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Design Optimization of X-ray Security Scanner Based on Dual-energy Transmission Imaging with Variable Tube Voltages

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At domestic ports and airports, an X-ray security scanner based on dual-energy transmission imaging has been operated to prevent the importation of contraband articles including weapons, narcotics, and explosives. Korea Customs Service (KCS) also conducts X-ray screening for all baggage and express shipments. Security scanners operated by KCS use a fixed tube voltage (i.e., 160 kVp); hence, it has limitation to detect the thinly-coated organic contraband articles. In this study, Monte Carlo simulation codes (MCNP6 and GATE) were used to optimize the performance of a dual-energy X-ray security scanner with variable tube voltages. Monte Carlo simulation could be the best option for optimizing and estimating performance under various conditions. The X-ray generator, dual-array detector, and integrated system were optimized in terms of various parameters (Figure 1).

To estimate the performance of the optimized system, dual-energy material classification variables (i.e., R-value) for various materials were derived and pseudo-coloring images classifying between organic and inorganic materials were obtained [1]. Through the security screening with variable tube voltages, it was possible to detect organic contraband articles that are relatively hard to be confirmed by the conventional X-ray security screening. The optimized tube voltage for obtaining the best security image of organic, inorganic, and metal material was determined to be 100, 120, and 160 kVp, respectively.

For quantitative performance estimation, an ASTM F792 test kit, which is applied to the performance evaluation of the X-ray security scanner was modeled [2]. Two evaluation parameters of simple penetration and wire display performance were estimated using the test kit. The results showed that the simple penetration of 30 mm at 160 kVp and wire display above 42 AWG (Φ 0.064 mm) at 80 kVp was achievable with the optimized design (Figure 2).

The wire display performance of commercial security scanners was up to 38 AWG (Φ 0.102 mm), and simple penetration performance was over 30 mm (Table 1). Because simple penetration depends on the tube voltage, it was estimated to have similar performance with that of commercial products. In the case of wire display, the performance was estimated to be improved by more than 30% compared to commercial products thanks to the optimized design and tube voltage.

The results of this study can be used for the development of a dual-energy X-ray security scanner with variable tube voltages customized for different types of material to be inspected. It is expected that the newly designed system will contribute to the improvement of the detection rate for organic contraband articles.

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