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# Relation Between Density and Porosity in Sintered $UO_2$ Pellets

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## Abstract

The relation between sintered densities and porosities in $UO_2$ pellets is investigated. The open porosity decreases linearly up to about 95% T.D.(theoretical density) as the sintered density increases whereas, above 96% T.D., sintered $UO_2$ pellets do not have any open pores. The fraction of open porosity to the total porosity also decreases linearly as the sintered density increases, though the slope is lower than that of open porosity and, above 95% T.D., the fraction decreases rapidly to approach a zero.

**Key Words** : sintered density, $UO_2$ pellet, open porosity, closed porosity

## 1. Introduction

$UO_2$ is the most widely used as a nuclear fuel for current nuclear power generation. The fabrication process of $UO_2$ pellets is generally similar to powder metallurgy. Pores are an inherent part of sintering. Accordingly, porosities are present in $UO_2$ pellets. Total porosity includes both open (those connected to the surface) and closed(those not connected to the surface) pores. In general, open pores directly affect properties such as permeability, vacuum tightness, and surface available for catalytic reaction and chemical attack, whereas closed pores have little effect on these properties[1]. In the case of $UO_2$, if any open pores are present in a pellet, moistures in air can be much easily adsorbed through open pores. Moisture-adsorbed pellets can degrade the function of fuel during operating in the nuclear power plant. Therefore it is requested to fabricate a pellet without open porosity to avoid any moisture adsorption.

In this work, a relation between the sintered density and the porosity(open and closed) is investigated as a function of density for the sintered $UO_2$ pellets.

## 2. Experimental

ex-AUC $UO_2$ powders, which were manufactured from a UNH solution in KAERI, were used in this work. In order to adjust the sintered density of UO2 pellets, various contents of zinc stearate(0~4wt%) were admixed with the $UO_2$ powder. In the case of zinc stearate admixed in $UO_2$ powder, sintered density of $UO_2$ pellet decreased 4%T.D.(Theoretical Density) as 1 wt% of zinc stearate was admixed. Cylindrical compacts were prepared from the mixtures at various compacting pressures in the ranges between 200 and 500MPa, using a constant weight fill of 20g of $UO_2$ powder, by means of a double acting hydraulic press. These compacts were sintered at 1700℃ for 4 hrs under a hydrogen gas atmosphere in a continuous pusher-type furnace. Sintered density of $UO_2$ pelles was measured by impregnation method with m-xylene solution. From the data obtained by density measurement using m-xylene, open porosity, $\varepsilon_o$, can be calculated as follows[2,3] :

$$\varepsilon_o = \frac{W_{sat} - W_{dry}}{W_{sat} - W_{susp} - W_{dry}\frac{\rho_x}{\rho_{TD}}} \times 100\,(\%)$$

where $W_{sat}$, $W_{dry}$ and $W_{susp}$ are the saturated weight, the dry weight and the suspended weight of $UO_2$ pellet, respectively. $\rho_x$ and $\rho_{TD}$ is the density of m-xylene and the density of $UO_2$ pellet, respectively.

## 3. Results and Discussion

Fig. 1 shows open porosity, $\varepsilon_o$ and open porosity/total porosity, $\varepsilon_o/\varepsilon_t$ as a function of sintered density for the sintered $UO_2$ pellet and Fig. 2 shows a magnification of part A in Fig. 1. As shown in these figures, the curves of $\varepsilon_o$ and $\varepsilon_o/\varepsilon_t$ is of a sigmoidal type as a function of

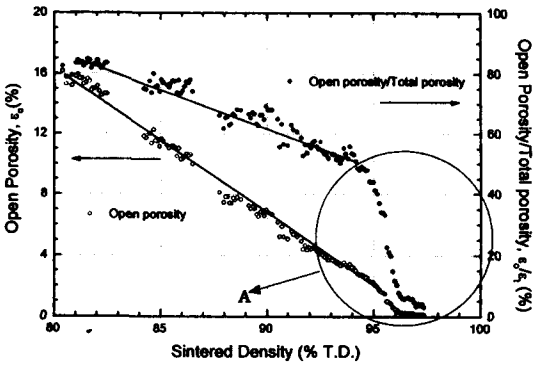


**Fig. 1. Open Porosity and Open Porosity/Total Porosity as a Function of Sintered Density of $UO_2$ Pellet**

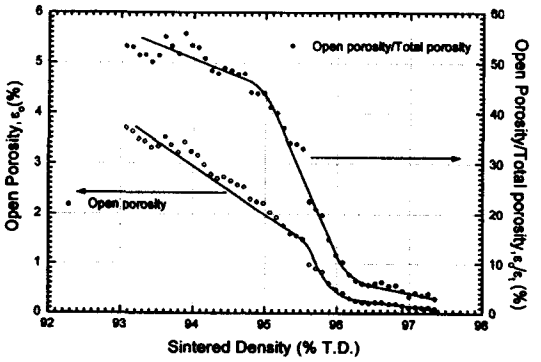


**Fig. 2. Magnification of Part A in Fig. 1**

sintered density. That is, the open porosity decreases with a linear relation ($\varepsilon_o$ = 94.09-0.97x, x ; sintered density(%T.D)) up to 95% T.D. But above this density, the open porosity decreases rapidly and nearly all the open pores eliminated when the sintered density reached to 96% of theoretical density. This is in good agreement with other results[4-6]. The curve of $\varepsilon_o/\varepsilon_t$ shows a similar tendency to that of $\varepsilon_o$. That is, $\varepsilon_o/\varepsilon_t$ decreases with a linear relation ($\varepsilon_t/\varepsilon_t$ = 294.3-2.6x) up to about 94%T.D. At this sintered density, both the open and closed pores are present in nearly equal amounts. Thereafter, $\varepsilon_o/\varepsilon_t$

decreases rapidly toward 0% at about 96%T.D.

Therefore, in order to avoid any moisture adsorption on a pellet surface through open porosities, it is necessary to fabricate the sintered pellet having a density of at least 96%T.D.

## 4. Conclusions

Results of the experiments described in this work lead to the following conclusions :

1) Open porosity decreases in a sigmoidal type as the sintered density increaes.
2) Open porosities are not present in $UO_2$ pellets having a density of at least 96%T.D. in this fabrication process.

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