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X-ray CT Analysis on Stainless Steel - Aluminum Dispersion Plate

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1. Introduction

Developing LEU targets with high uranium density is necessary to sustain the medial radioisotope supplement. [1]. In Korea, U-Al dispersion plates up to 9.0 gU/cm^3 uranium density were fabricated based on centrifugal atomization technique, and the interaction layer consisting of intermetallic compounds was found to be formed during the fabrication process [2, 3]. The lower density of the interaction layer leads to a volumetric increase, which results in degradation of the thermal properties. Larger fuel particle sizes resolve the problem but causes a particle aggregation problem [4].

In this study, the X-ray CT technique was used to analyze the internal particle distribution of the dispersion plate. CT technique has advantages over the conventional analysis methods: providing entire internal information without damaging the specimen [5]. Reduction ratio effect on the particle distribution of stainless steel - aluminum dispersion plates was investigated using X-ray CT.

2. Methods and Results

Type 304L stainless steel was selected as a surrogate for uranium fuel element due to its similar yield strength with uranium, and an appropriate X-ray attenuation property [6]. Dispersion plates were fabricated according to the conventional picture-frame method [7, 8]. Samples were rolled to the same thickness, but with a different rolling reduction ratio per rolling pass by controlling the number of passes. The detailed reduction ratio was set as the tables below.

Table I: Rolling reduction ratio settings

		A	B	C
Compact thickness		2 mm		
Hot Rolling	#Passes	9	4	3
	Reduction	15%	30%	40%
Cold Rolling		10%		

		D	E	F
Compact thickness		4 mm		
Hot Rolling	Pass: Reduction	1: 12% 2-8: 25%	1-13: 15%	1-2: 30% 3-8: 12%
Cold Rolling		10%		

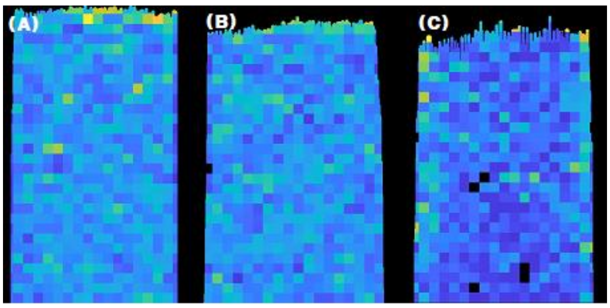
The fabricated dispersion plates were then observed using X-ray CT. Three methods were used to estimate the particle homogeneity. First, the thickness of fuel meat which directly shows the presence of dog-bone, was visualized and the deviation values were calculated. Also, the color mapping, which can provide the 2D information like radiography, was performed and the deviation values were calculated. Lastly, the proposed volume fraction calculation method was used to estimate the overall particle homogeneity. The volume fraction of the particle inside a cell converges as the cell size increases, but it converges at a smaller cell size in the case of the uniformly distributed sample. Based on this concept, the volume fraction calculation algorithm was constructed using MATLAB. The standard deviation value of the calculated volume fraction was plotted.

Figure 1. Visualized thickness distribution of the fuel meat part in the fabricated samples

Table II: Thickness deviation of fabricated samples

	A	B	C
Thickness STD [um]	79.31	126.9	243.8

	D	E	F
Thickness STD [um]	212.2	139.1	263.0



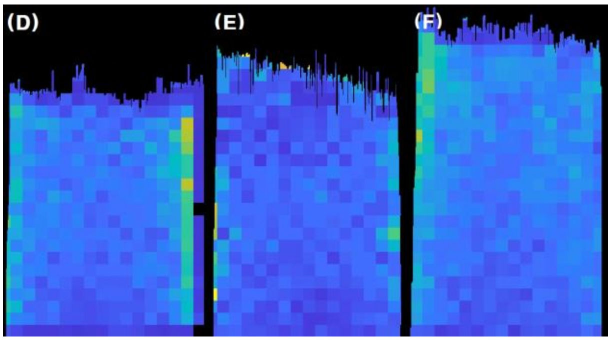


Figure 2. Color mapping results of fabricated samples

Table III: Mapping deviation of fabricated samples

	A	B	C
Normalized STD	0.02182	0.02397	0.02978

	D	E	F
Normalized STD	0.03203	0.02809	0.03269

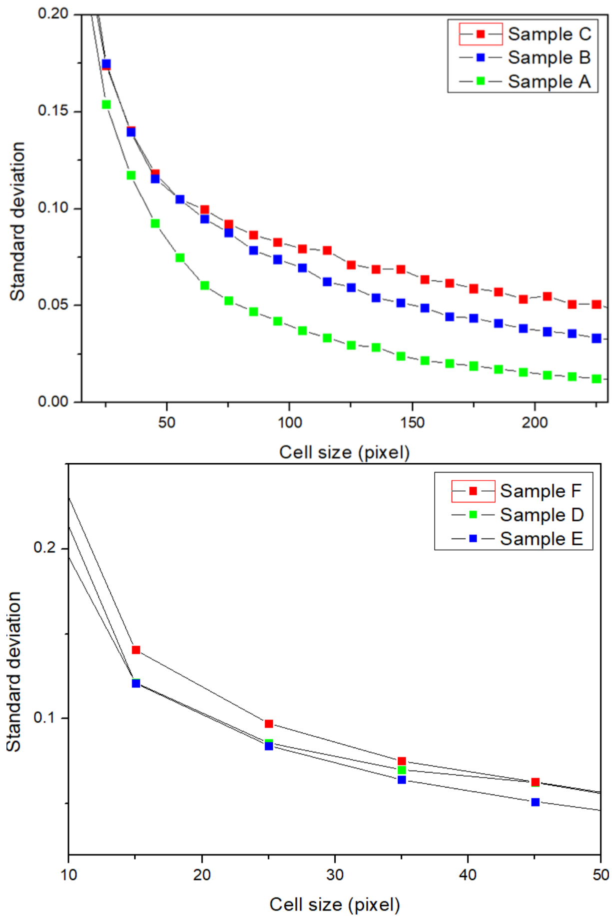


Figure 3. Standard deviation plot of fabricated samples

The aspect of fuel meat thickness (Figure 1), color mapping results (Figure 2) and calculated deviation values (Table II, III) show the higher convergence for samples fabricated with a lower reduction ratio per rolling pass. At the same time, setting a lower reduction ratio at the front steps results in the higher convergence. Volume fraction calculation results (Figure 3) also show the same tendencies. Results imply that the internal particle aggregation can be reduced by increasing the number of rolling passes, and the front rolling steps contribute more.

3. Conclusions

In this study, an effect of the rolling reduction ratio on particle homogeneity of the dispersion plate with coarse particle size was investigated using X-ray CT technique. Results including the fuel meat thickness, color mapping, and the calculated particle volume fraction point that decreasing the reduction ratio per rolling pass can enhance the particle homogeneity, and also the first pass of the rolling process takes the greatest contribution to the particle distribution.

This analysis is expected to contribute to improved stability and performance of the high density LEU targets.

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REFERENCES

[1] Pillai, M. R., Ashutosh Dash, and F. F. Knapp Jr. "Sustained availability of 99mTc: possible paths forward." J Nucl Med 54.2 (2013): 313-23.
[2] Ryu, Ho Jin, et al. "Development of high-density U/Al dispersion plates for Mo-99 production using atomized uranium powder." Nuclear Engineering and Technology 45.7 (2013): 979-986.
[3] Ryu, Ho Jin, et al. "Metallurgical considerations for the fabrication of low-enriched uranium dispersion targets with a high density for 99Mo production." Journal of Radioanalytical and Nuclear Chemistry 305.1 (2015): 31-39.
[4] Adamson Jr, G. M. FABRICATION OF RESEARCH REACTOR FUEL ELEMENTS. No. ORNL-TM--2197; CONF-680105--5. Oak Ridge National Lab., Tenn., 1968.
[5] Cnudde, Veerle, and Matthieu Nicolaas Boone. "High-resolution X-ray computed tomography in geosciences: A review of the current technology and applications." Earth-Science Reviews 123 (2013): 1-17.
[6] Hubbell, J. H. "Photon mass attenuation and energy-absorption coefficients." The International Journal of Applied Radiation and Isotopes 33.11 (1982): 1269-1290.
[7] Kaufmann, Albert R., ed. Nuclear Reactor Fuel Elements: Metallurgy and Fabrication. Interscience Publishers, 1962.
[8] Cunningham, J. E., and E. J. Boyle. "MTR-Type fuel elements." UNITED NATIONS. Peaceful uses atomic energy: proceedings of the International Conference on Peaceful Uses of Atomic Energy, held in Geneva. Vol. 9. 1955.