Analysis of Material Behaviors of Integrated Operation Model of Pyroprocessing and the Phased Approach Strategy of Optimized Mass Flow

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1. Introduction

Pyroprocessing technology has been developed at Korea Atomic Energy Research Institute (KAERI) as an alternative for management of spent nuclear fuel [1-2]. Each fundamental unit process of pyroprocessing has been developed successfully up to the lab-scale so far [3-4], while integrated process for continuous operations from spent nuclear fuel to waste product has not been achieved completely. Modeling and simulation studies for integrated pyroprocessing have been challenged up to now[5]. However they had limitation in that they had focused into material flow of their own pyroprocessing technique. As the result the integrative studies including mechanical operation condition, safety analysis, and safeguards for nuclear materials has remained at the basic state. Thus the first integrated operation model for pyroprocessing(IOMP) needed to be developed, reflecting various needs of safety, safeguards and mechanical operation conditions. This model implements the current flowsheet of pyroprocessing and covers the up-to-date process operation schedules.

2. IOMP Purpose

The objective of IOMP is that it is supplied on the process designers as an analysis tool for each capacity of unit process, the bottle-neck points, and the distribution of nuclear spent fuel stream for integrated operation and mass flow of pyroprocessing. IOMP has functions for tracking the target nuclear element over the whole integrated process in real time. Hence it is possible to analyze efficiency of the current flowsheet, the distribution of main nuclear materials, and the total operation days. The most important is it will give perception of phased approach strategy for establishment of the integrated pyroprocessing technology. It is possible to change in-cell structure so that the influence of logistics by 2D-design can be determined.

3. Methods

3.1 System Modeling

This program has been invented with ExtendSim. It consists of model file(.mox), library file(.lib) and EXCEL import file for user-defined conditions. The integrated pyroprocessing consists of spent fuel storage vault, head end cell, oxide reduction cell, electrolytic recovery cell, and waste treatment cell. Above all conceptual diagram of each unit cell was constructed [Fig. 1].

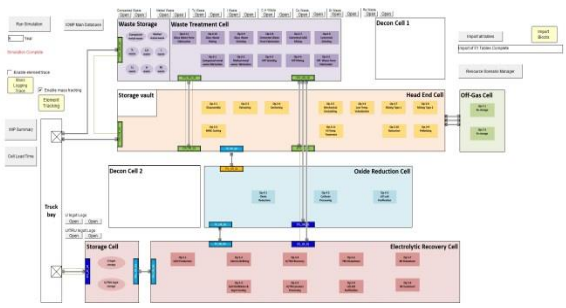

Fig. 1. Conceptual diagram of IOMP.

The next, various operation conditions of each unit process were reflected into the process diagram. There are reference batch size, operation time, the number of operators, user-defined separation ratios, the number of equipment, frequency of breakdown and setup for individual process, mean time between failure, time for inter-cell transfer lock according to hot cell configuration, and the number of utility like robot crane.

3.2 Mass tracking system.

Mass tracking of nuclear materials is very important for the dynamic mass balance and nuclear material accountancy. This program is implemented to trace main target nuclear materials mass in all paths through which the material passes. It counts the mass whenever the material items departure from the start point and arrive at the end point. Hence it gives the insight for distribution of main nuclear materials over the whole integrated processes.

3.3 Process capability analysis.

IOMP has been implemented for analysis of process capability, including process lead time, operation utilizations by standalone state and fully-linked state, total number of batch, and buffer capacity. It is also including the procedure for nuclear material accountancy operation because even though the influence of accountancy operation on the processing ability is small, the increase of the lay-off time for the analysis of the nuclear material samples can be observed.

4. Result and Conclusion

Salt-soluble element can remain in the oxide reduction molten salt. The representative elements as Cesium (Cs), Strontium (Sr) and Barium (Ba) are accumulated in LiCl molten salt bath. These species concentration is very important since it can affect process operation procedures or the quality of waste product due to high heat elements. Fig. 2 shows amount of Sr, Ba in oxide reduction molten salt bath during long-term process time. At the first year the concentration were not saturated. However they were fully-saturated from around 400 batches and reached to the equilibrium state.

Fig. 2 also means that the optimal mass balance and flow should be conducted after the integrated process reaches to the equilibrium state. The current designed integrated operation model is not satisfied to the target operation capacity since it is based on the assumptions of each unit process and does not reflect the interaction between pre- and post-pro process. It means that various parameters and process scenario should be considered and optimized. The phase approach strategies have to be proposed for solving complex equations for optimization of process operation and material flow through stepwise computer simulation

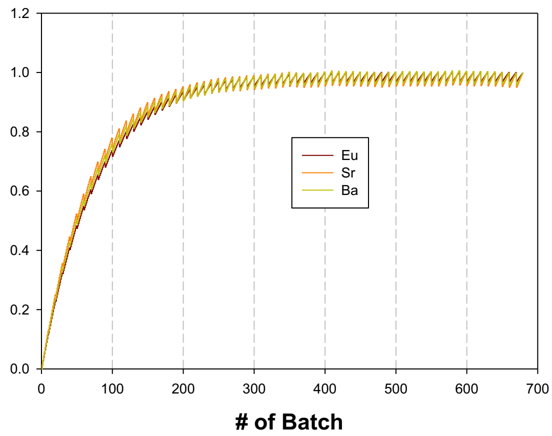

Fig. 2. Behaviors of salt-soluble element in the oxide reduction.

Several scenario of operation model based on the separation ratio, process capacity, WIP capacity and process line balancing can be simulated as well. It will play a significant role for the analysis of process operation, logistics. This work was supported by National Research Foundation of Korea (NRF) (NRF-2017M2A8A5015083).

REFERENCES

[1] H. S. Lee et al, “Pyroprocessing technology development at KAERI,” Nuclear Engineering and Technology, 43, 4, 3171 (2011).

[2] D. H. Ahn et al, “Technical development of Pyroprocessing for managing spent fuel,” News & Information for chemical engineers, 34, 3, 249 (2016).

[3] J. M. Hur et al, “Electrochemical reduction of uranium oxide in the Li2O-LiCl molten salt,” Seventh information exchange meeting on actinide and fission products partitioning and transmutation, Journal Name, Vol. , p. , Publisher, City, Country (year).

[4] H. S. Lee et al, “Current status of Pyroprocessing development at KAERI,” Science and Technology of Nuclear Installations, 2013, issue numbers, page number (year).

[5] F. M. LAST, The Title of the Book, page or chapter numbers, Publisher, City (year).