Particle Size Analysis of Atomized U_3Si_2 Powder

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1. Introduction

KAERI has been developing atomization technology which is a key technology for achieving the high-density LEU fuel. With the atomization technology presented in Fig. 1, KAERI can fabricate spherical powder; its process is much simpler than that of conventional comminuted one. The atomized powder has high purity with fewer defects, excellent irradiation performance, and high production yield rate.

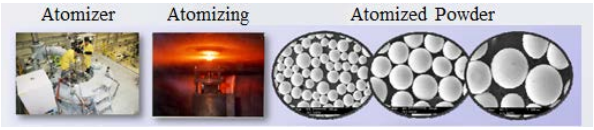

Fig. 1. KAERI Centrifugal Atomization Technology [1]

2. Methods and Results

2.1 Particle Size Analysis Methods based on ASTM

ASTM B214-16 specifies standard test method for sieve analysis of metal powders and ASTM B215-15 specifies standard practices for sampling metal powders. To meet the ASTM's standard, KAERI used a multi-level slot sampler presented in Fig. 2 and sampled 100±10 g of U_3Si_2 powders for each batch which had been sieved 100 mesh(150 ㎛) in advance. The sampler was inserted into the powder at a point about 70% of the distance from the center of the cross-section to the periphery and straight down to the bottom of the powder container. After sampling, the contents of the sampler were emptied into a separate tray.

Fig. 2. Multi-level slot sampler

To conduct sieve analysis of U_3Si_2 powders, KAERI used a vibration action sieve shaker using sieves with 203 mm in diameter presented in Fig. 3. To follow the sieve series guidelines based on ASTM, the sieves ranged from 140 mesh(106 ㎛), 200 mesh(75 ㎛) and 230 mesh(63 ㎛) to 325 mesh (45 ㎛) were assembled with the coarsest sieve at the top. After fastening the sieve assembly securely in the sieve shaker, KAERI operated the shaker for 15 minutes with pouring the sampled U_3Si_2 powders onto the coarsest sieve at the top.

Fig. 3. Vibration action sieve shaker

After sieving, the procedures of cleaning sieves and collecting powders were proceeded. Firstly, remove the coarsest sieve and tap gently its powders to one side and pour them upon a tray. Secondly, brush the powders adhering to the bottom surface of the sieve to drop them into the next finer sieve. Thirdly, brush the top surface of the sieve and pour the powders into the previous tray. Lastly, repeat this process for each sieve in the nest and weigh the powders collected in the separate trays. The sum of the masses of all the fractions had to be more than 99 wt.% of the initial mass for credibility of the analysis.

2.2 Particle Size Analysis Result

ASTM sieve analysis of 4 DU_3Si_2 batches(C2011, C2126, C2128 and C2202) was carried out so that KAERI could find out the relevance between process conditions and particle size distributions. Chemical composition of the all batches was DU-7.6wt.%Si. The process conditions of the atomization and the results were presented in Table I and Fig.4.

Table I: Process conditions and result for DU_3Si_2 batches

Process condi-tions	Batch Name	C2126	C2128	C2202	C2011

	Loading (g)	1209.61	1251.94	1251.37	1912.64
	Disk Speed (RPM)	22000	24000	26000	26000
Results	Powder (g)	1133.13	1169.10	1160.37	1830.18
	Yield Rate (%)	93.68	93.38	92.73	95.68
	-325 mesh (≦45 ㎛) (wt.%)	8.17	10.45	11.09	10.15

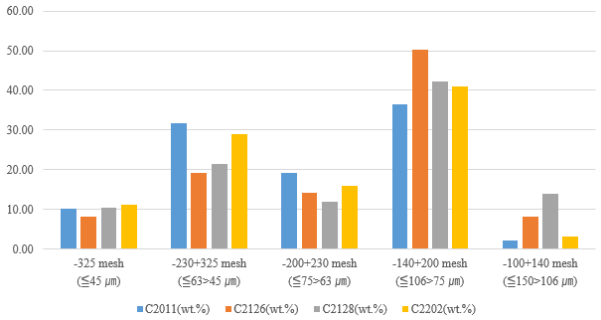

Fig. 4. Particle size distribution graph for DU_3Si_2 batches

All batches had similar results showing first peak at -140+200 mesh and second peak at -230+325 mesh. The phenomenal was explained with mechanism of direct droplet formation by Champagne and Angers[2]. The mechanism presented in Fig. 5 was applied when a liquid supply rate was slow. The mechanism of direct droplet formation contributed in spherical particles and bimodal particle size distribution. As the liquid supply rate was increased, spherical particles from direct droplet formation changed into ligament shaped particles and then film shaped particles after all.

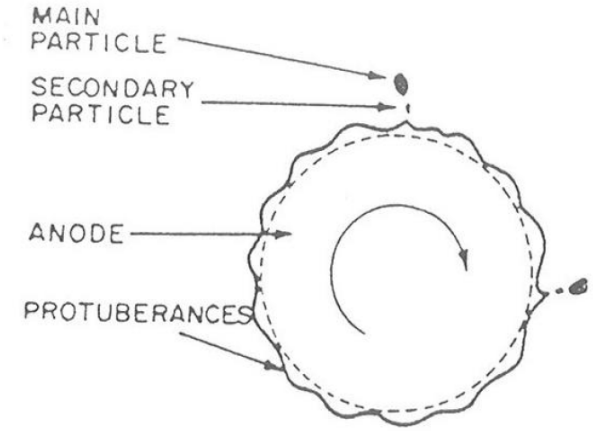

Fig. 5. Mechanism of direct droplet formation by Champagne and Angers[2]

The proportion of DU_3Si_2 particles with diameter under 45 ㎛ increased as the disk speeds increased. The proportion of DU_3Si_2 particles with diameter under 45 ㎛ decreased as the loadings increased. Champagne and Angers developed an empirical model for determining the diameter of droplets[3]. The diameter was given as:

$$d = 4.63 \times 10^6 \frac{\gamma^{0.43} Q^{0.12}}{\rho^{0.43} \omega^{0.98} D^{0.64}}$$

where d is the diameter of droplets in ㎛, γ is the interfacial energy in J/m^2, Q is the liquid supply rate in m^3/s, ρ is the density in kg/m^3, ω is the angular velocity in rad/s, and D is the rotating disk diameter in m. According to the formula above, the angular velocity(ω) and the diameter(d) were in inverse proportion and the liquid supply rate(Q) and the diameter(d) were in direct proportion. The results related to between the disk speed, the supply rate and the particle's diameter corresponded with Champagne and Angers' studies.

3. Conclusion

Considering the analysis results, we can conclude that the process conditions such as the disk speed and loading have an important role in determining a particle size. Furthermore, the particle size distribution results with two main peaks could be explained with the mechanism of direct droplet formation by Champagne and Angers. This study can be used to design and establish better manufacturing procedures for U_3Si_2 powder atomization.

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ACKNOWLEDGMENT

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