Full scale earthquake accident experiment of simulated spent fuel within partial cell of storage rack under water

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1. Introduction

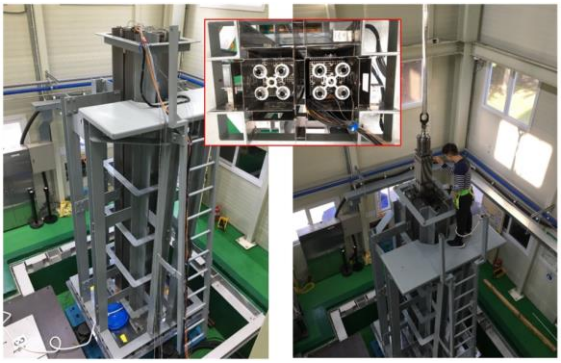
Integrity of spent nuclear fuel, stored in wet storage pool of the nuclear power station, has been concerned against impact loading while severe seismic ground acceleration in the core and anticipated transportation [1~2]. The cumulative degradation of the fuel material from long-term in-reactor operation and wet storage environment can increase the probability of structural failure of the spent fuel, particular to impact or dynamic loading acting for a short period of time.

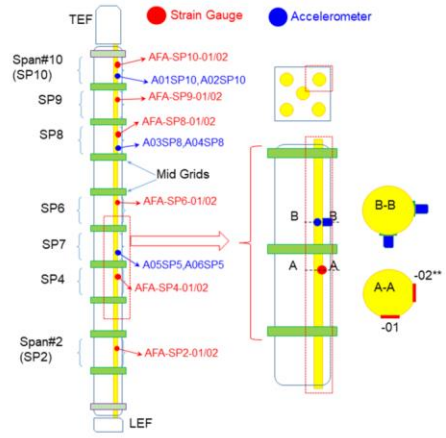
To assess their integrity by numerical modeling, realistic frictional relative motion of free standing fuel assembly in the multi-cell storage racks under the large water pool and fluid-structure interaction effect from the free surface water sloshing should be understood, but these can be quite challenging due to complex geometry of structures, nonlinearity effect from frictional impact motion and chaotic nature of multi-physics in the gross water pool including small fluid gap between neighboring structures [3~5].

Only realistic way to check spent fuel integrity in wet storage environment against anticipated seismic accident loading is to carry out the real-scale storage rack and fuel assembly testing. We, here in this paper, thus discuss earthquake accident simulation testing for the two real-scale fuel assemblies within storage rack partial cell using a 5-ton biaxial shaking table and vibration controller. Measurement results and their comparison according to the seismic input and test condition will be presented in the conference.

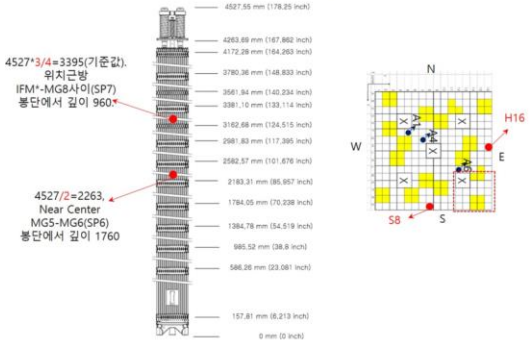
2. Experimental overview

Using two full-scale fuel assembly mockups and partial storage rack platform, we experimentally simulated the actual wet storage environment of spent nuclear fuel, and applied the site-specific earthquake input by the biaxial hydraulic shaking table to reproduce the seismic accident condition of the pool in the domestic power nuclear plant. Measurement sensors were installed in the outer guide tube inside the dummy test fuel assembly, and the simulated fuel rods with lead pellet that interfered with the periphery was removed. Strain responses were also measured on the corner fuel rods to obtain strain pickups in rods scale. Figure 1 shows configuration of the test setup, instruments and sensor location for fuel assembly and rod vibration measurement. Also, acceleration and displacement response of the test fuel assembly were measured and compared according to the type, magnitude and direction of the earthquake input.





(a) Accelerometer and strain for fuel assembly vibration



(b) Strain gauge for fuel rod seismic strain response

Fig. 1. Test facility / setup, instruments and sensor location for fuel assembly and rod vibration measurement

3. Representative Test Results

From Fig. 2 to Fig. 5 show representative results of earthquake accident simulation test for the real-scale fuel assembly at simulated storage environment under water. Technical details and interprentation of the measured results according to the testing parameters will be explained at the conference room.

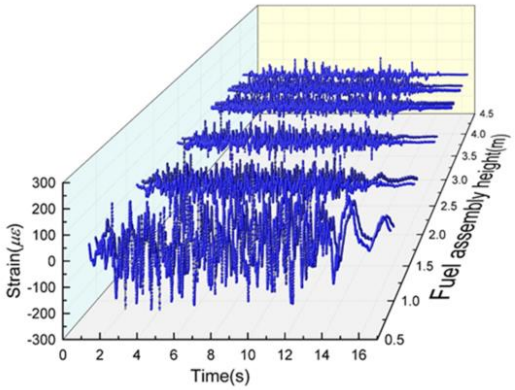
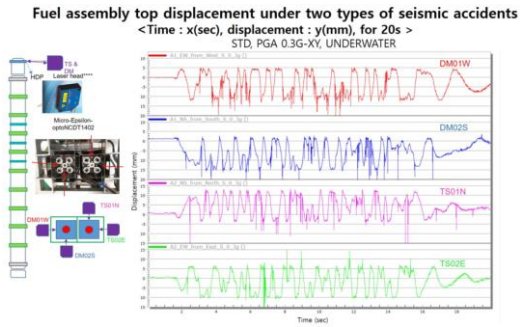
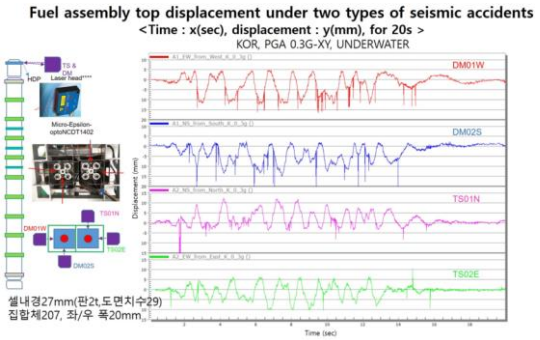


Fig. 2. Measured fuel assembly strain time history under simulated seismic accident under water, along the fuel height



(a) Design standard input case



(b) Site specific input case

Fig. 3. Measured fuel assembly displacement under simulated accident according to the type of seismic input.

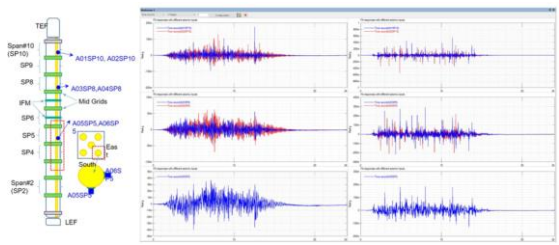


Fig. 4. Measured fuel assembly acceleration during the simulated accident according to the type of seismic input.

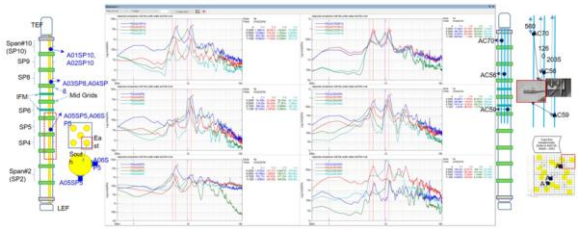


Fig. 5. Measured fuel assembly acceleration during the simulated accident according to the type of seismic input.

4. Conclusion

This experiment discusses the seismic safety of spent nuclear fuel stored in a wet storage pool under virtual, large-scale Korean earthquake accidents. Using two full-scale nuclear fuel assemblies and partial storage rack platform, we simulated the actual wet storage environment of spent nuclear fuel, and applied the site-specific earthquake input by the biaxial hydraulic shaking table to reproduce the seismic accident condition of the pool in the domestic power nuclear plant. As a result of the test, the earthquake responses according to the type and magnitude of earthquake accidents, the atmospheric conditions of the fuel storage environment was compared based on the measured test data, and the maximum impact stress that the nuclear fuel can receive in the wet storage environment was estimated. Resultant data and experimental method for physical realization will be used for the numerical code validation and enhance test technology to evaluate the seismic safety of the spent fuel pool and spent fuel assembly in the future.

Acknowledgments: This work was funded by the Industrial Technology Innovation Program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP), granted financial resource from the Ministry of Trade, Industry & Energy(MOTIE), Republic of Korea. (No. 20171510101920).

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