Contribution ID: **5** Type: **Poster**

Experimental Validation of Gamma Emission Tomography to Inspect Partial-Defects within the Pressurized Water Reactor-Type Spent Nuclear Fuel

Wednesday 3 July 2024 14:00 (1 minute)

Experimental Validation of Gamma Emission Tomography to Inspect Partial-Defects within the Pressurized Water Reactor-Type Spent Nuclear Fuel

Hyung-Joo Choi a, Yoon Soo Chung a, Hojik Kim b, Sung-Woo Kwak b, Hee-Kyun Baek c, Jung-ki Shin c, Yong Hyun Chung a, and Chul Hee Min a*
a Department of Radiation Convergence Engineering, Yonsei University, Republic of Korea
b Korea Institute of Nuclear Nonproliferation And Control, Republic of Korea
c NeosisKorea Co. Ltd, Republic of Korea
E-mail: chmin@yonsei.ac.kr

ABSTRACT
Spent nuclear fuel (SNF) is a byproduct of nuclear power generation, and it is classified to high-radioactive waste. SNF is generally managed in following order: at-reactor SNF pool, intermediate storage, and deep geological repository. However, in the event of theft and lose of SNF during the transportation procedure between the facilities, the unwanted harmful radiation can release to environment and public. For this reason, the accurate and effective inspection techniques of SNF have been needed to meet the non-proliferation of nuclear materials. Gamma Emission Tomography (GET) is one of the most reliable method to inspect the partial-defects of SNF at pin-by-pin level. In our previous study, we optimally designed the GET device named Yonsei single-photon emission computed tomography version 2 (YSECT.v.2) using Monte Carlo methods. The objective of current study is to fabricate the YSECT.v.2 prototype device, and to experimentally evaluate the its performance.
The detection module of the YSECT.v.2 prototype device consisted of the tungsten collimator, 46-channel GAGG scintillators, and silicon multiplier. On the basis of results of previous study, the total number of four detection modules were manufactured. The number of 184-channel signals acquired with four detection modules were processed using data acquisition module composed with the TOF Front-end module and Front-end-board type D from PETsys Electronics Co. Ltd. Additionally, the waterproof housing was fabricated, and the Peltier device-based temperature reduction module was also employed to keep temperature in the sealed detection system. The performance of the fabricated YSECT.v.2 was evaluated using the mock-up of fresh nuclear fuel and Cs-137 check sources. The dominant energy of each source is 185 and 661.7 keV, respectively, and the activities were calculated to be 0.01 and 5 μCi. The projection and tomographic images were obtained with the YSECT.v.2 device in air. Subsequently, to quantitatively validate the performance, the signal-to-noise ratio (SNR), full-width at half-maximum (FWHM), and pattern identification accuracy were analyzed.
Base on the results of experimental validation with mock-up of fresh nuclear fuel, the SNR of projection image for each detection module was calculated to be 2.50, 3.82, 3.31, and 2.89, respectively, and the FWHM of the entire detection module was analyzed to be 10.8 mm. These results demonstrated that the fabricated device was capable to discriminating each nuclear fuel rod arranged with the interval of 14.12 mm. Through applying filtered back-projection with Ram-Lak filter, the tomographic images for three patterns were obtained. The source locations were clearly distinguished when the sources were spaced apart, however, the source distribution was not clearly distinguishable when the sources were located densely. To enhance the pattern identification accuracy, the thresholding approach developed in our previous study was employed. This approach could improve the image quality through Hadamard product and excluding pixel value below the certain threshold level. When the thresholding approach was applied, the pattern identification accuracies for entire pattern were significantly improved. On the basis of results of experiment with the Cs-137 check sources, the SNF of tomographic image for two patterns were calculated to be 8.87 and 8.16, respectively. In accordance with the rose model, in that the SNR was greater than 5, we expected that the source distribution on the tomographic image obtained with the YSECT.v.2 device can be distinguished to the human eye.
In this study, we fabricated the YSECT.v.2 prototype device, and its performance was experimentally validated with the mock-up of fresh nuclear fuel and Cs-137 check sources. Based on the results of experimental performance evaluation of YSECT.v.2 prototype device, we believe that the proposed device can be effectively

employed to improve inspection accuracy of partial-defects within the SNF. In the future, the performance of the YSECT.v.2 device will be evaluated using the mock-up of SNF under the condition in water.

ACKNOWLEDGEMENTS

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety (KoFONS) using financial resources granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea (No. 2106073); the Korea Institute of Energy Technology Evaluation and Planning (KETEP), and the Ministry of Trade Industry & Energy (MOTIE) of the Republic of Korea (No. 20214000000070).

Primary author: CHOI, Hyung-Joo (Department of Radiation Convergence Engineering, Yonsei University, Republic of Korea)

Co-authors: Mr MIN, Chul Hee (Department of Radiation Convergence Engineering, Yonsei University, Republic of Korea); Mr BAEK, Hee-Kyun (NeosisKorea Co. Ltd, Republic of Korea); Mr KIM, Hojik (Korea Institute of Nuclear Nonproliferation And Control, Republic of Korea); Mr SHIN, Jung-Ki (NeosisKorea Co. Ltd, Republic of Korea); Mr KWAK, Sung-Woo (Korea Institute of Nuclear Nonproliferation And Control, Republic of Korea); Mr CHUNG, Yong Hyun (Department of Radiation Convergence Engineering, Yonsei University, Republic of Korea); Mr CHUNG, Yoon Soo (Department of Radiation Convergence Engineering, Yonsei University, Republic of Korea)

Presenter: CHOI, Hyung-Joo (Department of Radiation Convergence Engineering, Yonsei University, Republic of Korea)

Session Classification: Poster Session