The effect of additives on the pore structure of sintered UO_2 pellets

Jang Soo Oh, Jae Ho Yang, Dong-Joo Kim, Jong Hun Kim, Keon Sik Kim, Young Woo Rhee, Yang-Hyun Koo*

Korea Atomic Energy Research Institute,
989-111 Daedeokdaero, Yuseong-gu, Daejeon-si 305-353, Korea
jangsoo@kaeri.re.kr

1. Introduction

In order to enhance the nuclear fuel safety, it may be the essential solution to reduce the fission gas release and improve the pellet-cladding interaction (PCI). The PCI improvement can be achieved by enlarging the pellet grain size and enhancing the fuel deformation at an elevated temperature. Large grain pellets can reduce fission gas release and deform easily at an elevated temperature. So, the recent development of advanced fuel pellet materials is mainly focused on the large grain pellets[1].

The fabrication of large grain UO_2 pellets has been investigated extensively. Among those, additives doping technology has been widely studied due to its effectiveness at increasing grain size and compatibility with an industrial pellet fabrication process. Cr_2O_3 doped UO_2 pellets and MnO and Al_2O_3 doped UO_2 pellets are being developed as a potential candidate for PCI solution by KAERI[2,3].

The UO_2 pellet properties (such as density, pore structure, and grain size) greatly influence the in-reactor performance of the UO_2 pellet. The density and pores of sintered UO_2 pellets are important factors to assure a stable nuclear reactor control, because they have large effects on the densification and swelling behavior of nuclear fuel during an irradiation. [4].

In this paper, the effect of pore structure on sintered UO_2 pellets with additives was investigated by measuring pore size and pore numbers of relative axial position in pellet. Also, the density of relative axial position in pellet was calculated by image analysis program.

2. Experimental

The staring materials were UO_2 powder produced through the Integrated Dry Route (IDR) UO_2 powder. Cr_2O_3 powder and mixture of MnO and Al_2O_3 powder were selected as additives. The composition of additives are 95MnO-5Al_2O_3(mole%). Amount of the Cr_2O_3 in UO_2 was determined to be 1000, 1500ppm in weight ratio of Cr to U. The contents of the Cr_2O_3 were determined to be 1500ppm in weight. The contents of the MnO-Al_2O_3 additive were determined to be 1000ppm (Mn+Al)/U in weight. These powders were mixed for 12h using tumbling mixer. The prepared additives containing UO_2 powder mixtures were pressed into green pellets at 3 ton/cm^2. The green pellets were sintered by using two sintering process. The Cr_2O_3 doped UO_2 pellet was sintered at1700°C for 4h in mix gas of H_2 and CO_2. The Mn-Al doped UO_2 pellets were sintered at 1730°C for 6h in H_2. For comparison, pure undoped UO_2 pellets were also prepared.

The sintered density of the UO_2 pellets was measured by the water immersion method. The pellets were sectioned axially, ground and polished. Optical images were sequentially and equidistantly taken along the axial line of pellets.

The pore number, pore size and pore area in an individual image were calculated by using image analyzer. The polished pellets were thermally etched at 1290°C in carbon dioxide gas in order to examine their grain boundaries. The grain structures were examined by an optical microscope and the grain size was determined by the linear intercept method.

3. Results

Fig. 1 shows density variation along the axial position in sintered pellets. The average density of doped UO_2 pellets increased more than pure UO_2 pellet. Standard deviation of density in pure UO_2 and Cr-doped UO_2 pellets is high. However, in case of Mn-Al doped UO_2 pellet, standard deviation is low. Generally, the margin of error between calculated average density and measured density is less than 1%

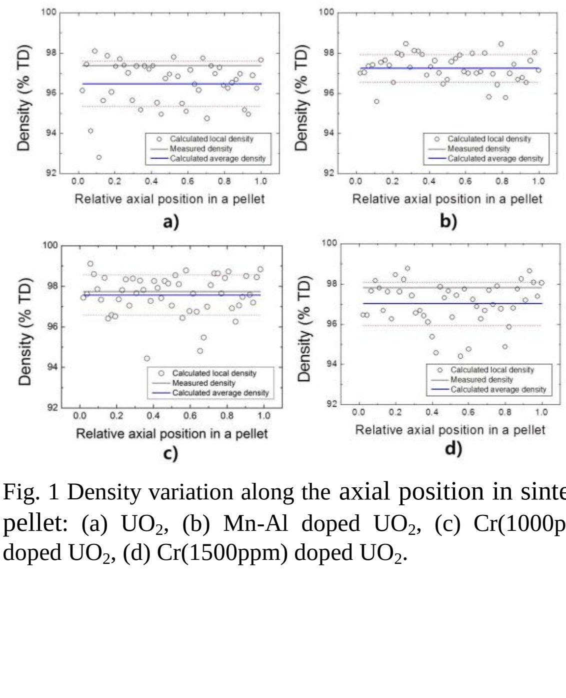

Fig. 1 Density variation along the axial position in sintered pellet: (a) UO_2, (b) Mn-Al doped UO_2, (c) Cr(1000ppm) doped UO_2, (d) Cr(1500ppm) doped UO_2.

Fig 2 shows the number of pore along the axial position in pellets. The pure UO_2 pellet had quite a number of pores. The number of pore in pure UO_2 pellet had about 4 times more than Mn-Al doped and Cr(1500ppm) doped UO_2 pellets. In case of Cr doped UO_2 pellet, the number of pore in pellets decreased with increase of Cr contents. It is revealed that additives decrease the number of pore in sintered pellets. In case of doped pellets, peripheral region in doped UO_2 pellets tends to increase the number of pore.

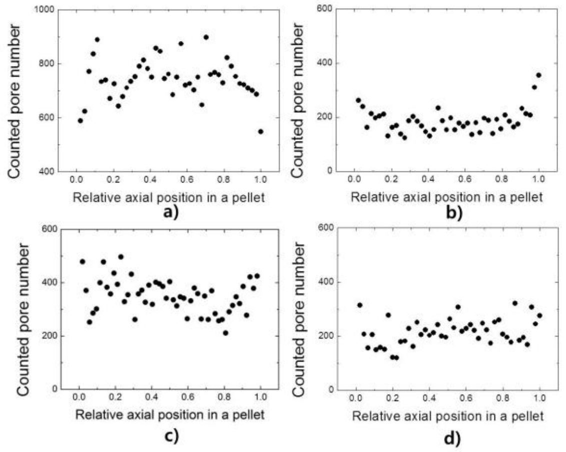

Fig. 2 The number of pore variation along the axial position in sintered pellet: (a) UO_2, (b) Mn-Al doped UO_2, (c) Cr(1000ppm) doped UO_2, (d) Cr(1500ppm) doped UO_2.

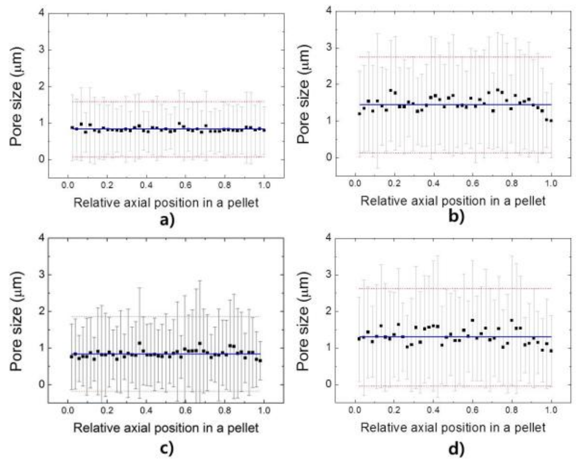

Fig. 3 The pore size variation along the axial position in sintered pellet: (a) UO_2, (b) Mn-Al doped UO_2, (c) Cr(1000ppm) doped UO_2, (d) Cr(1500ppm) doped UO_2.

Fig 3 shows the pore size along the axial position in sintered pellets. The average pore size of doped UO_2 pellet is bigger than pure UO_2 pellet. Also, the pore size deviation of relative axial position in doped UO_2 pellet increased more than pure UO_2 pellet. In case of Cr doped UO_2 pellet, the average pore size of pellets increased with increase of Cr contents. It is revealed that the additives have an influence on the pore size

4. Conclusions

To study pore structure on sintered UO_2 pellets with additives, pore size, pore number and density along the axial position were investigated by image analysis program.

As a result, when the additives were add to UO_2 pellet, pore size increased and the number of pore decreased more than pure UO_2 pellet.

Amount of additives and kind of additives have an influence on the pore structure in pellets.

ACKNOWLEDGEMENT

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