Gamma-ray inspection of rotating object

T. Kambara,*1 H. Takeichi,*1 and A. Yoshida*1

Radioisotopes (RIs) have long been used as tracers for wear diagnosis of mechanical parts. We proposed a surface activation method that utilizes RI beam implantation[1)] instead of the conventional ion-beam irradiation.

The degree of wear is determined by the decrease of the radioactivity of the object part or the increase of the radioactivity of the lubricant, through external gamma-ray measurements. Therefore, a lubricant circulation system is required for removal of activated surface debris from the machine. If the spatial distribution of the radioactivity in a running machine can be obtained, wear diagnosis can be performed for a closed system without a circulation system.

In many cases, the mechanical parts being subject to wear diagnosis work in continuous and periodical motions such as rotation. We are developing a new method to determine the spatial distribution of positron-emitting RIs on periodically-moving objects in a closed system, which is based on the same principle as medical PET systems but is simpler and less expensive.

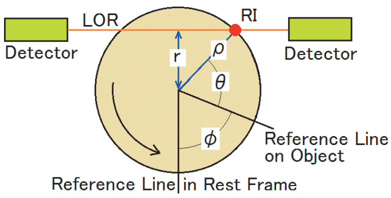

Fig. 1. Geometrical Concept.

Figure 1 shows the geometrical concept. A positron-emitting point source is located at (r, θ) in the polar coordinate fixed to the object. The orientation of the object is denoted by ϕ. A pair of gamma-ray detectors are located at both sides of the object to detect the 511-keV photons from positron annihilations. Since the photons are emitted in the opposite directions, the coincident detection is allowed only when the source is on the straight line between the detectors (line of response: LOR). This condition is followed by an equation $y = r\cos(\theta + \phi)$, where y is the distance between LOR and the rotation center. If the pair of detectors is moved in parallel so that LOR scans the object and the coincidence rate is measured as a function of ϕ and y, the coincidence events from a point source fall on a sinusoidal curve in the ϕ-y plane. If the source is spatially distributed on the object, the coincidence rate on the ϕ-y plane yields a diagram called sinogram, which is a superposition of the sinusoidal curves. Conversely, the spatial distribution of the source can be reconstructed from the sinogram. Therefore, with only two detectors, the RI distribution on a rotating object contained in a vessel can be inspected without stopping the rotation, if y and ϕ at the time of coincidence detection are determined.

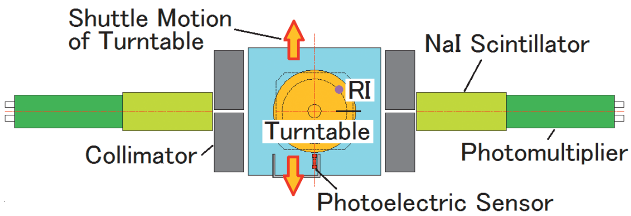

Fig. 2. Prototype setup.

In order to prove the feasibility of the method, we have constructed a prototype (Fig. 2). A pair of NaI scintillator detectors are placed on the opposite sides of a rotating turntable (diameter of 14 cm) that holds RI sources and moves back and forth. Gamma rays from the sources are collimated by a pair of Pb blocks placed in front of each detector. A pin fixed to the turntable generates a pulse signal from a photoelectric sensor at each turn. The orientation of the turntable is determined by a clock-pulse counter that is started by the photoelectric sensor. At each coincidence detection the orientation and the position of the turntable and the pulse heights from the detectors are recorded.

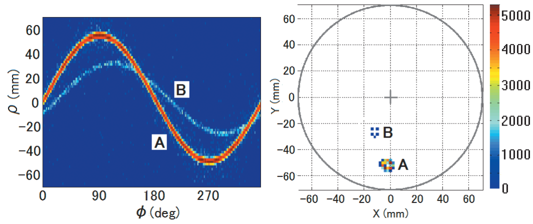

Fig. 3. Sinogram (left) and reproduced image (right) where the circles show the turntable and the RI sources.

Figure 3 shows a sinogram and a reconstructed radioactivity distribution for two ^{22}Na sources, (A) 65 kBq and (B) 1.55 kBq, fixed on the turntable that rotates at 150 rpm and moves back and forth by 2-mm step/minute over a 140-mm range. The aperture width of the collimator is 6 mm. The sinusoidal curves marked A and B in the sinogram correspond to each source. The positions of the sources are reconstructed within 3.5 mm. Details of the reproduction algorithm are described elsewhere.

*1 RIKEN Nishina Center

References

1) A. Yoshida, et al,: Nucl. Instr. Meth. B **317**, 785 (2013).