

## Introduction of slip casting for disposition solidification fabrication using $\text{CeO}_2$

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### 1. Introduction

SF(Spent nuclear Fuel) contains both highly toxic, long half-life, and high heat dissipation nuclides that pose a direct disposal burden, as well as recyclable nuclear species such as U and Pu. Therefore, selective separation and capture of major nuclides contained in spent fuel can reduce the environmental burden (disposal area and stability) of spent fuel disposal and maximize disposal efficiency. After separation of the major nuclides, only the powdered form of  $\text{U}_3\text{O}_8$  remains. The remaining spent nuclear fuel also needs to be returned to the disposal facility, but in this case, it should be returned in a solid form rather than a powdered form[1]. Therefore, it is necessary to manufacture and re-sinter  $\text{UO}_x$  blocks, and if it is possible to make pellet with a large-scale block, the sintering time and the cost can be reduced, helping to reduce the disposal area. We introduced the slip casting method to manufacture large-scale  $\text{UO}_x$  blocks, and established the feasibility of manufacturing with  $\text{CeO}_2$  powder, which has similar uranium chemical properties, and the optimal conditions for each process.

### 2. Methods and Results

In this section some of theory and flow of the research are described. What slip casting is, why it was selected and the optimal conditions for each process to manufacturing large-scale oxide blocks.

#### 2.1 Slip casting

Originally used to make pottery, it is now used to mold ceramic and metal powders. It has known to be able to obtain more than 60% of the theoretical density by using the capillary phenomenon of porous molds. This method has the advantages of low production cost, no dangerous process, and easy to make by anyone compared to other molding methods. The slip is prepared by mixing the raw material powder with a water and injected into the mold, which causes the plaster mold to absorb and remove moisture. This is then sintered at a high temperature(1,600 °C) to form the final molded material. The flow diagram of slip casting is shown in Figure. 1.[2]

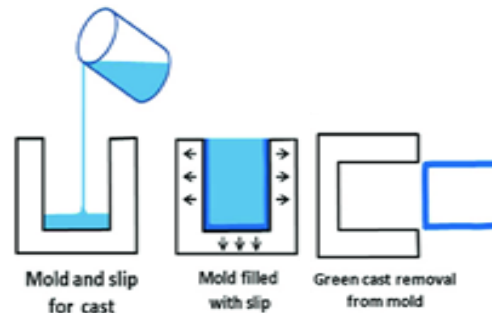


Fig. 1 Flow diagram of slip casting.

#### 2.2 Why slip casting was selected

##### 2.2.1 Density difference in the pellet

When the diameter and height are small, the density difference inside the pellet is small, but as the diameter and height increase, the pellet density gradient inside the mold can cause defects.

##### 2.2.2 Limitations in selecting to press

Since pressure is inversely proportional to surface area, a diameter of about 100 mm would require a press with 100 times the capacity of the presses used to mold nuclear fuel for commercial power plants. These presses are limited for experimental use and difficult to install and operate in hot cells that will handle spent fuel in the future.

##### 2.2.3 High theoretical density

Slip casting allows for the production of ceramic products with a high theoretical density, often exceeding 60%.

##### 2.2.4 Cost-effectiveness

The method is relatively cost-effective compared to some alternative manufacturing techniques, making it an economical choice for certain applications.

##### 2.2.5 Safe process

Slip casting does not involve hazardous processes, making it a safer option compared to some other shaping methods in the production of ceramics.

##### 2.2.6 Ease of production

The technique is known for its simplicity, allowing for easy production. This ease of use makes it accessible to a wide range of individuals.

### 2.3 slip casting process

In this study, slip casting was divided into six processes to identify the optimal conditions.[3]

#### 2.3.1 Preparing a binder

Since  $\text{UO}_2$  powder has poor plasticity, a binder is used. In this study, sodium carboxymethyl cellulose (CMC) was used as a binder. The binder was prepared by mixing CMC and distilled water at a volume ratio of 1:100.

#### 2.3.2 Slip Manufacturing

Mix 200 ml of water with 20 ml of binder and add the  $\text{CeO}_2$  powder little by little while stirring with a stirrer. If the viscosity of the slurry is high and the rotation of the stirrer slows down, add a dispersant to reduce the viscosity. In this study, Darvan C (Ammonium polymethacrylate aqueous solution) was used as a dispersant, and about 400cc of  $\text{CeO}_2$  powder was used.

#### 2.3.3 Injection and molding

The slurry should be injected into the mold as soon as possible before it settles to the bottom. If the slurry concentration is too high, the center will rise convexly, and if the concentration is low, the center will sink concavely. In this study, plaster molds with diameters of 30, 60, and 95 mm were used.

#### 2.3.4 Demolding

When the mold has absorbed all the moisture from the slurry, lift the mold upside down to allow the mold to demold under its self-load. Holding the mold at an angle can damage the mold by colliding with the mold, so hold it upright.

#### 2.3.5 Wet dry

The residual moisture in the slurry after demolding from the mold must be removed. In the case of dry drying, the drying speed of the slurry inside and outside should be similar, as the difference in drying speed can damage the slurry. For this purpose, wet drying was performed instead of dry drying.

#### 2.3.6 Sintering

It was sintered for about 10 hours at  $1,600\text{ }^\circ\text{C}$  in an  $\text{Ar}+4\%\text{H}_2$  atmosphere. CMC and impurities were volatilized at  $625\text{ }^\circ\text{C}$  for about 2 hours before sintering.

### 3. Conclusions

The slip casting method utilized in the manufacture of pottery and ceramics has been successfully introduced and applied to the manufacture of  $\text{CeO}_2$  oxide blocks, and the results are shown in Figure 2.



Fig 2. Sintered large-scale  $\text{CeO}_2$  block.

Through this study, we have established a process for the production of solids for disposal using  $\text{CeO}_2$  powder and derived the optimal conditions for each process. In addition, this technology can be applied to the production of  $\text{UO}_x$  blocks from uranium powder which is radioactive material in the future. It can significantly contribute to the management of  $\text{U}_3\text{O}_8$ , the final byproduct of spent nuclear fuel.

### REFERENCES

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