Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Application of PLUTO Test Facility for U.S NRC Licensing of a Fuel Assembly

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1. Introduction

Korea Electric Power Corporation (KEPCO) took an early step toward exporting the APR-1400 to the United States by meeting with the U.S Nuclear Regulatory Commission (NRC) on November 18, 2009, regarding the possible standard design certification for the reactor. NRC's licensing schedule shows the KEPCO design certification review beginning in mid 2013 [1]. In addition the fuel assembly of the PLUS-7 loaded in the APR-1400 follows the same schedule.

Meanwhile, In July 1998, the U.S. NRC adopted a research plan to address the effects of high burnup from a Loss of Coolant Accident (LOCA). From these programs, several important technical findings for rule revision were obtained [2]. Based on the technical findings, the U.S NRC has amended the 10 CFR 50.46 which will be proclaimed sooner or later. Through the amendment, a LOCA analysis on the fuel assembly has to show the safety at both a fresh and End of Life (EOL) state. The U.S NRC has already required EOL effects on seismic/LOCA performance for a fuel assembly since 1998 [3, 4].

2. Methods and Results

In this section some damping techniques in a LOCA analysis are described.

2.1 Damping on LOCA Analysis

The fuel assembly should maintain a coolable geometry such that the reactor core can safely shut down during a postulated seismic event and a LOCA. During seismic and LOCA events, the fuel assembly experience strong lateral accelerations, which results in a large lateral motion of the fuel assembly. Seismic and LOCA analyses must be reasonable as a safety analysis tool. The fuel assembly models are an indispensable factor in the code. The fuel assembly damping significantly affects the fuel assembly grid impact forces which are design parameters in seismic and LOCA analyses.

2.2 Damping Factor

The fuel assembly motion after a quick release based on the pluck displacement, decay ratio, and damping, is expressed as the ratio of successive amplitude. The damping is calculated using the logarithmic decrement method shown in figure 1 [5].

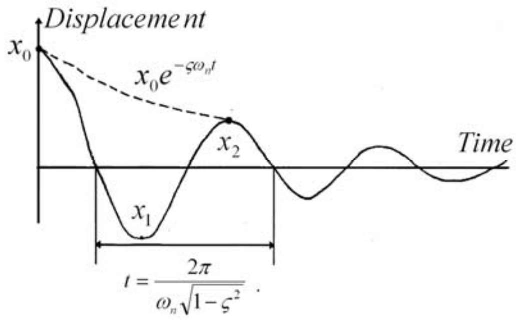

Fig. 1. The Decay Motion of Under Damped Vibration System

$$\delta_i = \ln(\frac{x_{i-1}}{x_{i+1}}) = \frac{2\pi\varsigma}{\sqrt{1-\varsigma^2}} \qquad (1)$$

Solving for the damping factor, ς, results in the following:

$$\varsigma = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}} \qquad (2)$$

The fuel assembly damping factor is taken using a pluck test. The pluck test is perfumed by pulling or pushing the fuel assembly with a given amount and releasing it for free vibration without the initial velocity. In a pluck test, sensors measure the displacement of the spacer grid for the specific position. We are able to obtain the correct damping factor with the accurate relative amplitude.

2.3 Test Facility and Test Conditions

The pluck test in still water and flowing water can be performed in an out-of-pile full scale fuel assembly hydraulic verification test facility with isothermal hydraulic conditions. The significant parameters on the pluck test are the maximum operating flow rate and temperature. The high flow rate and temperate of a fluid can produce high velocity in the rod bundle. The flow rate is bypassed though the gap, which is between the fuel assembly and housing wall for the plucking assembly. The CEA (Commissariat a l'Energie Atomique) and Stern Laboratory have performed a pluck test in flowing water. The performance of the two test facilities have been compared with that of PLUTO(Performance Test Facility on Fuel Assembly in

Vibrations and Hydraulics) which was constructed at KAERI(Korea Atomic Energy Institute). The maximum operation flow-rate and temperature of PLUTO is higher than others. The pluck test at PLUTO has larger flexibilities in determining the test parameters including pluck displacement and flow velocity than the other two test facilities.

Table I: Comparison of Perforce on Test Facilities

Facility	HERMES-T (CEA) [6]	FATS (Stern Lab.) [7]	PLUTO (KAERI) [8]
Max. Flow rate (M3/hr)	1200	1220	1400
Max. Temperature (℃)	170	150	210
Max. Pressure (MPa)	3	1.5	3.5
Test Temperature (℃)	50, 170	38, 93, 149	50, 95, 150, 200
Test Flow Velocity (m/s)	0,3,5	0, 1.7, 3.0, 3.4,5.1	0, 3, 5, 6
Pluck Displacement (mm)	8, 14	2, 4, 6, 8, 10, 13	2, 4, 8, 15

2.4 Comparison with Test Data

The results of a test performed for the AREVA and the Westinghouse fuel assembly for each test facility have been summarized in Table II. The damping factor of a fuel assembly in flowing water is significantly high in both test results.

Table II: Damping Factor Comparison

Fuel Assembly	AREVA 17X17 Mark-C [6]	Westinghouse 17X17 RFA [7]
In Air [%]	18	12
In Still Water [%]	28	18
In Flowing Water [%]	45	50

3. Conclusions

To obtain U.S NRC licensing of a fuel assembly, based on the amendment of 10CFR50.46, a LOCA analysis of the fuel assembly has to show safety both fresh and EOL states. The proper damping factor of the fuel assembly measured at the hydraulic test loop for a dynamic model in a LOCA and a seismic analysis code are at least required. In this paper, we have examined the damping technologies and compared the test facility of PLUTO with others in terms of performance. PLUTO has a better performance on the operating conditions than any others.

ACKNOWLEDGMENTS

This work was supported by Korea Electric Power Cooperation Nuclear Fuel (KEPCO-NF).

REFERENCES

[1] Mark Holt, “U.S and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations” Congressional Research Service 7-5700, R41032, June 25, 2013.
[2] Andong Shin, “Role and Perspectives on Fuel Safety in Nuclear Safety Analysis”, KNS Workshop on ATF Development Needs and Status, May 29, 2013.
[3] U.S NRC, “Request for Additional Information - FRAMATOME Topical Report BAW-10133P, Rev. l, ADDENDA 1 AND 2, “MARC-C Fuel Assembly Loss-of-Coolant Accident Seismic Analysis” (TAC NOS. M99906 and MA5902)”, June 28, 2000
[4] Westinghouse, “Transmittal of "End of Life Effects on Seismic/LOCA Performance for the AP1000 Pressurized Water Reactor Fuel Assembly” (Proprietary/Non-Proprietary)", September 25, 2012
[5] W. T. Thomson, “Theory of Vibration with Applications”, third edition, 1988, Prentice-Hall.
[6] Fardeau P., Barbier D., de Langre E., and Rigaudeau J., “Damping from Axial Coolant Flow in the Responses of PWR Fuel Assemblies to Horizontal Seismic Loads”, Transactions of the 14th International Conference on Structural Mechanics in Reactor Technology(SMiRT14), Lyon, France, August 17-22, 1997
[7] Roger Y. Lu and David D. Steel, “PWR Fuel Assembly Damping Characteristics”. Proceedings of ICONE14 International Conference on Nuclear Engineering July 17-20, Florida, USA
[8] Dongseok Oh, “Construction of Out-of-pile Fuel Assembly Hydraulic Verification Test Platform” , Annual Report 2012, Korea Atomic Energy Research Institute.