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Optimal Air Flow Rate and O_2 Concentration of UO_2 Pellet Vol-oxidation

Jae-Beop Uhm,a Young-Hwan Kim,a Jae-Hoo Jung,a Ji-Sup Yoon,b Woon-Kwan Chung
a Korea Atomic Energy Research Institute, Yusung, Daejeon 305-600, Korea, demo3195@naver.com
b Chosun University Department of Nuclear Engineering
375 Seosuk-dong, Dong-gu, Gwangju 501-759, Republc of Korea

1. Introduction

In the ACP(the Advanced Spent Fuel Conditioning Process), UO_2 pellet is converted into U_3O_8 powder since U_3O_8 powder is much desirable form for the following metallization process. The 20 kgUHM/batch size voloxidizer is under development in KAERI. Prior to the bulky and tricky 20 kg batch experiment, we tried to find the optimal condition of air flow rate and O_2 concentration, which provides the maximum oxidation rate and prevents scattering of the fine U_3O_8 powder in the reactor caused by the excessive air flow rate, by using the small sized oxidation reactor. This reactor is similar in structure with the full sized one. Also the particle size of oxidized U_3O_8 powder was measured using the particle size analyzer.

2. Experiment and Result

2.1 Experiment setup

Experiment setup of vol-oxidation device and its schematics are shown in Fig. 1 and Fig. 2. The reactor is made by SUS 304L, and its size is 100 mm in radius and 210 mm in height. It is temperature controlled up to 1200℃. It is equipped with the impeller and handle which simulate the motorized impeller of the full sized voloxidizer [1]. This motorized impeller makes the over 99% recovery rate of U_3O_8 powder.

Figure 1. Experimental setup

2.2 Experimental method

The irradiated natural uranium pellets of CANDU fuel are used [2]. A temperature is controlled to keep 500℃ which is revealed as the best temperature to obtain the maximum oxidation rate [2]. The oxidation time is measured while varying the air flow rate and O_2 concentration.

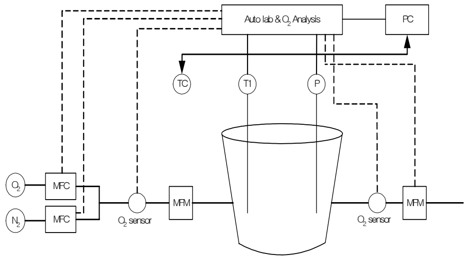

Figure 2. Schematics of the experiment setup

Also to check the powder scattering, the outlet port made by visible plastic pipe is monitored whether the scattered powder exists while varying the air flow rate. O_2 concentration was varied in the range of 21% to 40%. The theoretical amount of air required to oxidize five pellets is calculated to be 35,520 cc. Also from a series of experiments the oxidation time was revealed to be roughly 10-40 min. The logical air flow rate was assumed to be 1500 cpm(=35,520 cc / 24 min). Thus, the air flow rate was varied 500 through 2500 cpm.

2.3 Experimental result

Fig. 3 shows UO_2 pellets and oxidized U_3O_8 powder. Fig.4 shows the oxidation time with various O_2 concentrations and the air flow rates. As can be seen in the figure the oxidation time is reduced as the O_2 concentration increase. However the excessive O_2 concentration may cause safety problem and in this regards, the optimal concentration was set 40 % [2]. The oxidation time decreases with the increased flow rate and the optimal flow rate is revealed to be 2000 cpm regardless of changing O_2 concentration. On the contrary, the oxidation time increases with larger flow rate of 2000 cpm. This can be explained that thin oxidation film is formed at the surface of pellets due to rapid oxidation and it interferes with the direct contact of O_2 with the inner part of the pellet.

Throughout the experiments, the visible outlet port was monitored whether the powder scatters. No scattering was monitored. This shows that the powder does not scatter in the given geometry of the reactor throughout the range of the air flow rates.

Whether the UO_2 pellet is fully changed to U_3O_8 powder, XRD(X-Ray Diffraction) and TGA (Thermogravimetric Analysis) [4] have performed. The results are shown in Fig.5 and 6. The pattern shown in Fig.5 represents the typical XRD of U_3O_8, which shows that the UO_2 pellets are fully converted to U_3O_8. Also as can be seen in Fig.6, the weight change of the sample powder can not be found while heating it up to 700℃. This shows that the powder has already been fully changed to U_3O_8.

Figure 3. UO_2 pellets and U_3O_8 powders of a vol-oxidation experiment

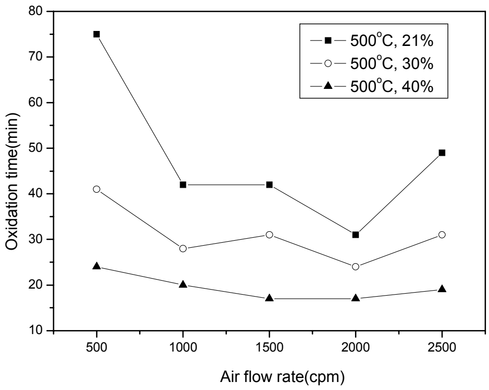

Figure 4. The oxidation time classified by the air flow rate and O_2 concentration

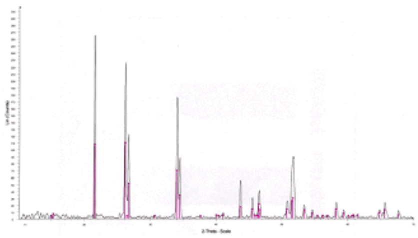

Figure 5. The analysis result of XRD in a vol-oxidation experiment

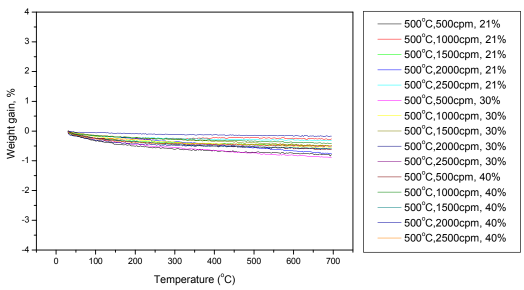

Figure 6. The analysis result of TGA in a vol-oxidation experiment

The particle size of U_3O_8 powder is shown in Fig 7. The average particle size is about 50 ㎛. In the metallization process, the desirable particle sizes of U_3O_8 powder is in the range of 20 ㎛ to 60 ㎛ [1,5].

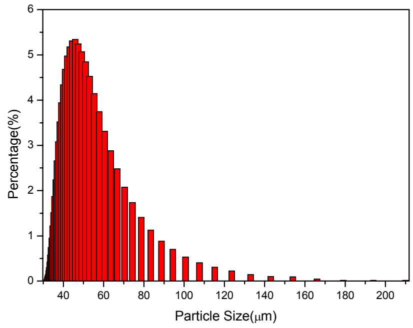

Figure 7. The average particle sizes of U_3O_8 powders

3. Conclusion

The optimal air flow rates and the O_2 concentration for vol-oxidation process has been investigated from a series of the oxidation experiments of UO_2 pellets using the small reactor. Also TGA and XRD analysis performed to check whether the UO_2 pellets are fully oxidized. The results shows that the optimal condition, which minimizes the oxidation time, are 2000 cpm of air flow rate and 40% of O_2 concentration at 500℃. Also all the UO_2 pellets were found to be fully oxidized to U_3O_8. This will be used to find out the optimal condition of the 20 kg/batch size vol-oxidation reactor.

Acknowledgement

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