APPLICATION OF PORTABLE 950 KEV X-BAND LINAC X-RAY SOURCE TO CONDITION BASED MAINTENANCE FOR PUMP-IMPELLER

Tomohiko Yamamoto, Takuya Natsui, Kiwoo Lee, Shunsuke Hirai, Eiko Hashimoto,
Mitsuru Uesaka, Nuclear Professional School, the University of Tokyo, Ibaraki, Japan
Naoki Nakamura, Masashi Yamamoto, Joichi Kusano, Eiji Tanabe, Accuthera Inc., Kawasaki, Japan

Abstract

We are developing X-ray nondestructive testing (NDT) system using with portable X-band linac. This system uses 9.4 GHz X-band linac and 250 kW magnetron. Our system energy is 950 keV for Japanese regulation. Therefore we can use it on-site using local radiation protection. We measured electron beam and X-ray. We have started X-ray imaging test. We will use this system for condition based maintenance of pump-impeller at nuclear plants. The linac based X-ray source can generate pulsed X-ray. Therefore we can get still images without stopping rotation when x-ray repetition rate synchronizes impeller's rotation rate. We are successful in proof of principle using a simple fan and a synchronized circuit. We prepare real-time imaging for conventional pump. In this paper, we will explain the detail of this system and experimental results.

INTRODUCTION

We are developing the portable X-ray nondestructive testing (NDT) system using with 9.4 GHz X-band Linac and 250 kW magnetron for RF source[1]. This X-ray source completed system construction. We experiment electron accelerating test and X-ray generation test. We think that this system can use corrosion of tube, impeller real-time check. Impeller real-time check is very useful of condition based maintenance (CBM). The reason why this Linac X-ray source is useful to impeller real-time check is that Linac can generate pulse electron beam so, X-ray is pulse beam. Therefore we can get some still images of rotating impeller when X-ray pulse reputation rate is synchronized with impeller rotating rate. We can check the impeller without stopping, so we can cut back on checking time and cost. We succeeded to get still image of rotating PC fan using this system[2].

CONDITION BASED MAINTENANCE

Condition Based Maintenance (CBM) is one of the methods of maintenance for nuclear plants. Nuclear plants in Japan are normally maintenanced by Time Based Maintenance (TBM). Figure 1 shows the diagram of nuclear plants' maintenance in Japan. However, TBM causes hypercautious maintenance. Therefore methods of nuclear plants' maintenance comes up for debate in nuclear field.

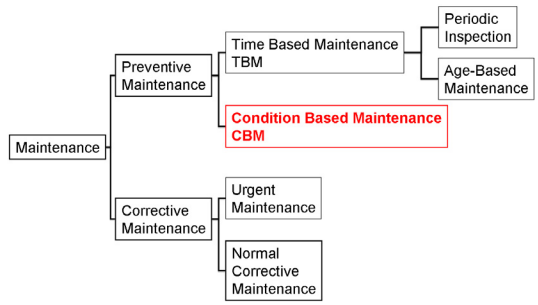

Figure 1: Maintenance Diagram for Nuclear Plants

CONCEPT OF REAL-TIME IMAGING

A feature of Linac based X-ray source is a pulsed X-ray generator. Therefore we can get still images without stopping rotating if the pulsed X-ray reptation rate synchronizes an impellers rotaiting rate. Figure 2 shows the concept of real-time imaging with Linac X-ray source.

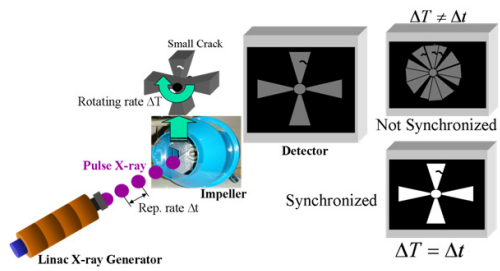

Figure 2: Concept of real-Time Imaging of Impeller

However Linac pulse rate is not always have to be equal to rotating rate of impeller. The reason is that X-ray pulse is synchronized with rotating rate of impeller if X-ray pulse rate is the submultipule of rotating rate as you see (1) and (2).

$$R\ [\mathrm{rpm}] = \frac{R}{60}\ [\mathrm{Hz}] \equiv T\ [\mathrm{Hz}] \tag{1}$$

$$T\ [\mathrm{Hz}] = n \cdot t\ [\mathrm{Hz}] \tag{2}$$

EXPERIMENT & RESULT

We experiment imaging using synchronized circuit and He-Ne laser. In this chapter, we explain this experiment and results.

Experimental Setup

Figure 3 shows the drawing of experimental setup. We use He-Ne Laser as the signal of a synchronized circuit. The laser light reflects on the air blower and is incident to the photo transistor of synchronized circuit.

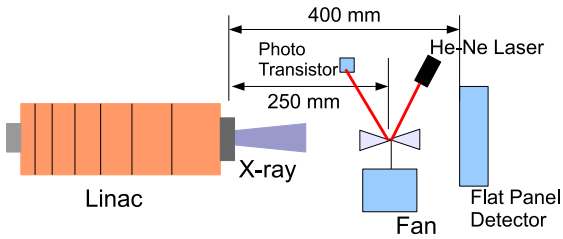

Figure 3: Drawing of Experimental Setup

Figure 4 shows the photogragh of experimental setup.

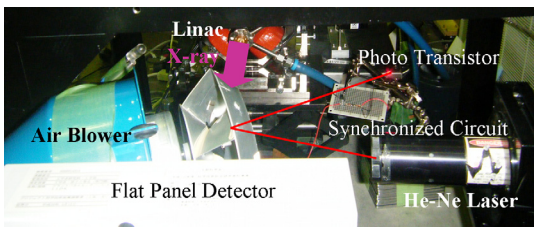

Figure 4: Experimental Setup

We use an air blower as a test sample for this experiment (See Fig.5). We put in the mark and mirror. The role of mirror is the reflector of laser light. The role of mark is a spot because the material of blades is aluminum, so we cannot check the static image when the air blower rotate. Therefore we put in the mark made of lead.

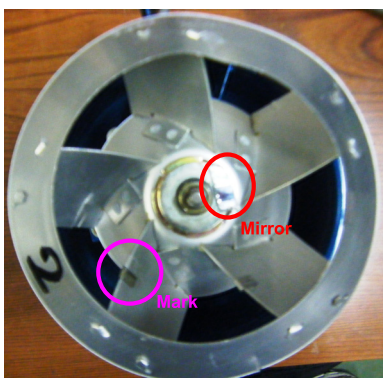

Figure 5: Test Sample

The rotating rate of air blower is about 2670 [rpm], therefore it is about 45 [Hz]. We set 15 [Hz] as Linac pulse rate when we want to get the synchronized image.

Results

Figure 6 is an image of "not synchronized" air blower. As you see Fig. 6, you can recoginize "not synchronized."

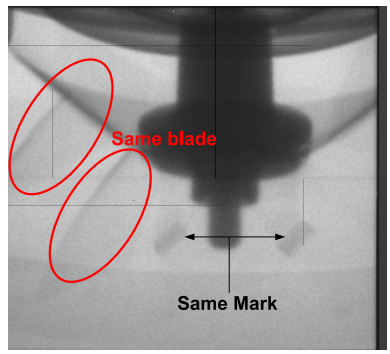

Figure 6: Not Synchronized Image

Figure 7 is an image of "synchronized" air blower. We can get a still image of rotating air blower without stopping rotation.

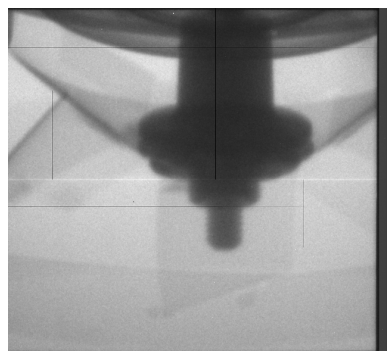

Figure 7: Synchronized Image

FUTURE WORKS

We plan to experiment other real-time imaging using bearing and design new accelarated tube for high efficiency. The one of our plan is the imaging using actual bearing of nuclear plants. This bearing is used by a shaft of pump at nuclear plants.

The other of our plan is the designing of new cavities. The first cavity adopted on-axis coupling because it is a simple structure. However electron beam and X-ray is the lack of current and dose rate. We estimate the reason is beam modulation. Therefore we start to design new cavity for more current and dose rate.

Bearing Experiment

We think next step of real-time imaging. We succeeded the proof-of-principle experiment using PC fan and air blower. We can prove the metod of real-time imaging with pulse X-ray generator using X-band Linac by conventional experiment However we did not use actual impeller or bearing. Therefore we plan to experiment the actual bearing (see fig.8). We will start to experiment the real-time imaging at June.

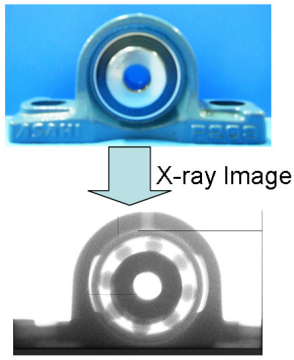

Figure 8: Test Sample & X-ray Image of Bearing

New Cavity Design

Table 1 and table 2 show beam parameter and X-ray parameter of the accelerated tube. The current accelerated tube is lack of beam current as you see tables.

Table 1: Electron Beam Parameter

	Design	Measurement
Current	200 mA	60 mA
Energy	950 keV	$\simeq$ 950 keV
Spot Size	2 mm	1.10 - 1.95 mm

The X-ray spot size is bigger than design in addition as you see table 2.

Table 2: X-ray Parameter

	Design	Measurement
Spot Size	1 mm	2.5 mm
Dose Rate @ 1 m	200 mGy/min	7.5 mGy/min
Discrimination		3 %

We estimate the reason why beam current is lack is the electron beam modulation. The occasion of beam modulation is mainly π-mode structure as low β part. Therefore the beam is unstable and beam current very low. We think the X-ray dose rate is low because a beam current is low.

We consequently start to design new accelerated tube. We adopt side-coupled cavities as new accelerated tube. All cavities are side-coupled cavities.

Table 3 shows the comparison of two accelerated tube we designed. The new type tube is very short length, so electric field is higher than a current tube and the number of cavity is less than old tube. Therefore the new tube is more compact and cost is lower.

Figure 9 is the example drawing of new accelerated tube. We will manufacture this accelerated tube as soon and start to experiment from this fiscal year.

Table 3: Comparison of Accelerated Tubes

	1st Tube	2nd Tube
Structure	On-axis Coupling	Side Coupling
Shunt Impedance	80 MΩ/m	150 MΩ/m
Size	260 mm	100 mm
Number of Cavity	38	13
Current	80 mA	80 mA

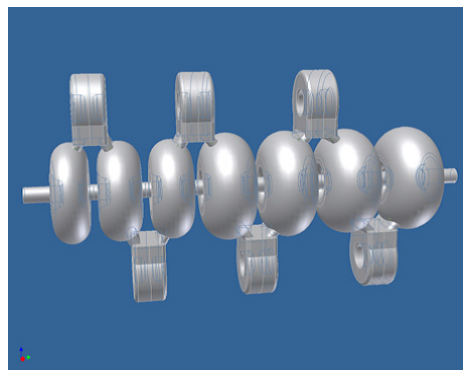

Figure 9: 3D Darwing of Side-coupled Cavities

CONCLUSION

We are developing the portable X-ray NDT system using X-band compact Linac. We succeed real-time imaging of rotating air blower using X-band Linac based X-ray source with the synchronized circuit. We consider the real-time imaging of rotating bearing with the same scheme for condition based maintenance of nuclear plants as next step. Furthermore we start to design a new accelerated tube using side-coupled cavities for higher efficiency.

ACKNOWLEDGEMENT

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REFERENCES

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