Optimization of High-density Dispersion Target Using Atomized Uranium-Aluminum Alloy-Powders

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1. Introduction

One of the major roles of research and test reactors is to produce radioisotopes for medical and industrial applications. However, worldwide intentions have been focused on replacing high-enriched uranium (HEU > 20% U-235) to low-enriched uranium (LEU < 20% U-235) due to nuclear proliferation issues. The decrease of uranium enrichment involves a performance degradation in ^{99}Mo production and an increase of radioactive waste.

In our previous works [1, 2], we developed high-density LEU dispersion targets using atomized uranium-aluminum (U-Al) powders. Although we successfully made out high-density targets and established fabrication conditions for phase transformation, we needed some optimization in the target fabrication to minimize defects such as over target meat size, homogeneity, blistering, de-bonding, and dog-bone effect. It seems that the meat expansion arisen from fuel phase transformation is the main source for the defects. In this work, the fabrication were optimized to improve the fabrication quality.

2. Methods and Results

2.1 Fabrication of high-density targets

Using atomized U-xAl (x = 5 and 15 wt%) powders, high-density dispersion target plates were fabricated by adopting a typical target fabrication procedure including mixing and blending, compaction, heat-treatment, assembling, and hot-rolling. Fig. 1 shows a typical fabrication process of the hot rolling process for the fabrication of the dispersion target plates.

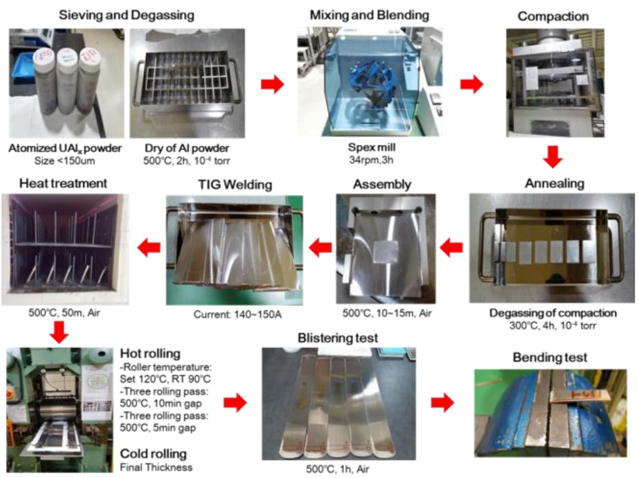

Fig. 1. Typical fabrication process of high-density targets [3].

The compact thickness was adjusted by decreasing the amount of Al. As seen in Table 1, the thickness of compacted samples ranges from 3.7 to 4.2 mm for U-5Al and from 4.0 to 4.2 mm for U-15Al. Since U-5Al shows much higher volume expansion during phase transformation, its thickness was adjusted to be less than that of U-15Al. Besides, it was noticeable that the porosity increased as the amount of Al decreased.

Table 1. Density and porosity information of U-Al compacts

Type	Sample ID	Thick. (mm)	Density (g/cm^3)		Porosity (%)
			Theo.	Meas.	
U-5Al	T5Al-1	4.14	6.68	6.34	5.18
	T5Al-2	3.92	6.92	6.52	5.72
	T5Al-3	3.73	7.19	6.69	6.99
U-15Al	T15Al-1	4.21	6.72	5.92	11.93
	T15Al-2	4.07	6.92	6.05	12.56
	T15Al-3	4.01	7.02	6.06	13.60

We adopted the hot-rolling conditions established in our previous work [2]. U-5Al targets were annealed at 570 °C for 12 hours and U-15Al targets were annealed at 550 °C for 12 hours after the first hot-rolling pass. After the annealing, the targets were manufactured by a conventional process as detailed in Fig. 1. Fig. 2 shows images of U-5Al and U-15Al targets after the final machining without any drawbacks on the surface.

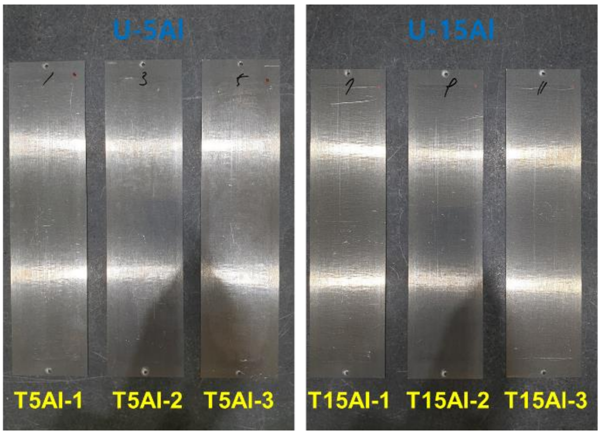

Fig. 2. Images of high-density U-5Al and U-15Al targets after the final machining.

2.2 Non-destructive and destructive examinations

After the fabrication, the targets were examined by non-destructive testing. First, Fig. 3 shows radiography testing (RT) images indicating the target meat size, location, and homogeneity.

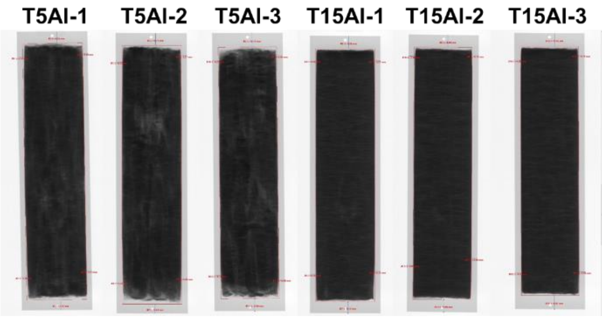

Fig. 3. Radiography images of U-5Al and U-15Al targets.

The measured target meat sizes are given in Table 2. Both U-5Al and U-15Al targets showed good compatibility with commercial target specifications. However, U-5Al targets occasionally showed a slight excess of size less than 0.2 mm while all U-15Al targets satisfied the specification.

Table 2. Target meat size measured by radiography testing.

Sample ID	Width		Height	
	Min.	Max.	Min.	Max.
T5Al-1	40.41	41.82	180.63	184.11
T5Al-2	39.80	40.80	178.37	183.45
T5Al-3	38.71	40.27	176.73	180.25
T15Al-1	38.81	41.07	179.31	182.28
T15Al-2	39.32	40.27	179.13	181.48
T15Al-3	39.65	40.41	177.95	180.54

The meat position was inspected by measuring the distance between the meat edge and target edge as seen in Fig. 4. The measured location information is detailed in Table 3. All targets satisfied the minimum required distance for all edges.

Using the gray level information from radiography images, the homogeneity of target meat was analyzed. U-5Al shows low quality of homogeneity, whereas U-15Al shows very good quality of homogeneity.

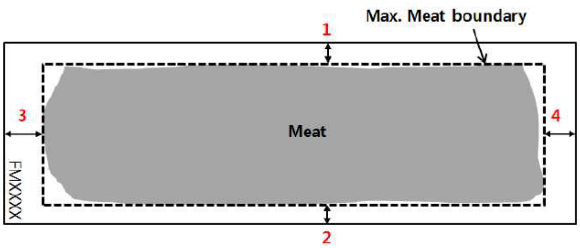

Fig. 4. Schematic representation for target location inspection.

Table 3. Target meat location measured by radiography testing.

Location	Min. size (mm)	Measurement (mm)					
		T5Al-1	T5Al-2	T5Al-3	T15Al-1	T15Al-2	T15Al-3
1	3.47	3.53	3.90	4.00	3.72	3.90	3.95
2	3.47	3.53	4.23	4.23	3.95	3.90	4.05
3	7.00	8.23	8.70	10.11	9.22	8.84	9.55
4	6.00	7.23	6.44	8.94	8.14	9.08	9.93

Next, the targets were inspected using ultrasonic testing (UT) to identify de-bonding or blistering. Fig. 5 shows the results of ultrasonic testing. Both de-bonding and blistering were not observed. This is corresponding to bending test results as seen in Fig. 6.

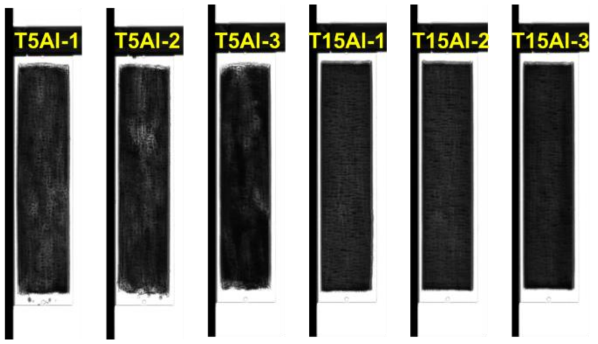

Fig. 5. Results of ultrasonic testing of U-5Al and U-15Al targets.

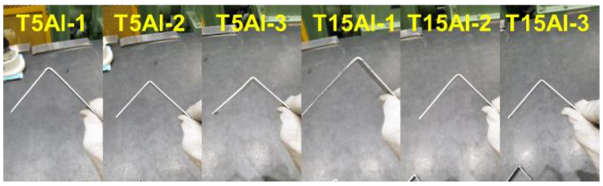

Fig. 6. Bending test results of U-5Al and U-15Al targets.

3. Conclusions

High-density targets were successfully fabricated using atomized uranium-aluminide powders at KAERI. The fabrication process was optimized to minimize defects and improve quality. As a first step, the aluminum contents were adjusted to compensate meat expansion arisen from the fuel phase transformation. The targets showed very good surface conditions. U-15Al targets satisfied all the criteria in meat size, location, homogeneity, and de-bonding. However, U-5Al targets showed slight excess of meat size and poor homogeneity, which will be improved in the next step. Besides, microstructures of the targets will be examined and their composition will be investigated using an x-ray diffractometer.

REFERENCES

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[2] T.W. Cho, K.N. Kim, Y.J. Jeong, K.H. Lee, S.H. Kim, J.M. Park, Development Status of Very High-density LEU Dispersion Target Using Atomized Uranium-Aluminum Alloy Powders, *Transaction of KNS Autumn meeting*, Goyang, Korea, (2019)