# Evaluation of Capacity on a High Throughput Vol-Oxidizer for Operability

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## 1. Introduction

KAERI is developing a pyro-process. As a piece of process equipment, a high throughput vol-oxidizer which can handle a several tens kg HM/batch was developed to supply $U_3O_8$ powders to an electrolytic reduction(ER) reactor. To increase the reduction yield, $UO_2$ pellets should be converted into uniform powders. In this paper, we aim at the evaluation of a high throughput vol-oxidizer for operability. The evaluation consisted of 3 targets, a mechanical motion test, a heating test and hull separation test. In order to test a high throughput vol-oxidizer, By using a control system, mechanical motion tests of the vol-oxidizer were conducted, and heating rates were analyzed. Also the separation tests of hulls for recovery rate were conducted. The test results of the vol-oxidizer are going to be applied for operability. A study on the characteristics of the volatile gas produced during a vol-oxidation process is not included in this study.

## 2. High Throughput Vol-oxidizer

To design the high throughput vol-oxidizer, we evaluated various mechanical and chemical methods, and calculated the required volumes according to various weights and lengths of rod-cuts to design the reactor size. Also, by using the modeling and analysis tools, we built a 3D-model and performed an analysis of the main mechanisms for the safety design.

### *2.1 Mechanism device design*

To design the main mechanisms, we evaluated various mechanical (slitting, ball mill, roller straightening) and chemical methods (muffle furnace, rotary kiln). Through the analysis results, we selected a rotation method for a rotary drum to increase the decladding ratio of the rod-cuts.

### *2.2 Engineering design*

In order to design the size of the reactor, the bulk and compact volumes of the rod-cuts are measured in a beaker with scale (the number of rod-cuts: 20~100 EA), and proportional constants between the rod-cuts volumes and lengths (1~20 cm) are obtained. The size of the rod-cuts is referred to the model of KORI-spent fuel (PWR 14x14, 55,000 MWD/MTD).

The design considerations are as follows: the inner diameter is 300 mm, the rod-cuts are filled up to 50 % into the reactor. With the proportional constants and expansion ratio of $U_3O_8$ (2.7), we produced a theoretical equation that can estimate the volume of rod-cuts according to a variation of their weights (spent fuel: 5 kg, 20 kg, 50 kg, 100 kg) and lengths (3 cm, 5 cm, 7 cm, 10 cm). The reactor size was calculated by using the following theoretical equation;

$$V_t = f_i L_i N_i \frac{\pi D^2}{4} \tag{1}$$

($V_i$: theory volume, $f_i$: bulk factor, $L_i$: length of rod-cut, $N_i$: the number of rod-cuts, $D$: out-dia. of hull,)

### *2.3 Thermal analysis*

By using a design SW (SolidWorks) and analysis SW (COSMOSWorks), a thermal and mechanical analysis was conducted. The materials of some parts (shaft, mesh, heater modules) were considered for thermal analysis. The boundary conditions are as follows: the material of the reactor is the inconel 601, conditions in the reactor are 1300 ℃ and atmospheric pressure. The characteristics of heat transfer are analyzed during the variation of temperature. The boundary condition is as follows: the gap between the reactor and heater is 35 mm. We also measured the variation of the temperature in the reactor according to various gap sizes between the heater and the reactor (10, 20, 30, 50 cm).

## 3. Methods and Results

The vol-oxidizer was manufactured and an evaluation of this device was conducted as shown in Fig 1.

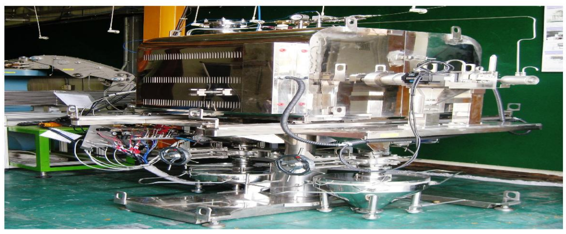

Fig. 1. High throughput vol-oxidizer.

### *3.1 Mechanical motion test*

Mechanical motion tests were conducted for targets (air cylinder, motor, vibrator, valve and clamper). From the test results of the vol-oxidizer for operability, each target operated without any difficulty. But utilities for air and electricity should be modularized to enhance operability and maintainability.

### *3.2 Heating test*

The reactor was heated up to 500 ℃. The heating rate was increased from 9 to 14 ℃/min. In the results, the range of the heating time is 35 minute- 55 minute as shown in Fig. 2 and Fig. 3. But an overvoltage appeared on 14 ℃/min. If a heating rate of 14 ℃/min were continued for a long time, the cutting of the heater wire with tantalum could occur. Therefore, If the distance between the heater and the reactor were 30 mm, the optimum heating rate should be below 14 ℃/min.

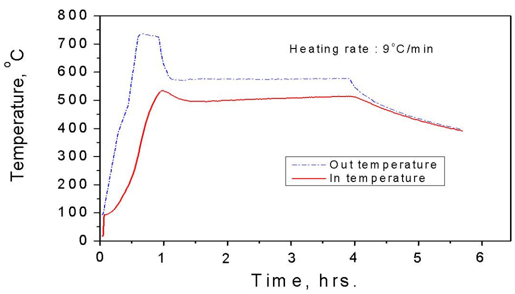


Fig. 2. Heating results at 9 ℃/min of heating rate.

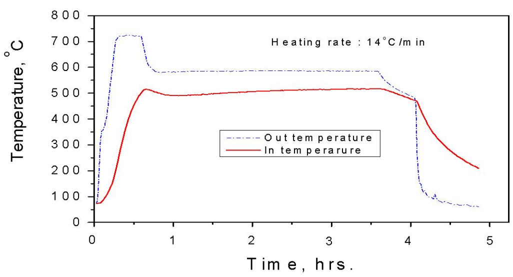


Fig. 3. Heating results at 14℃/min of heating rate.

### *3.3 Hull separation test*

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Hull separation tests were conducted using the vol-oxidizer and hulls with 50kgHM/batch for the recovery rate of hulls. The conditions of the hull separation tests are as follows; the rotation speed of the reactor is 3~5rpm and vibration didn't run. From the results of the hull separation tests, the recovery rate of the hull was 100% in the range of 10 kg to 50 kg of spent rod-cuts. But a recovery rate of the hull was 99% when the rotation speed of the reactor and the weight of the rod cuts were increased up to 10 rpm and above 40% (Table 1). Consequently, The Inlet size for the hull should be designed below 13% of the inlet size for powders.

As shown in Table 1, the recovery time of the hull decreased up to 87% when the rotation speeds of the reactor increased and the weight of the rod cuts were decreased. Also, when a rotation speed of the reactor was below 20 rpm, hulls didn't come out of the reactor because of centrifugal force. Therefore, rotation speeds of reactor should be below 20 rpm to enhance the recovery rate of the hulls.

Table 1: Recover rate of hulls

| Rod-cuts, Kg | The number of hull | RPM | The number of recovery | Recovery rate (%) | Time (sec) |
|---|---|---|---|---|---|
| 10 | 284 | 3 | 284 | 100 | 226 |
| | | 5 | 284 | 100 | 131 |
| | | 10 | 284 | 100 | 75 |
| 20 | 568 | 3 | 568 | 100 | 227 |
| | | 5 | 568 | 100 | 150 |
| | | 10 | 568 | 100 | 78 |
| 30 | 852 | 3 | 852 | 100 | 277 |
| | | 5 | 852 | 100 | 154 |
| | | 10 | 852 | 100 | 82 |
| 40 | 1136 | 3 | 1136 | 100 | 279 |
| | | 5 | 1136 | 100 | 165 |
| | | 10 | 1135 | 99 | 98 |
| 50 | 1420 | 3 | 1420 | 100 | 327 |
| | | 5 | 1419 | 99 | 171 |
| | | 10 | 1418 | 99 | 99 |

## 4. Conclusions

The new vol-oxidizer was manufactured and an evaluation of this device was conducted

The mechanical motion test operated without any difficulty, but utilities for air and electricity should be modularized to enhance operability and maintainability. If the distance between the heater and reactor were 30 mm, optimum heating rate should be below 14 ℃/min, and the inlet size for hulls should be designed below 13% on it for powders. Also, the rotation speeds of reactor should be below 20 rpm to enhance the recovery rate of hulls. The test results of the vol-oxidizer are going to be applied for operability

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