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Development of a High Energy X-ray Non-destructive Inspection System based on a Linear Electron Accelerator

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1. Introduction

A high energy X-ray generator based on a linear electron accelerator is required to penetrate a thick steel plates of 10 cm or more. Most of a high energy X-ray non-destructive inspection systems used in Korea are imported products. And X-ray inspection system with energies greater than 10 MeV is under strict control of international trade, so it is having difficulties in expansion and maintenance of the existing system. Therefore, in order to use X-ray generator having an energy of 10 MeV or more, we have to develop our own system

The high energy X-ray inspection system consists of an X-ray generator based on linear electron accelerator, beam collimators, sample transportation and detector. We have developed a 15 MeV X-ray generator based on S-band linear electron accelerator. Using this accelerator, we constructed X-ray non-destructive inspection system to obtain 2-D and 3-D images. In this presentation, we will introduce the development results and performance tests.

2. Methods and Results

2.1 X-ray Inspection System

Due to the high energy and high intensity of X-ray beam the system installed in 2 meters thick concrete bunker. The X-ray inspection system consists of two modes: a 2-D mode for large objects and 3-D mode for small ones. In the 2-D mode, the X-ray transmission image is acquired while the object linearly moves with fan-shape X-ray beam. To obtain a 3-D tomography image, the object is rotated. Figure 1 and 2 show the concept of 2-D and 3-D image acquisition modes, respectively.

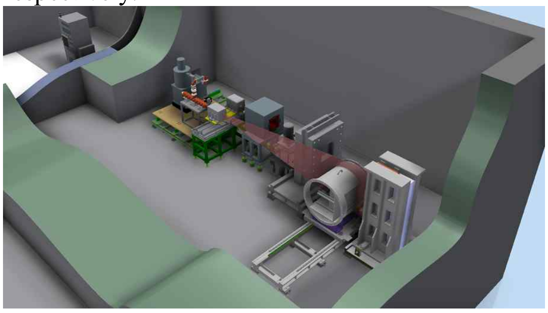

Fig. 1. 2-D X-ray image acquisition mode

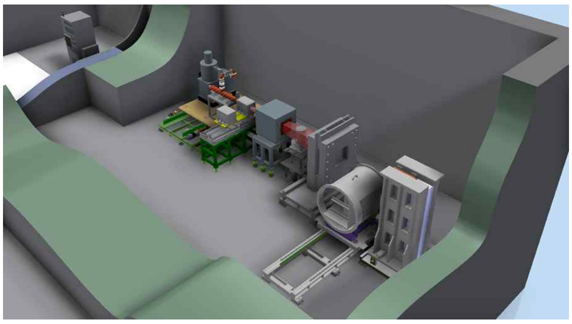

Fig. 2. 3-D X-ray image acquisition mode

Fig. 3. Developed high energy X-ray inspection system

2.2 X-ray Production System

High energy electrons are needed to generate high energy X-rays above the MeV level. In order to develop electron linear accelerator, electron beam simulation was carried out using PARMELA code and CST Particle Studio together. After detailed and repetitive simulations, the accelerator was designed and the set of accelerating cavity was machined using oxygen free high conductivity copper [1].

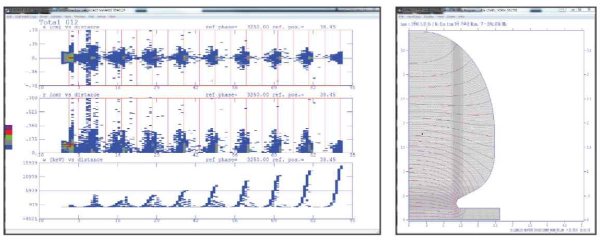

Fig. 4. Simulation of the accelerating cavity

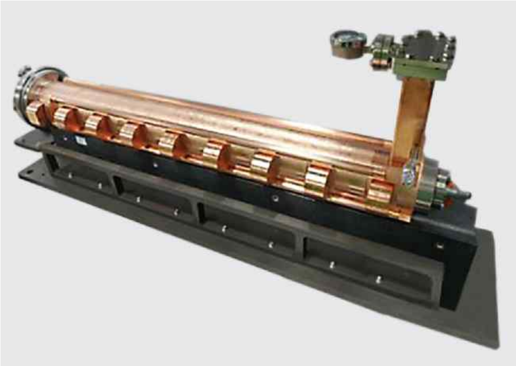

Fig. 5. Fabricated electron accelerator

The energy of the accelerated electron beam was measured using the ASTM 51649 standard [2], and it was found that the energy of the accelerated electron beam was 15.24 MeV.

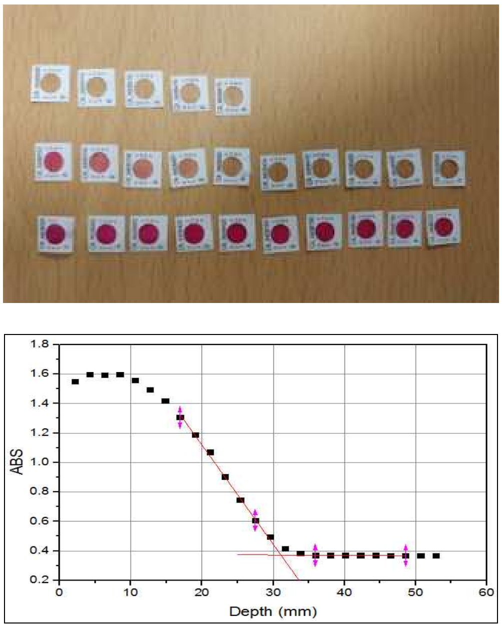

Fig. 6. E-beam energy measurement by ASTM 51649 standard

2.3 Radiographic Quality

The Radiographic quality can be determined by ASTM E1025 standard [3]. Two hole-type indicators were installed in front of a 46 cm thick steel plate and a transmission image was obtained. As a result, it was possible to distinguish 2-1T, 1-2T and 1-1T when the irradiation dose was 650 Gy.

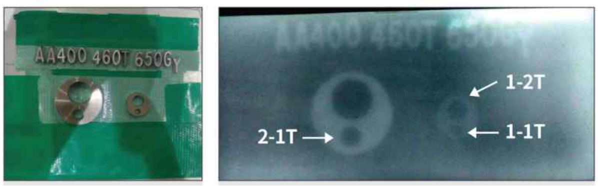

Fig. 7. Hole-type indicators and radiograpic image

Figure 7 also shows that the developed X-ray generator has high X-ray beam energy, high X-ray dose rate and even small spot size. Figure 8 shows the 2-D and 3-D images taken by the development system.

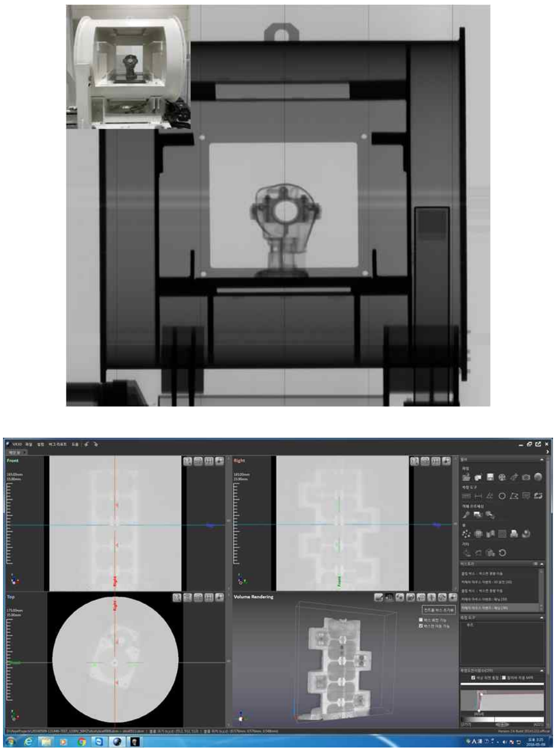

Fig. 8. Radiographic images taken by developed system

3. Conclusions

We have developed a non-destructive inspection system that can acquire 2-D and 3-D images using a high energy X-ray generator based on a 15 MeV electron accelerator. The maximum sample size for 2-D images is up to 1 meter, and the 3-D image sample size is up to 0.3 meter. It is expected that non-destructive testing of various samples including heavy industry and nuclear power field will be possible using the developed system.

REFERENCES

[1] Jae Hyun Kim, Byeong-No Lee, Moonsik Chae, Kyung Min Oh, Jin Sik Ju, Soo Min Lee, Myungkook Moon, Han Soo Kim, Hyung Ki Cha, Jang Ho Ha, Construction of 15 MeV NDT system Based on S-band LINAC, Transactions of the Korean Nuclear Society Spring Meeting, 2017

[2] ISO/ASTM 51649:2015, Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies between 300 keV and 25 MeV.

[3] ASTM E1025-05, Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology