Thickness Measurement of Coating layers of Simulated TRISO-Coated Particles by X-ray Radiography under an IAEA CRP Program

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1. Introduction

The TRISO-coated fuel particle for a HTGR(high temperature gas-cooled reactor) is composed of a nuclear fuel kernel and outer coating layers. The coating layers consist of a 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 to measure a coating thickness without generating a radioactive waste. Phase contrast X-ray radiography technology is more powerful for acquiring a radiography image with clear boundaries between coating layers, when compared with the conventional X-ray radiography[6].

In this experiment, the SiC specimens and the O-PyC specimens of 4 kinds of simulated TRISO-coated particles with ZrO_2 kernel were measured by the phase contrast X-ray radiography under the IAEA CRP-6 (coordinated research project 6) program for characterizing TRISO-coated fuel particles for HTGR through the round robin tests with 4 different samples distributed from 4 member organizations to the 9 participating organizations.

2. X-ray imaging system

To acquire the phase contrast X-ray image for the simulated TRISO-coated fuel particles, a micro-focus X-ray imaging system was developed as shown in Fig. 1. The focus spot size of the x-ray generator was 1~2 μ m. The flat panel detector has 1024×1024 pixels with a pixel size of 48x48 μ m^2. In the experiment, the source to detector distance was adjusted from 40 cm to 140 cm, the tube voltage was adjusted from 40 kV to 80 kV to control the wavelength of the X-ray tube[6].

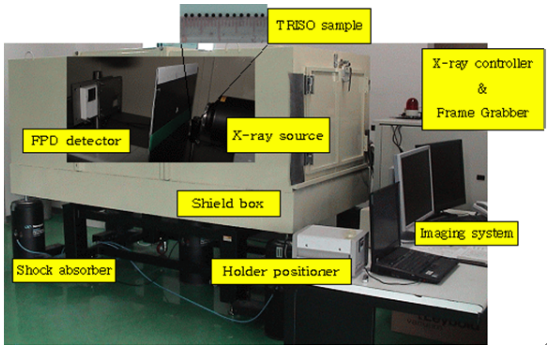


Fig.1. A micro-focus X-ray imaging system.

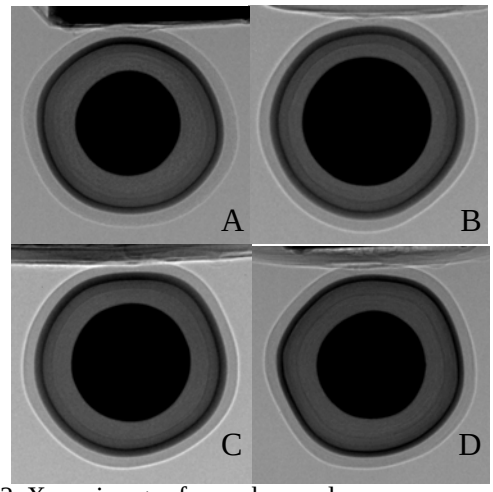
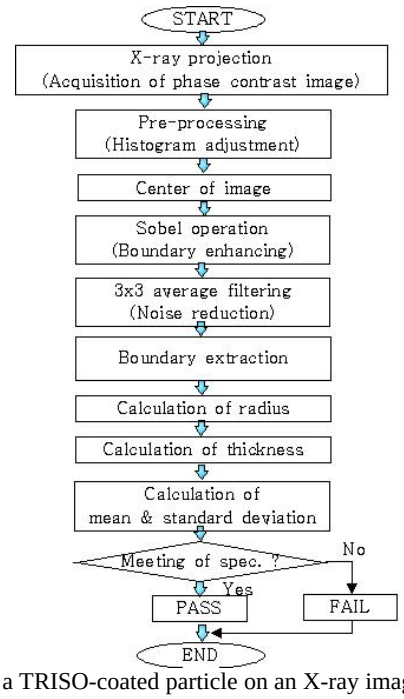


Fig.2. X-ray images for each sample.

3. Coating thickness measurement

The number of samples of each sample batch was 50. Fig. 2 shows X-ray images for a sample of each sample batch. The coating thickness was automatically measured by the developed measurement algorithm based on digital image processing techniques as shown in Fig. 3.

Fig.3. Automatic measurement algorithm for the coating thickness of a TRISO-coated particle on an X-ray image.



The distance between the boundary position and the center of a particle is the radius of the coating layer. The radii of the coating layers were circularly measured through 360 degrees with a step of 30 degrees on the X-ray image. The coating thickness was calculated by using the measured radius of the boundaries. The mean value and standard deviation(STD) for the coating thickness are listed in Table 1 and Table 2. Fig. 4 shows the measured coating thickness for each sample.

Table 1. The mean value of coating thickness of TRISO-coated particles by X-ray radiography.

Samples	Mean, μ m			
	Buffer	I-PyC	SiC	O-PyC
A	104	40	37	52
B	57	37	33	42
C	79	37	35	40
D	107	70	36	56

Table 2. The standard deviation of coating thickness of TRISO-coated particles by X-ray radiography.

Samples	Standard deviation, μ m			
	Buffer	I-PyC	SiC	O-PyC
A	9	2	3	6
B	8	3	1	3
C	6	3	1	2
D	12	6	1	4

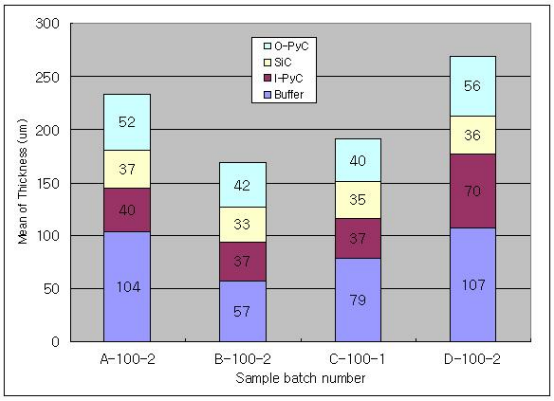


Fig.4. Coating thickness of TRISO-coated particles by X-ray radiograph.

4. Conclusion

In this study, the thickness of coating layers of coated particle distributed from 4 organizations was measured by the phase contrast X-ray radiography and digital image processing techniques. The experimental results are as follows.

- Micro X-ray imaging system was developed to acquire a phase contrast X-ray radiograph with clear boundary image for a TRISO-coated particle.
- The coasting thickness was automatically measured by the image processing algorithms with a small error of less than 10 % based on the results of the ceramography.
- The thickness of buffer layer of sample A and D was large than that of sample B and C.
- The I-PyC thickness as well as the O-PyC thickness for sample D was much larger than the references for HTR-10.
- The thickness of SiC layer of each sample ranged from 33 to 37 μ m with a small difference among samples.
- The coating thickness of the TRISO-coated fuel particles will be nondestructively measured by the X-ray radiography and digital image processing technology.

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