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Coating Thickness Measurement of TRISO-Coated Fuel Particles Using X-ray Image Plate

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1. Introduction

A TRISO-coated fuel particle for an HTGR (high temperature gas-cooled reactor) is composed of a nuclear fuel kernel and outer coating layers. The coating layers consist of buffer PyC (pyrolytic carbon), inner PyC (I-PyC), SiC, and outer PyC (O-PyC) layer. The coating thickness is measured to evaluate the soundness of the coating layers [1-5]. X-ray radiography is one of the nondestructive alternatives for measuring the coating thickness without generating a radioactive waste [6,7]. The acquired X-ray images for the measurement of coating thickness have included a small number of particles because of the restricted resolution and size of the X-ray detector.

In this experiment, an X-ray image was acquired for 49 TRISO-coated fuel particles using an Image Plate with high resolution. The coating thickness for the particles could be measured on the image in a reduced amount of time.

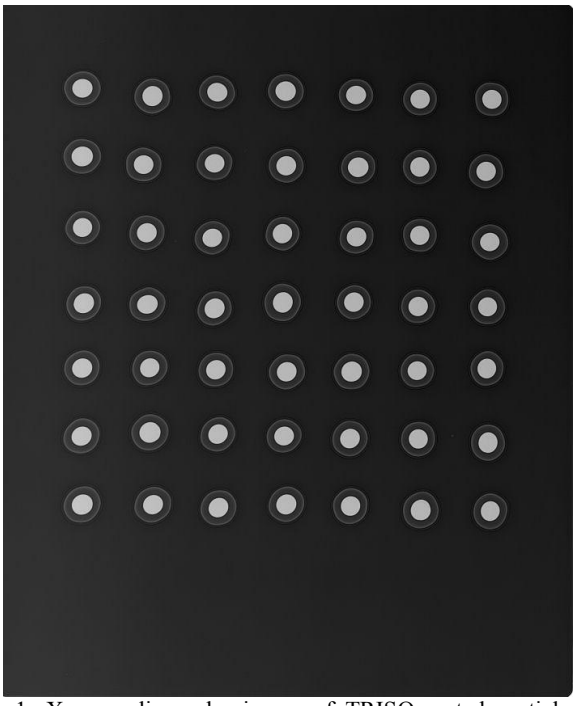

Fig.1. X-ray radiography image of TRISO-coated particles acquired by Image Plate detector.

2. Acquisition of X-ray image for TRISO-coated fuel particles using Image Plate detector

An X-ray film is one of the most accurate detectors to acquire an X-ray image. In addition, the size of the X-ray film varies for different applications. However, it is too difficult to process the image data using a computer. An Image Plate can be one of the alternatives instead of an X-ray film. The resolution as well as the sensitivity of the Image Plate is enough to measure the coating thickness of TRISO-coated fuel particles. The size of the Plate is large enough to acquire an X-ray image including a lot of particles. It is possible to process the image data digitally by a computer. In this study, an X-ray image is acquired for 49 particles arranged in a 7x7 format as shown in Fig. 1. We can observe the clear boundaries between coating layers on an enlarged image area for a particle as shown in Fig. 2.

To acquire a phase contrast X-ray image for the TRISO-coated fuel particles, a micro-focus X-ray imaging system was developed with a focus spot size of 1 to 2 μm. The Image Plate detector has 7040×8560 pixels with a pixel size of 50x50 μm^2 and is made by Fuji Photo Film Co. In the experiment, the source to detector distance was adjusted from 100 cm to 120 cm, and the tube voltage was adjusted from 40 kV to 80 kV to control the wavelength of the X-ray tube. UO_2 kernels with a diameter of 480 μm were used to fabricate TRISO-coated fuel particles in the experiment.

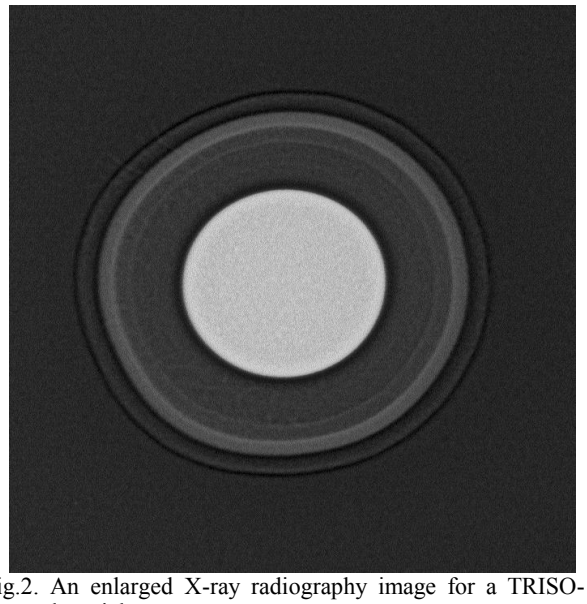

Fig.2. An enlarged X-ray radiography image for a TRISO-coated particle area.

3. Coating thickness measurement

Fig. 3 shows the radiography image of standard steel balls with a diameter of 1 mm. As shown in Fig. 3, the projected image has an elliptical form instead of a circle

form owing to geometric distortion. We have to compensate for this distortion. The distortion depends on the orientation angle and the projection angle of the particle from the axis of the X-ray beam. The measurement error can be reduced by compensating the distortion level. 5% of the error was reduced for the most distorted ball pattern. The coating thickness was automatically measured for 49 particles on an X-ray image using a developed measurement algorithm based on digital image processing.

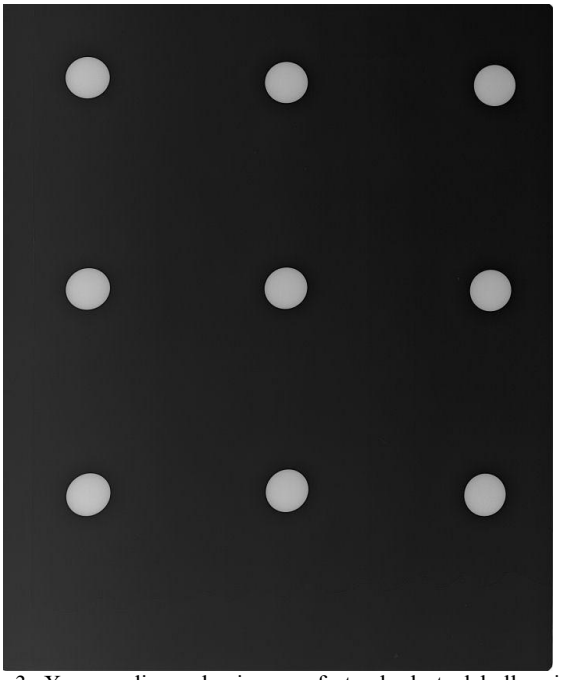

Fig.3. X-ray radiography image of standard steel balls with diameter of 1 mm for calibration.

3. Conclusion

In this study, the thickness of the coating layers of 49 coated particles was measured using an Image Plate detector and digital image processing techniques. The experimental results are as follows.

- An X-ray image was acquired for 49 TRISO-coated fuel particles using an Image Plate with high resolution in a reduced amount of time.
- We could observe clear boundaries between coating layers for 49 particles.
- The geometric error was compensated for the standard samples.
- The coating thickness of the TRISO-coated fuel particles can be nondestructively measured using X-ray radiography and digital image processing technology.
- We can increase the number of TRISO-coated particles to be inspected by increasing the number of Image Plate detectors.

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