Thermal Analysis for a Salt Evaporation System with a Computational Fluid Dynamics Method.

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1. Introduction

In an elelctrorefining process, uranium is sepated from spent fuel which is dissolved in a molten LiCl-KCl eutectic salt by electrolysis and uranium metal is deposited onto a solid cathode in a dendritc form. Uranium deposits contain about 30 wt% salts. In order to recover pure uranium metal and to convert it into a metal ingot, these salts have to be removed. In the Argonne National Laboratory (ANL), a vacuum distillation process was employed for the recovery of uranium. By using a batch operation, a distillation of a LiCl-KCl eutectic salt and a uranium melt with a crucible mold were achieved. This process is called a “cathode process”[1]. In KAERI, the cathdoe processing is divided into a salt evaporation system and a casting uranium ingot system for uranium deposits. A bench-sacle salt distiller of a batch type is employed and a continuous salt distiller is developed in order to improve a throughput of cathode processing. In the salt evaporation operation, the evaporated salt is emitted to the salt recovery system. When the evaporated salt is transfered by the Ar carrier gas, the temperature of the system might be lowered. The salt tends to be solidifed by the temperature drop and the solidifed salt sticks to the inner wall of the distiller. The efficiency of salt recovery is very low. In order to improve the salt recovery, the behavior of the evaporated salt has to be understood. In this work, thermal analysis for a salt evaporation system is carried out by using a commercial computational fluid dynamics code, CFX. Temperature distributions in a bench scale salt distiller were evaluated as a function of the Ar flow rate. In a continuous salt distiller, temperature distribution and the streamline of Ar gas flow in the distiller were analyzed.

2. Methods and Results

A bench scale salt distiller and a continuous salt distiller are employed for a salt evaporation of uranium deposits from an electrorefining process. Fig.1 and 2 show the schematic diagrams of the bench scale salt distiller and the continuous salt distiller. The continuous salt distiller was designed as a kiln type distiller. In the bench scale salt distiller, Ar gas flows downward as shown in Fig.1. In the continuous salt distiller, Ar gas is feeded into the kiln distiller through the two inlets which are located in front-end and back-end of the kiln distiller and is emitted through vacuum line. By using the commercial computational fluid dynamics code, ANSYS CFX, the distribution of the temperature and the Ar flow patterns in the distiller were calculated according to the Ar gas flow rate.

2.1 Bench scale salt distiller

An Ar gas flows downward from the upper inlet to the bottom vacuum line as shown in Fig.1. The distill tube is made of stainless steel. In the middle of the tube, a crucible containg the uranium deposit is heated by a heater. The salt evaporation is carried out at 700 °C and 0.05 Torr.

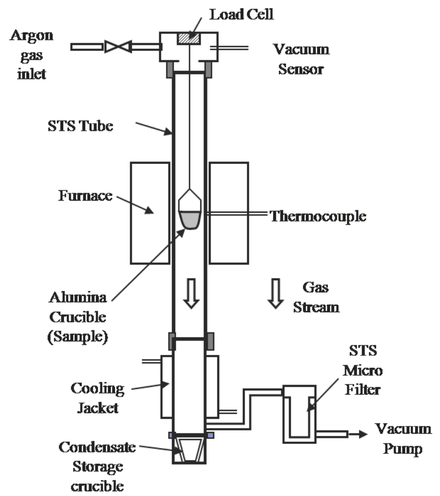

Fig.1 Schematic diagram of the bench scale salt distiller.

In the furnace region, the temperature was kept at 700 °C for a salt evaporation. The thermal analysis from the top to the bottom of the distill tube is important in understanding the behavior of salt evaporation and condensation. In order to analyze the salt evaporation system, the system was simplified. The distill tube was divided into 3 compartments, an Ar gas inlet upper region, a furnace region and an Ar gas outlet bottom region. By using the ANSYS CFX code, the temperature distribution in the tube was calculated with regard to the Ar gas flow. Fig.2 shows the result of the simulation at 1 mm/s Ar gas flow. In the furnace region, the temperature was higher than 700°C. In the bottom region, the temperature was lower than 700°C and the salt might condense in this region.

2.2 Continuous salt distiller

Uranium deposits are fed into the left chamber of the kiln type distiller. The uranium deposits are transferred by the rotation of the kiln. In the heating zone, the salt in the uranium deposits is evaporated at 700 ^{o}C and 0.05 Torr. The evaporated salt is transferred by an Ar carrier gas or condensed by the temperature drop. The temperature of the kiln is a function of the Ar gas. For simplicity of calculation, the distiller was designed as shown in Fig.3. In the regions of the front- and back-end chamber, the temperature of the outer walls is assumed to be 25^{o}C. When the outer wall in the heating zone is heated to 700^{o}C, the temperature distribution of the distiller was calculated by using the ANSYS CFX code according the Ar gas flow. Fig.3 shows the result of the simulation with 1m/s Ar gas flow at front- and back-end chamber, respectively.

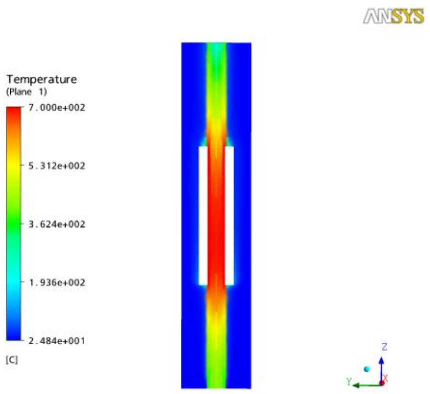

Fig.2 Calculated distributions of the temperature in the distill tube at 1mm/s Ar gas flow

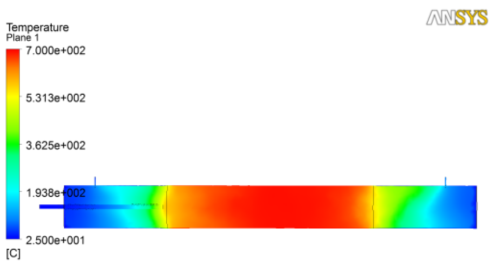

Fig.3 Calculated distributions of the temperature in the continuous distiller with 1m/s Ar gas flow.

3. Conclusions

By using a commercial computational fluid dynamics code, ANSYS CFX, the distribution of temperature in a bench scale salt distiller and a continuous salt distiller was evaluated according to the Ar gas flow. The calculated results can be useful to obtain the operation conditions of the salt evaporation and scale-up design data of the salt distiller.

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