Input Material Accounting Method With Homogenization Mixers for an Engineering Scale Pyroprocessing Facility

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1. Introduction

Pyroprocessing is a promising technology to recycle spent fuel, and to reduce the volume and toxicity as well as an advantage on proliferation resistance compared to Plutonium and Uranium Extraction (PUREX) reprocessing [1]. To secure proliferation resistance, Nuclear Material Accountancy (NMA), especially input material accountancy, is the most difficult in an engineering scale facility because the solid form of input material is different from aqueous processing, PUREX in which an Input Accountability Tank (IAT) is used for input material accountancy.

In this study, two homogenization mixers were tested with surrogate powder materials, and powder and Pu heterogeneity were estimated using the test results. Additionally, the Pu accounting uncertainty was calculated with respect to the number of Destructive Analysis (DA) samples in the double stage homogenization process.

2. Double Stage Homogenization Process

2.1 Concept of the Double Stage Homogenization

The homogenization method for input accountancy was proposed in the REPF model [2] in which a 500 kg large homogenization mixer was adapted to process a spent fuel assembly per operation. However, Equipment operated in hot-cell should be remotely controlled and maintainable. Thus, homogenization mixers should be relatively small and the operation mechanism should be simple for maintenance. Two types of homogenization mixers were used for the double stage homogenization. The first mixer is three tumbler mixers of 75 kg which 75 kg spent fuel powder is charged into, and the second one is a 10 kg Nauta or tumbler mixer as shown in Fig. 1. After mixing spent fuel powder in each 75 kg tumbler mixer, kg scale samples are taken from three tumbler mixers to represent the whole population, and three samples are charged into a 10 kg mixer. After mixing in the 10 kg mixer, DA samples of 1 g are taken. The Pu accounting uncertainty is not affected only by the mixing performance, but also by the distribution of Pu concentrations in spent fuel powder, the mass uncertainty charged into the first mixer (75 kg tumbler), and the first sampling mass uncertainty in double stage homogenization process. Thus all parameters should be considered to estimate the Pu accounting uncertainty.

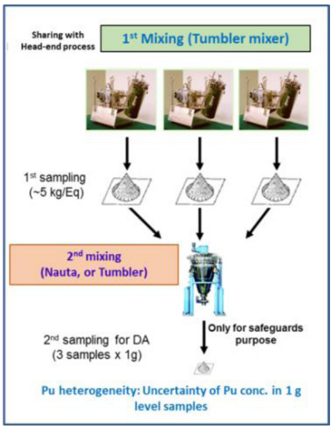

Fig. 1. Concept of the double stage homogenization process.

2.2 Performance evaluation of mixers

As shown in fig. 2, a 10 kg Nauta and tumbler mixer were designed and fabricated to evaluate the mixing performance. 10 kg and 50 kg containers for the tumbler mixer were tested to check the scale-up effect. 45 *u*m CuO and NiO were prepared and charged into each container at a mass ratio of 3:7, nine DA samples of 1 g were taken from various positions of the container, and analyzed by

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, Thermo Scientific iCAP 6300). Relative Standard Deviations (RSD) of the mass ratio with respect to the mixing time are shown in Fig. 3 in which RSDs from the Nauta mixer is smaller than 0.3% at an arm speed of 0.7, and all RSD values are lower than 0.8% after 3 hours of mixing.

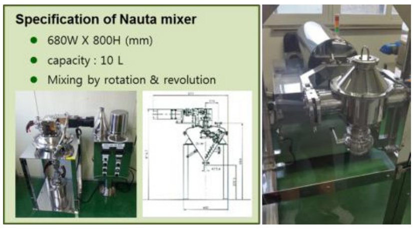

Fig. 2. Nauta mixer (left) and tumbler mixer (right).

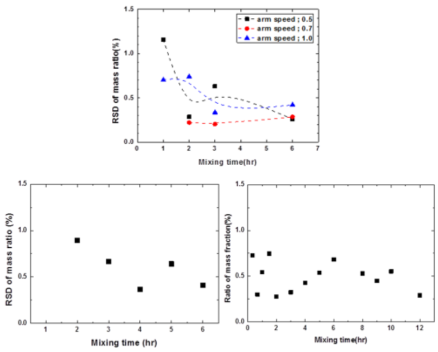

Fig. 3. Measured RSD of the mass ratio (10 kg Nauta: top, 10 kg tumbler: bottom left, 50 kg tumbler: bottom right).

2.3 Powder heterogeneity

Mixing two types of powder (binary mixture) is a general method to evaluate the powder heterogeneity and determine the variance of the composition. However, spent fuel powder has many different types (multi-component mixture) of powder containing various Pu concentrations rather than a binary mixture. Thus, the uncertainty (RSD) of each powder component having different mass fractions was calculated as explained by R. Hogg [3]. Based on the RSD of mass ratio from the test, the powder heterogeneity was plotted as a function of mass fraction in Fig. 4. The powder with the lower mass fraction is more heterogeneous because the number of powder particles in the DA samples is smaller than the higher mass fraction.

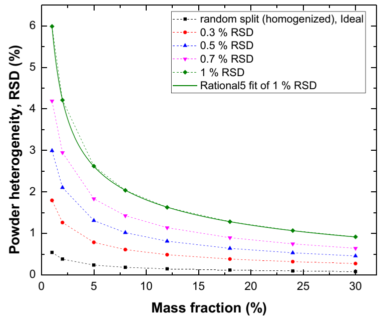

Fig. 4. Powder heterogeneity as a function of mass fractions.

3. Discussion

In the previous section, the powder heterogeneity based on the performance test result was calculated. The Pu heterogeneity is affected by the distribution of Pu concentration as well as the powder heterogeneity. The Pu heterogeneity will be calculated with the calculated powder heterogeneity using the existing gamma scan profile of a spent fuel rod. The result will be presented including estimate of the Pu accounting uncertainty at the conference.

4. Conclusion

The double stage homogenization was proposed for input accountancy in an engineering scale pyroprocessing facility, and the candidates of homogenization mixers were tested and analyzed. To minimize the Pu accounting uncertainty, the method to charge the spent fuel powder into the first mixer, and the first sampling method should be carefully designed. The estimate of the Pu accounting uncertainty in this study will help in conceptual design of devices used in the double stage homogenization process.

REFERENCES

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