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Tomographic Image Reconstruction Techniques for Accurate Spent Fuel Assembly Verification

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To realize the non-proliferation and security of nuclear material, the international atomic energy agency (IAEA) considers a tomographic image acquisition technique of spent fuel assemblies as a promising technique to accurately verify rod-by-rod spent fuel conditions stored in a water pool. Our previous research developed and experimentally validated a highly sensitive single-photon emission tomographic (SPECT) system to quickly evaluate the radioactivity distribution of test fuel rods in the Korea Institute of Nuclear Nonproliferation and Control (KINAC) (Figure 1). In order to quickly verify the fuel assembly, it is important to develop a high-quality image reconstruction algorithm that enables image acquisition within a short time. The purpose of this study is to evaluate advanced tomographic image reconstruction techniques to accurately identify patterns of missing fuel rods.

Rotational projection image data sets were obtained for 15 patterns of test fuel rods for a total of 900 seconds using the SPECT system installed at KINAC. The projection images were acquired every 5 degrees while four 64-channel detectors rotated 90 degrees. The acquired images were reconstructed in the following methods: filtered back-projection (FBP), simultaneous iterative reconstruction technique (SIRT), order-subset simultaneous algebraic reconstruction technique (OS-SART), and maximum likelihood expectation maximization (MLEM). Among the reconstruction algorithms used in this study, the image quality of the MLEM showed the best performance. This algorithm preserved the image intensity and edge, and global homogeneity was significantly better with the reduced generative noise than that of other algorithms. Therefore, to accurately verify the patterns of fuel rods, we improved the signal-to-noise ratio of the tomographic image with the advanced image reconstruction technique (Figure 2). We expect that even for the low-quality measured data with the short-time scan of the SPECT system, this advanced technique will show better discriminability of the patterns of fuel rods in the assembly.

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