APPLICATION OF X-BAND 3.95 MeV LINAC X-RAY SOURCE FOR ON-SITE BRIDGE INSPECTION

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Abstract

A portable X-band (9.3-12GHz) 3.95MeV linear accelerator (linac) has been developed for an X-ray non-destructive (NDT) for on-site bridge inspection. Our compact and high energy linac enables on-site NDT of large structure. In this study, radiographic image of 40cm thick concrete sample were successfully taken with this linac. However, issue with high energy linac is the scattered X-rays which will decrease the contrast of the radiographic image. Eliminate scattered X-ray experiments did with 2 kinds of collimator.

INTRODUCTION

As the increase of ageing bridges, the collapse accidents of old bridges become serious issues. Additionally, load bearing ability of a Prestressed Concrete (PC) bridge relates to the condition of inner wire. On the other hand, X-ray NDT system has been developed for inspecting artificial structures in many fields. There are several X-ray NDT systems, such as X-ray tube assembly, synchrotron accelerator and linac. However, issue of conventional systems are those systems needs long time to get an X-ray radiographic image (e.g. 60min for 40cm thick concrete using 300keV X-ray tube assembly) and another problem are the size of those X-ray NDT system. They are too heavy for on-site inspection (mostly over tons). Therefore, we developed a portable high intensity X-band 3.95MeV linac system to inspect the PC bridge inner wire condition.

High energy and high intensity X-ray source are being developed in order to realize fast on-site inspection of bridges. We are also focusing to improve the X-ray detection system to realize that NDT system enables to achieve radiographic image of 40cm thick concrete in few seconds, with in 2mm spatial resolution.

X-BAND 3.95MeV LINAC SYSTEM

This system consists of 62kg X-ray head without the target collimator 80kg, the RF power source 62kg and other utility box 116kg. The X-ray intensity of this system is 2Gy/min at 1m. The detail of this 3.95MeV linac system is shown in Table 1.

For X-ray detection, we chose an 8-inch square size scintillation type flat panel detector. The spatial resolution of the detector is as high as 0.2mm, which is manufactured by Perkin Elmer Co. Cd_2O_2S:Tb is used for the scintillator crystal. The capable radiation energy range is 40keV to 15MeV.

Table 1: Parameter of 3.95MeV linac

Resonant frequency	X-band 9.3GHz
RF source	Pulse width : 4 μ s Repeat:200pps
Pulse output	3000kW
Electron gun current	300mA
Electron gun voltage	20kV
Electron beam current	100mA
X-ray intensity	2Gy/min @ 1m

X-ray energy spectrum of this system is shown in Figure 1. This spectrum is calculated with Electron Gamma Shower Version 5 (EGS5), a radiation Monte Carlo simulation code. 10^7 electrons used in this calculation and the incident beam set in pencil beam, the same size as incident beam size of this system (ϕ 3mm). The beam target is 0.5mm thick layer of tungsten and 1.6mm thick layer of cupper. The both of them are 5mm in diameter. The peak of X-ray energy is between 0.2~0.4MeV.

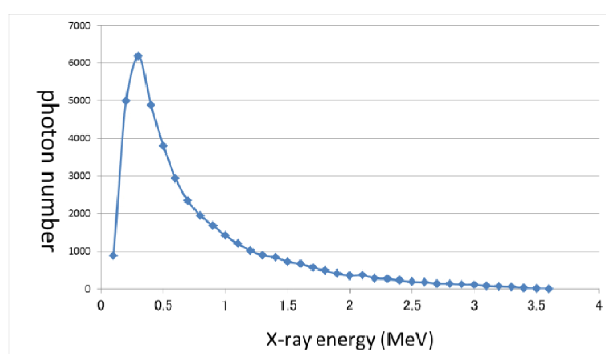

Figure 1: X-ray energy spectrum

EXPERIMENT ON 40cm THICK CONCRETE

Currently, our X-band 3.95MeV linac system still has a room for development. At this moment, the RF source repeat set to 20pps (designed value: 200pps) and the electron beam current set to 68mA (design value: 100mA). Therefore, the X-ray intensity is less than 10% of designed value.

For improving the radiographic image quality, offset correction and gain correction are done. The offset correction of images is to eliminate the influence of pixel dark currents in the acquired image. The Gain correction of images is to eliminate the influence of pixel sensitivities and influences of the used X-ray source in the acquired image. Images binning is also done for improving the radiographic image quality. (binning size: 2 ×2)

The 40cm thick concrete sample is shown in Figure 2. There is 3 ϕ7mm wire blocks and a ϕ10mm wire is set on detector side for comparison. Each wire block consist several wire.

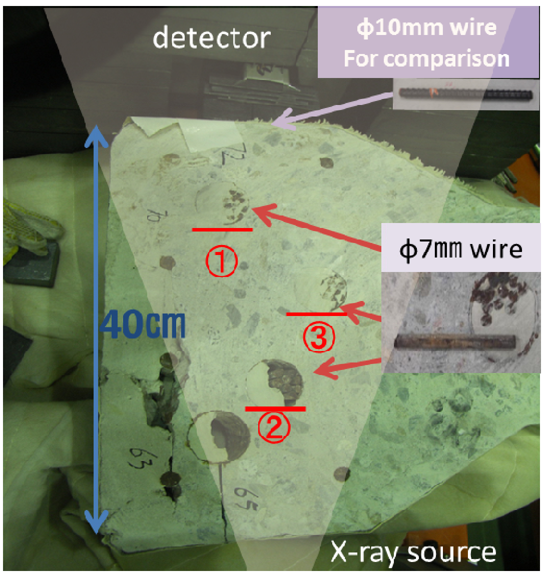

Figure 2: 40cm thick concrete sample

The radiographic image of 40cm concrete sample is shown in Figure 3. 3 ϕ7mm wire block and comparison wire are identified from this image. Since the X-ray source of this system is cone-beam and wire 2 is closer to X-ray source than wire 1, so even the size of wire 2 is the same as wire 1, wire 2 in Figure 3 appears larger than wire 1. Wire 3 is far from the X-ray beam center, so wire 3 is difficult to identify from Figure 3. Each wire block consist several wires, but only 3 wires are identified in each wire block. That means if we want to identify every wire, we need to take radiographic image from several directions. It took 20 seconds to take this image. However, we assume that after the ageing of our linac and when it becomes able to operate in maximum current, we expect only 2 seconds to take a radiographic image.

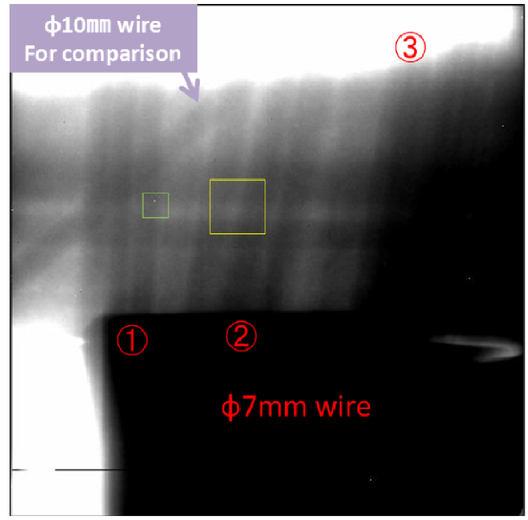

Figure 3: Radiographic image

EXPERIMENT WITH COLLIMATOR

For eliminating the scattered X-ray to improve the quality of 40cm thick concrete sample radiographic image, we held experiments with two different collimators.

The collimator 1 and collimator 2 are shown in Figure 4. Collimator 1 is made from lead block, and collimator 2 is made from 0.1cm thick lead board. For collimator 1, we compared the contrast of the 2.5cm square area. (yellow square area in Figure 3) And we compared the contrast of the 1cm square area for collimator 2. (green square area in Figure 3)

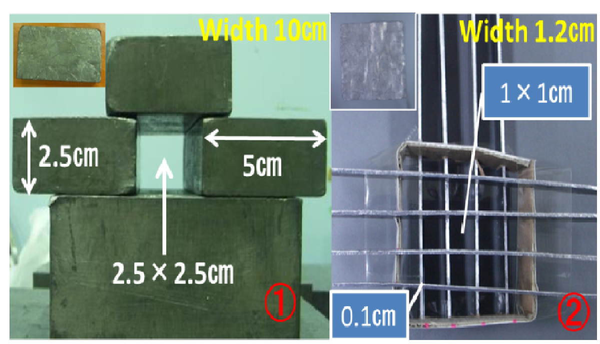

Figure 4: Collimator 1 and 2

The collimator 1 compared area (yellow square area in Figure 3) is the same as the one shown in Figure 5. We separated the area into 3 parts and made contrast graph for these 3 parts. The result is shown in Figure 5. The green line in Figure 5 shows the result of using collimator 1, and the blue line in Figure 5 shows the result of without collimator. From the maximum value of contrast, more than half incident X-ray was cut by collimator 1. And for the contrast ratio, the result of using collimator 1 is bigger than the result of without collimator.

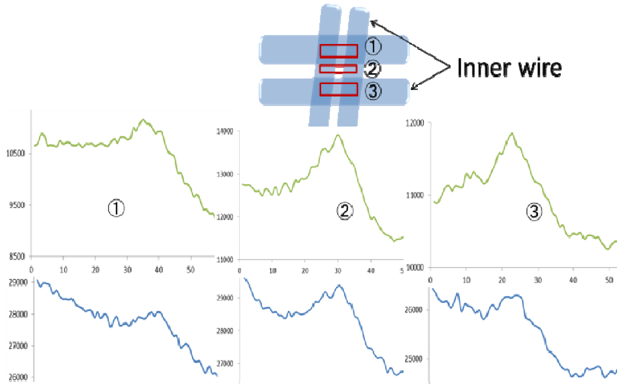

Figure 5: Contrast graph for collimator 1.

The collimator 2 compared area (green square area in Figure 3) is the same as Figure 6 shown. We made contrast graph for this area. (shown in Figure 6) The green line in Figure 6 shows the result of using collimator 2, and the blue line in Figure 6 shows the result of without collimator. From the maximum value of contrast, about third part of incident X-ray was cut by collimator 2. And we calculated the average contrast in area A and area B. For using collimator 2, the ratio of average contrast in area A to average contrast in area B is 1.057. For without collimator, the same ratio is 1.018. That means the contrast ratio using collimator is better than without collimator.

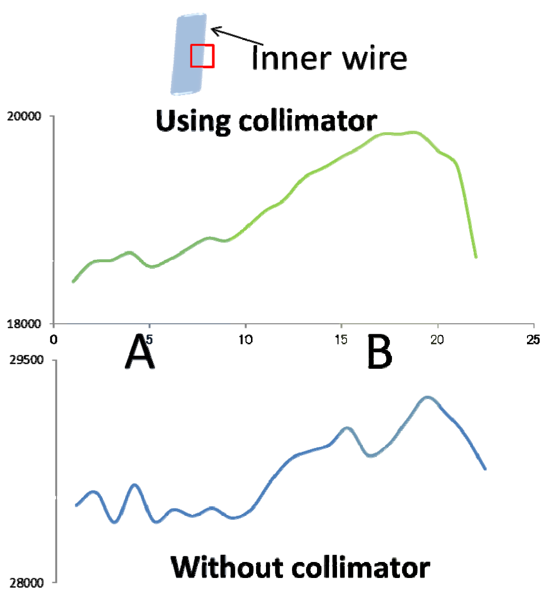

Figure 6: Contrast graph for collimator 2.

CONCLUSION

A portable X-band 3.95MeV X-ray non-destructive (NDT) system for on-site bridge inspection was developed. In spite of the system is still in ageing term, we successfully took a radiographic image for 40cm thick concrete sample in 20 seconds. The intensity of X-ray is expected to be 10 times higher after ageing scheme. On the other hand, we started designing collimators to improve the contrast of radiographic image. At the initial experiment with simple designed collimator, we found scattered X-rays were effectively reduced.

For the future work, we are going to simulate the scattered X-ray with EGS5, and design/manufacture a optimum collimator structure to minimize the scattered X-ray and improve the quality of radiographic image.

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