Installation of an Multi-radiation Generator System For Cargo Inspection

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1. Introduction

Airports and harbors are an important place for global economy chain with large quantities of cargo circulation from one to another. A role of cargo inspection system in the airports and harbors is growing because of the large quantities of cargos and their rapid flow. The cargo inspection system should separate an explosive, drug and unexpected materials from normal materials.

In this study, we have constructed a system capable of material discrimination in a cargo inspection system with dual energy X-ray and single energy neutron. We can discern an organic material and inorganic material with dual energy X-ray and determine separately an independent mass-per-unit area with neutron. We can discriminate more different materials than single energy X-ray system with this method. [1]

The dual energy 6/3 MeV linear accelerator was developed and installed for generating a dual energy X-ray and 14.1 MeV D-T device (GENIE 35 made by Sodern) was installed for generating neutron in KAERI/ARTI.

2. Design Feature

The dual energy 6/3 MeV linear accelerator and neutron generator are described in this section. The linear accelerator is based on an S-band cavity, consists of a target for X-ray generation and an RF system for stable acceleration energy supply. [2]

2.1 6/3 MeV Electron LINAC

Table I: Specification of Electron LINAC

Items	***parameters***
Beam Energy	6/3 MeV
E-gun Type	Triode
E-gun High Voltage	25 kV
Resonance Frequency	2.855 MHz
Repetition Rate	160 Hz/80 Hz
RF Generator	Magnetron
Pulse Width	5/7 μs
Q factor (unloaded)	14024
Accelerating Gradient	13.5 MV/m
Total Length	570 mm

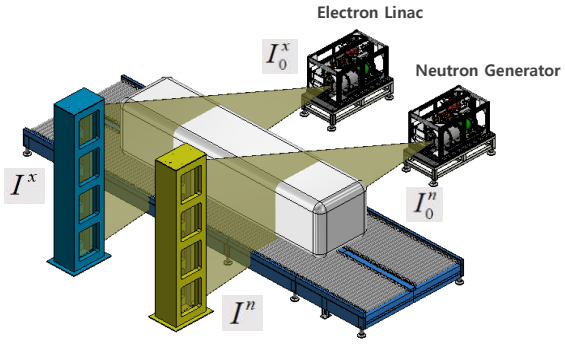

Fig. 1. Multi-radiation Generator System for Cargo Inspection

The specifications of the 6/3 MeV electron accelerator are shown in Table 1. As shown in Fig. 1, the electron LINAC is located with neutron generator. It consists with triode E-gun, a side-coupled accelerating tube with a resonant frequency of 2.856 MHz, and an S-band magnetron as an RF generator. The RF system parameters are shown in Table 2. The magnetron operates with a pulse width up to 5 us and a repetition rate of up to 500 Hz, the device delivers RF output to the accelerator through an average output of 2.7 MW Magnetron. [3]

Table 2: Parameters of RF system

Items	***parameters***
RF generator	Magnetron
Radio-frequency	2.856 MHz
RF Average Power	3.2 kW (@ 0.0012 duty)
RF Peak Power	2.7 MW
Max. Pulse width	5 us
RF pulse Rep. Rate	1 – 500 Hz
Modulator Average power	3.5 kW
Modulator Peak power	5 MW
Pulse Flatness(zero to peak)	±1 %

2.2 14.1 MeV Neutron Generator

The energy of neutron for cargo inspection is at least 14.1 MeV and generated neutron flux exceeds 109 n/s/4π sr. Single energy neutron is produced by DT (Deuterium-Tritium) method. It is installed with electron linear accelerator with a neutron detector. The distance between the neutron generator and the detector is 3.5 m.

Table 3: Specification of neutron generator

Items	***Parameters***
Energy	14 MeV
Voltage	160 kV
Current	2 mA
Life time	2,000 hours
Neutron dose-rate	$<10^{10}$ n/s/4π sr (±10%)
Repetition Rate	0~100 pps

The neutron generator needs a radiation shielding and collimator for safety. The collimator is made with polyethylene and can be assembled as shown in Fig. 2.

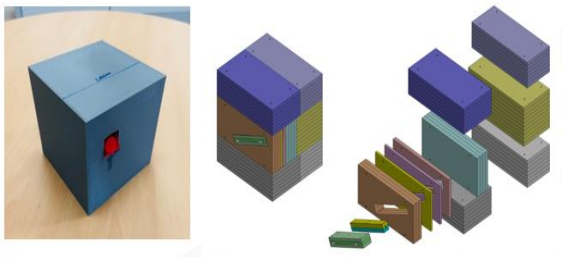

Fig. 2. The collimator for the neutron generator

2.3 Construction of cargo transporting system

Using the electron accelerator and neutron generator, we can generate the X-ray and neutron which is multiple radiation system introduced in the previous sections. We constructed a system for generating multiple radiation in the shielding room with radiation shielding which is constructed by the Advanced Radiation Technology Institute of KAERI. Figure 3 shows an established linear accelerator and neutron generator for cargo inspection.

Fig. 3. A demonstration facility for cargo inspection

Cargo transporting system is installed in front of the radiation generators for inspection. The real size of cargo is considered for transportation. The size of cargo is 2438×3175×2438 mm^3 and the weight is 7000 kg and the speed of cargo transporting vehicle is 300 mm/s. The vehicle is shown if Fig.4.

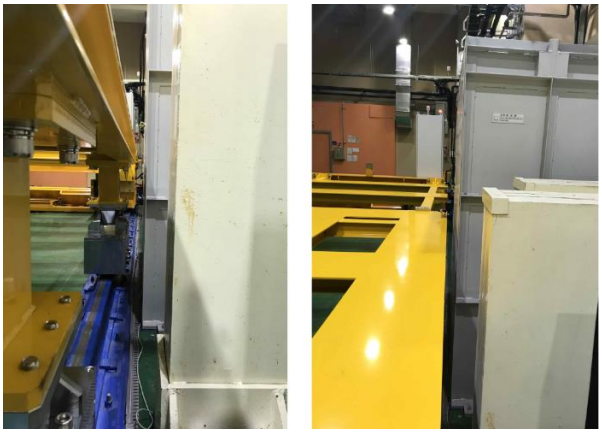

Fig. 4. The cargo transportation system in front of the radiation generators

3. Result and Conclusions

The linear accelerator and the DT neutron generator is installed in the Advanced Radiation Technology Institute of KAERI. Through the radiation generators, X-rays and neutron is generated for the cargo inspection system and the cargo transporting system is also developed. The needed equipment and systems are installed for the cargo inspection demonstration. The linear accelerator developed in this study can generate X-rays of up to 4 Gy/min at a distance of 1 m from the target and the neutron generator also generates 10^{10} n/s of neutrons at the target spot point.

At present, the development and installation of the radiation generator has been completed and measurement tests for each radiation are expected. We will prepare a detectors and visualization system in the 2019. The results are expected to be used in the multi radiation cargo inspection sytem.

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