the most correct was 2.8 mm from the pellet.

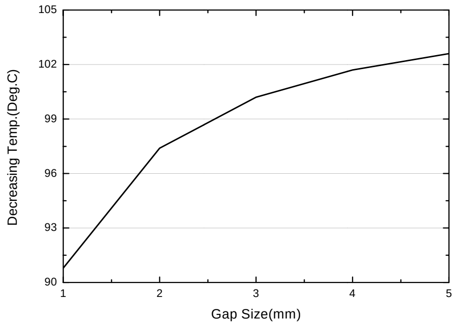

Fig. 2. Decreasing temperature depending on the gap size between the pellet and thermocouple.

Considering the location, Fig. 3 shows the result re-analyzed with the FRAPCON-3 Code. It is noticed that the difference between the data of the IFA-432 experiment and FRAPCON-3 Code is reduced.

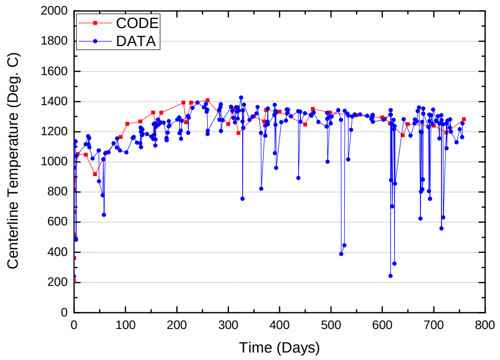

Fig. 3. Match between predicted and measured temperature versus time for post-compensation.

2.4 The Result of AECL Bundle - NR

Figure 4 shows the gap size change with the passing of time. From about 2 days onward, the gap size decreased by 0.02 mm. Various phenomena occurred in the fuel, such as swelling, densification, stress, and strain. Therefore, the radius of the pellet increased with the passing of time.

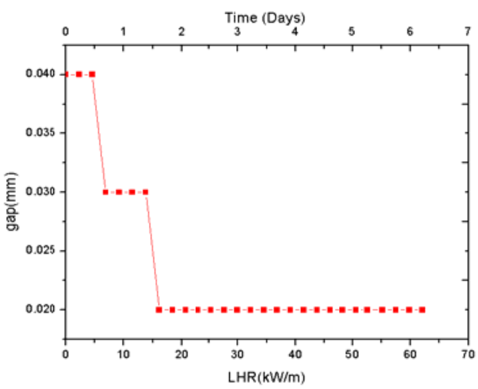

Fig. 4. The gap size changes with the passing of time.

Figure 5 shows the fission gas release with the passing of time. As time passed, the early helium decreased. On the other hand, Kr and Xe mostly increased with the passing of time. What is noteworthy is that the results of the FRAPCON-3 Code and the IFPE Database were analogous.

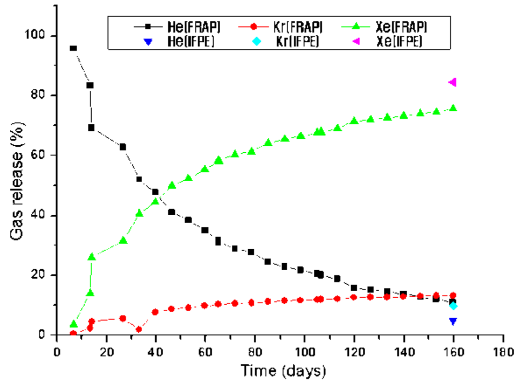

Fig. 5. The fission gas releases with the passing of time.

3. Conclusions

It was easy to simulate nuclear fuel rod performance with the FRAPCON-3 Code. However, the results of the IFA-432 experiment and the FRAPCON-3 Code were different, which may have an effect on the analysis of nuclear fuel rod performance. If the thermocouple within the rod is relocated to within 2.8 mm from the pellet, it will acquire more accurate and more credible data.

Furthermore, fuel swelling and gas release of the AECL Bundle – NR were enabled to simulate results analogous to the FRAPCON-3 Code. Therefore, it is possible that PHWRs can also be analyzed with the FRAPCON-3 Code.

REFERENCES

[1] A. Jonsson, L. Hallstadius, B. Grapen-giesser, and G. Lysell, Fuel for the 90's: ANS/ENS International Topical Meeting on LWR Fuel Performance, Avignon, France, 1991.

[2] The Public Domain Database on Nuclear Fuel Performance Experiments for the Purpose of Code Development and Validation [online]. Available at: http://www.nea.fr/html/science/fuel/ifpelst.html. Accessed 2009-02-24.

[3] D. D. Lanning, C. E. Beyer and C. L. Painter, FRAPCON-3: Modifications to Fuel Rod Material Properties and Performance Models for High-Burnup Application, Pacific Northwest National Laboratory, 1997.