DIGITAL RADIOGRAPHY WITH SMALL-SIZE BETATRON

Takehiro Ohnishi (a), Ichita Endo (b), Tohru Takahashi (c), Fumitaka Nishiyama (d)
V.L. Chakhlov (e), G.L. Chakhlov (e), E.L. Malikov (e)
(a) Hi-BEAM Technology Limited
(b) Kure National College of Technology
(c) Graduate School of Advanced Sciences of Matter, Hiroshima University
(d) Graduate School of Engineering, Hiroshima University
(e) Research Institute of Introscopy, Tomsk Polytechnic University

A small-size betatron with energy 1 MeV (0,95 MeV) was developed through the collaboration of Hiroshima University and Research Institute of Introscopy at Tomsk Polytechnic University.

We made some test exposures with the x-ray beam from the 1 MeV betatron to obtain digital radiograph images using Imaging Plate and X-ray Image Intensified Camera. We present some examples of obtained images and demonstrate the effect of their computer processing.

1. Introduction

Betatron, the circular accelerator which accelerates electrons using an induced electric field, was invented by Kerst[1] in 1940. Afterwards, many betatrons were manufactured globally and applied to nuclear physics researches as well as in industrial and medical fields. Nevertheless, due to their ceilings on acceleration energy in addition to unavailability of large beam current, more efforts were started to be concentrated to develop linacs, and thus, fewer and fewer betatrons were put to use.

Since 1956, Research Institute of Introscopy at Tomsk Polytechnic University in Russia has developed, manufactured, and sold small-size betatrons of different energy levels [2][3]. Particularly, in recent years, the number of units sold has been growing as detector sensitivity improved.

Hiroshima University and Tomsk Polytechnic University jointly developed and made a prototype of a small-size betatron with relatively good portability for use, whose electron acceleration energy is less than 1 MeV, because the Japanese radiation-related regulations on such radiological equipment are less stringent.

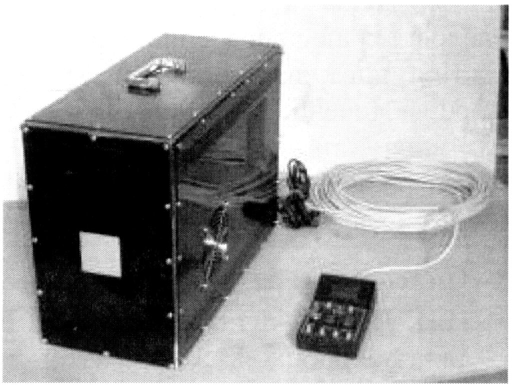

Fig. 1. 1MeV (0,95 MeV) small-size betatron

Fig. 1 shows the 1 MeV small-size betatron that was made in this project. This betatron comprises a controller (at the front on the right in the picture), a main unit (on the left in the picture), and a cable (at the back on the right in the picture) that connects the main unit and the operating device. The main unit whose dimensions are 250×395×570 mm weighs slightly over 50 kg. The main unit, which accommodates an acceleration electromagnet, a pulse power supply circuit, and the like, can be designed to consist of two enclosures so that the acceleration electromagnet and the power supply unit can be accommodated separately from each other.

As a forced air-cooling design is adopted, cooling water is unnecessary. In addition, use of a sealed vacuum chamber eliminates the necessity for a vacuum pump. Any 100-v receptacle can be used as a power supply. Therefore, when using, a user only has to connect between the main unit and the operating device with the cable and then plug the equipment into a receptacle to supply power.

The sealed vacuum chamber accommodates an electron gun and an internal target. Electrons emitted from the electron gun are accelerated and launched into the internal target so that X-rays are generated, and such cycle is repeated 400 times per second. This means the equipment generates 400-Hz pulse X-rays.

At the current X-ray intensity, ambient radiation doses drop down to the order of 20 μSv/h at a distance of 1 meter to 2 meters when the betatron is covered with a 2 mm-thick lead sheet.

As this relatively small and light equipment in a considerably simple configuration with remarkably simple inner structure can generate X-rays with hundreds of keV, it can be used as an X-ray source for radiographing relatively thick substances outdoors.

In the following section, the sample radiograph images that were obtained using a 1 MeV small-size betatron are explained. Small-size betatrons of different energy levels are described in [4].

2. Digital radiograph images with the x-ray beam from the 1 MeV betatron

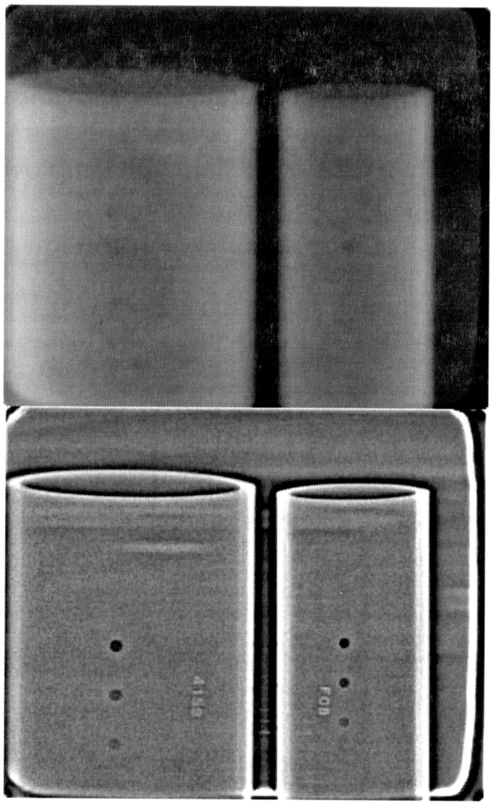

Fig. 2. Sample radiograph images of a 3Bsch80 pipe (right) and a 5Bsch80 pipe (left) before computer image processing (upper) and after computer image processing (lower)

Test radiographs were taken using X-rays from the aforementioned 1 MeV (0,95 MeV) small-size betatron while using an Imaging Plate and an X-ray I.I. Camera Unit to detect X-rays. Fig. 2 shows sample X-ray radiograph images of a 3Bsch80 pipe (right, outside diameter of 89,1 mm and thickness of 7,6 mm) and a 5Bsch80 pipe (left, outside diameter of 139,8 mm and thickness of 9,5 mm). The upper picture is before image processing and the lower picture is after image processing. The distance between the X-ray source and the Imaging Plate was 600 mm and the exposure time was 30 minutes. On the radiograph after image processing, thickness of those pipes as well as the artificial defects set on the pipe surfaces (φ6, those for 3 B were depth of 1,52 mm, 3,04 mm, and 4,56 mm from the surfaces of the pipe while those for 5 B were depth of 1,9 mm, 3,8 mm and 5,7 mm). Those sample images demonstrate that pipe thickness and artificial defects become clearer and sharper when obtained images are subjected to computer image processing. When compared with commonly used portable X-ray sources, the energy of X-rays generated by the small-size betatron is greater. Therefore, in addition to those test samples, the thickness and internal conditions of a relatively thick substance can be checked when the same means of radiographing and the same image processing methods are adopted.

Fig. 3 shows a sample radiograph image of a 8Bsch80 pipe (outside diameter of 216,3 mm and thickness of 12,7 mm) which was taken with an X-ray I.I. Camera Unit of Hamamatsu Photonics K.K. The distance between the X-ray source and the X-ray I.I. Camera

Unit was 320 mm, while the distance from the pipe surface to the X-ray I.I. Camera Unit was 30 mm. The exposure time was 1 minute. Similarly, obtained radiographs were subjected to image processing. Theφ3 artificial defects set on the pipe surface (the depth of 5,1 mm and 7,6 mm from the surface of the pipe) could be identified. With this method, radiographs can be taken in a short time even though the area to be radiographed at one time becomes smaller when compared with the area to be radiographed using an Imaging Plate.

For those test radiograph sessions, no attempt was made to control the conditions for radiographing. Therefore, for example, when consideration is given to a geometric arrangement for radiographing in addition to adoption of the appropriate image processing for test specimens and subjects while eliminating low energy parts of X-rays, image quality is likely to improve and exposure time is expected to become shorter. In addition, when a device such as a flat panel detector or an X-ray linear sensor is adopted depending on subjects as the means of detecting X-rays instead of using an Imaging Plate or an X-ray I.I. Camera Unit, reduction in exposure time and improvement in sharpness can be achieved.

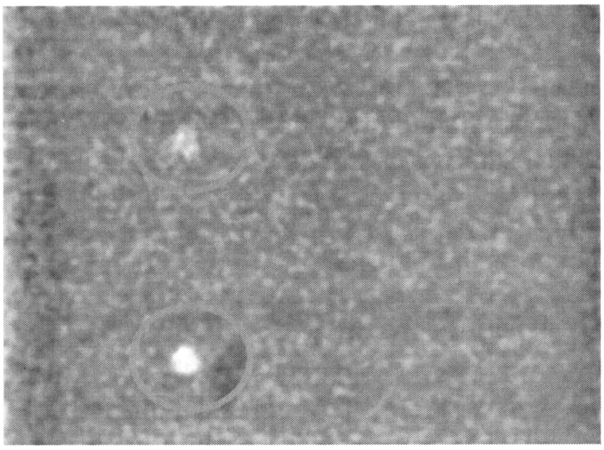

Fig. 3. Sample radiograph image of pipes using an X-ray I.I. Camera Unit The φ3 artificial defects (top: depth 5.7mm, bottom: depth 7.6mm) can be identified

3. Conclusion

1. Using a 1 MeV small-size betatron prototype (the main unit dimensions: 250×395×570 mm, and weight: slightly heavier than 50 kg), radiograph images were taken.
2. Due to a high energy level of the generated X-rays, the X-rays can penetrate well into materials, radiograph images of relatively thick specimens can be obtained. In addition, when those radiograph images were subjected to image processing, sharpness of the images improved.
3. When a more sensitive means of detecting X-rays is selected, exposure time can be reduced.

Acknowledgement

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References

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