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Prospectus of Fuel Assembly Damping Test in Flowing Water at KAERI

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1. Introduction

The damping factor of a full-scale fuel assembly is essential for a fuel seismic and LOCA analysis as an input. The higher damping factor in flowing water compared to that of in still water is very helpful in the design due to allowing its high margin. The US-NRC staff has also reviewed the Korea Hydro and Nuclear Power (KHNP) fuel seismic analysis report with a focus on the flow induced damping in pre-application audit on the APR1400 which has a seismic design criterion of a safe shutdown earthquake (SSE) of 0.3G [1,2]. Because the fuel, PLUS7, loaded in the reactor has been developed for the OPR1000 with SSE of 0.25G.

The damping factor of the fuel assembly in 1st mode vibration in flowing water can be measured by a pluck test in a hydraulic loop. The test prospectus of measuring the damping for the PLUS7 fuel assembly in flowing water at PLUTO (performance test facility for fuel assembly hydraulics and vibrations) is described [3].

2. Test Facility and Test Section

2.1 Test Facility

The damping factor of the full-scale fuel assembly in flowing water can be measured at the hydraulic test loop with a capability of flow rate more than the core flow rate of two fuel assemblies [4,5]. The Korea Atomic Energy Research Institute (KAERI) has constructed a hydraulic test facility with 1400 m^3/hr capability, named PLUTO The pressure drop, lift-off flow-rate, flow induced vibration, and endurance verification test have been performed with a single fuel assembly of PLUS7, ACE7, KSNP, HiPER16X16, HiPER17X17, and SMART fuel. The hydraulic compatibility test has been carried out with double fuel assemblies of PLUS7:HiPER16X16 and ACE7:HiPER17X17. We are conducting the hydraulic test for a Sodium-cooled Fast Reactor (SFR) fuel assembly and preparing a pluck test for a PLUS7 fuel assembly at present.

2.2 Test Section

The test section is designed with a modification of that used for a hydraulic compatibility test for 17X17 array fuel assemblies (Fig. 1). The test section is a rectangular duct containing the fuel assembly and providing a flow path and pressure boundary. The cross-section of the test section for the pluck test is wider than that used in the hydraulic test previously mentioned to provide room for the pulling fuel assembly in the lateral direction. The upper and lower parts are simulated the upper and lower core plates. The tabs are processed at each spacer grid level to mount the linear variable differential transformer (LVDT) to measure the relative displacement of the spacer grid after pulling and releasing the fuel assembly [6]. The window is also processed at the mid-spacer grid level to pass through the laser light to measure the lateral motion of the spacer grid to cross-check the LVDT results [7].

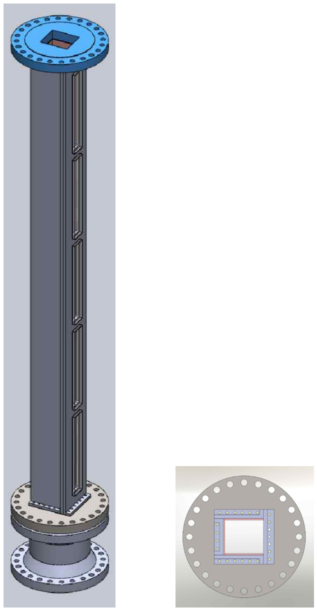

Fig. 1. The Schematic Diagram of Test Section for Pluck Test

3. Measurement

The data measurement during the pluck test is very simple. The relative displacement of the spacer grid lever in the lateral direction by two measuring methods mentioned in the previous section is only the pluck test specific data. The ordinary hydraulic parameters of fluid temperature, flow velocity and system pressure are also measured.

3.1 Test Condition

The pluck test is performed with a flesh mock-up fuel assembly. The mock-up fuel assembly means that the same weight tungsten carbide pellet is charged into the cladding tube instead of the uranium pellet. A holddown force is applied on the mock-up fuel assembly corresponding to the beginning-of-life condition in the reactor. The fuel assembly dynamic behavior is largely independent of the axial load. The fuel assembly tests were performed in still and flowing water with a variation of the flow velocity with a range of 0, 2, 4, 6 m/s and the fluid temperature with a range of 40, 80 and 120 °C to assess the impact of the parameters on the damping factor. The plucks are performed at each test condition with following displacement 5, 10, 15, 20 and 25 mm.

3.2 Data Reduction

The fuel assembly motion after a quick release is expressed as the ratio of successive amplitude. The damping is calculated using the logarithmic decrement method, as shown in Fig. 2 [8].

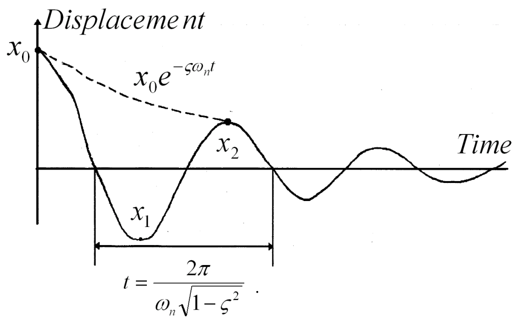

Fig. 2. The Decay Motion of Under Damped Vibration System

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

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

$$\varsigma = \frac{\delta}{\sqrt{4\pi^2 - \delta^2}}$$

For a high damping condition like in flowing water, it is hard to measure second amplitude, x_2 , due to the fast decay of the amplitude . However, the initial displacement, x_0 , and the first amplitude, x_1 , can be measured with better accuracy.

$$\delta_\pi = \ln\left(\frac{x_0}{x_1}\right) = \frac{\pi\varsigma}{\sqrt{1-\varsigma^2}}$$

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

$$\varsigma = \frac{\delta_\pi}{\sqrt{\pi^2 - \delta_\pi{}^2}}$$

4. Conclusions

The KAERI's preparation for a pluck test with the PLUS7 mock-up fuel assembly in flowing water at PLUTO has been described. The pluck test will provide the damping factor for the 1st mode of vibration, which is a conservative value compared to that of the high mode vibration [9]. However, it is necessary to accomplishing the resonance test for high mode vibration to assure the conservatism of the damping factor for the 1st mode vibration at a future time.

ACKNOWLEDGMENTS

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