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Coating Thickness Measurement of the Simulated TRISO-Coated Fuel Particles using an Image Plate and a High Resolution Scanner

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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 [6-8]. Several billion particles are subject to be loaded in a reactor. A lot of sample particles should be tested as much as possible. 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.

We tried to test many particles for an X-ray exposure to reduce the measurement time. In this experiment, an X-ray image was acquired for 196 simulated TRISO-coated fuel particles using an image plate and high resolution scanner with a pixel size of 25×25 μm^2. The coating thickness for the particles could be measured on the image.

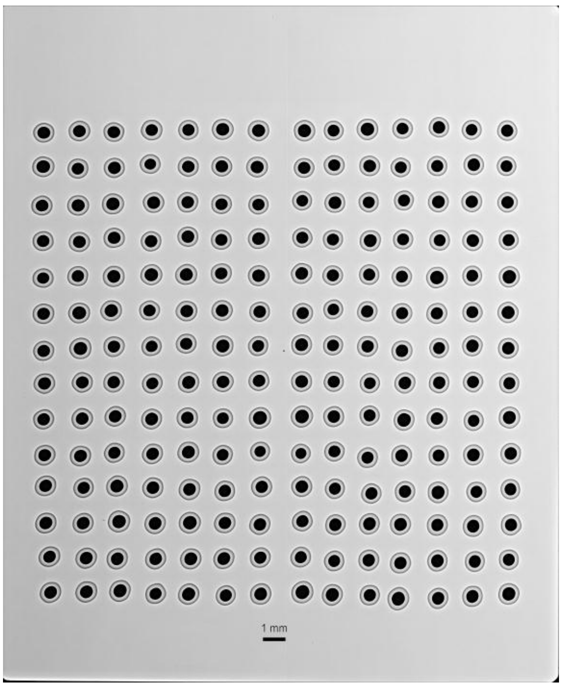

Fig.1. X-ray radiography image of the simulated TRISO-coated particles acquired by an image plate detector and a high resolution scanner..

2. Acquisition of X-ray image for the simulated TRISO-coated fuel particles using an image plate

An X-ray 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 196 particles arranged in a 14×14 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. The size of the image plate detector is 14x17 in^2. The pixel size of the used scanner is 25×25 μm^2. Then, the scanned image has 14080×17120 pixels with a pixel size of 25×25 μm^2. The image plate and the scanner were supplied 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. ZrO_2 kernels with a diameter of 500 μm were used to fabricate simulated TRISO-coated fuel particles in the experiment.

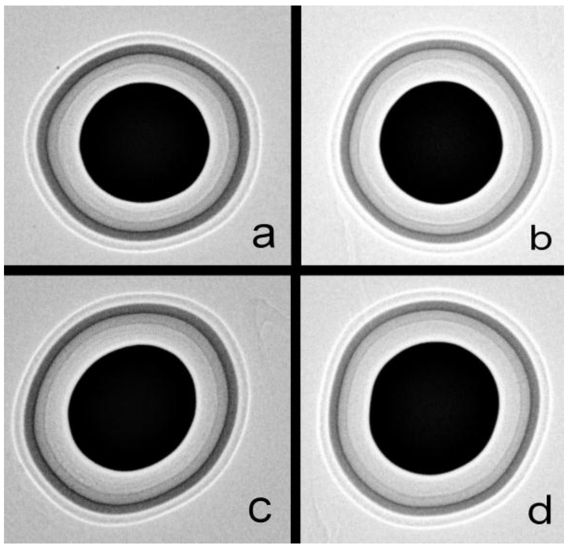

Fig.2. An enlarged X-ray radiography image for a simulated TRISO-coated particle area : a) an image for the upper leftmost particle, b) an image for upper rightmost particle, c) an image for lower leftmost particle, and d) an image for lower rightmost particle.

3. Correction of distortion

The X-ray image is distorted horizontally in Fig. 2 a). The X-ray image is distorted diagonally in Fig. 2 c). The X-ray image is distorted vertically in Fig. 2 d). The distortion level increases according to the distance between particle and X-ray beam center line

We have to compensate for this distortion depending on the orientation angle and the distance between the particle and the X-ray beam center line. The distortion was calculated theoretically according to the distance between a particle and an X-ray beam line. The measurement error can be reduced by compensating the distortion level. 4% of the error was reduced for the most distorted ball pattern as show in Fig. 3. The coating thickness was automatically measured for 196 particles on an X-ray image using a developed measurement algorithm based on digital image processing.

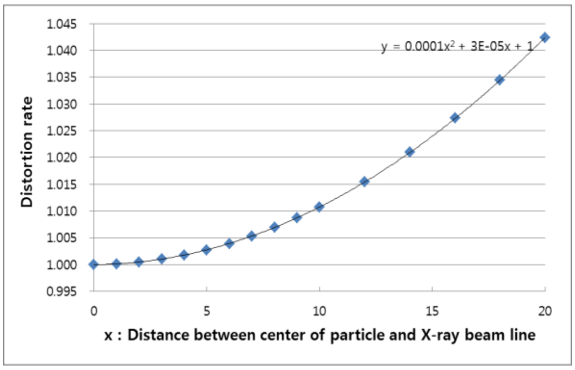

Fig.3. Distortion level of an X-ray radiography image according to the distance between a particle and an X-ray beam center line.

4. Conclusion

In this study, the thickness of the coating layers of 196 coated particles was measured using an Image Plate detector, high resolution scanner and digital image processing techniques. The experimental results are as follows.

- An X-ray image was acquired for 196 simulated TRISO-coated fuel particles with ZrO_2 kernel using an Image Plate with high resolution in a reduced amount of time.
- We could observe clear boundaries between coating layers for 196 particles.
- The geometric distortion error was compensated for the calculation.
- 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.

Acknowledgement

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