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Effect of the UO_2 powder type and mixing method on microstructure of Mn-Al doped pellet

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1. Introduction

Recently, the commercial LWRs are focused on the extending the burn-up and fuel cycle length in order to increase nuclear power plant economy as a maintenance and fuel cycle cost. Increasing the burn-up may lead to a faster and higher power variation such as a peak local linear power and normal operating transient (Load following operation). In such operating conditions, the risk of a fuel failure is considerably related to a pellet-clad-interaction (PCI). So, recent development of advanced UO_2 pellet for the LWRs is mainly focused on the large grain and soft pellet as they can reduce corrosive fission gas release and pellet-clad-interaction. In terms of the UO_2 pellet, the prevention of PCI induced fuel failure can be achieved by enlarging the UO_2 pellet grain size and enhancing the pellets deformation at an elevated temperature [1]. In Korea, in order to increase the grain size and deformation of UO_2 pellet on the high temperature, Mn-Al doped pellet with ADU (Ammonium Diuranate)-UO_2 powder are developed in lab scale [2]. But, the UO_2 pellets for the commercial nuclear power plants in Korea are fabricated using the DC (Dry Conversion)-UO_2 powder. So, it is necessary to understand the effect of microstructure on UO_2 powder type for Mn-Al doped pellets.

In this work, to investigate the effect of UO_2 powder type and mixing method on the microstructure of the Mn-Al doped UO_2 pellets, we fabricated the Mn-Al doped pellets using the DC-UO_2 powder. The measurement of sintered density and mean grain size for fabricated pellets was performed, and then the results of test was evaluated in comparison with a Reference 2.

2. Experimental procedure

The starting materials of Mn-Al doped pellets were UO_2 powder produced through the DC process at KEPCO NF. The contents of the additives were MnO and Al_2O_3 and controlled to be 1000 ppm in weight as a (Mn+Al)/U ratio. The additive materials of MnO and Al_2O_3 powders were evenly mixed using a ball milling in a jar containing zirconia balls and alcohol for 20hr. After the ball mill, the suspensions of powder mixture were dried in air. Also, in order to change the mean grain size for Mn-Al doped pellets according to the differential mixing method, UO_2 powder mixture was mixed using ball mill, tumbler mixer and rotary mixer. The prepared MnO-Al_2O_3 containing DC-UO_2 powder mixtures were pressed into green pellets at 1.5 ton/cm^2. The green pellets were sintered at 1730℃ for 4hr in flowing H_2 gas.

The sintered density of the UO_2 pellets was measured by the water immersion method. Also, the sintered pellets were cut in an axially direction, and then a grinding and polishing process was performed. The surface-polished pellets were thermally etched at 1300℃ 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. The test condition of the UO_2 powder types and mixing process in this study are shown Table 1.

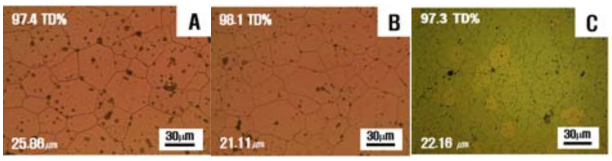
Table 1. The test condition of the UO_2 powder types and mixing method in this work

Sample	UO_2-Powder	Additives (dopant)	Mixing method
A	DC	MnO+Al_2O_3	Tumbler for 4hr
B	DC	MnO+Al_2O_3	Rotary mixer for 4hr
C	DC	MnO+Al_2O_3	Ball mill for 24hr
D* [Ref. 2]	ADU	MnO+Al_2O_3	Tumbler for 2hr

*** The sample D was fabricated according to Reference 2.**

3. Results

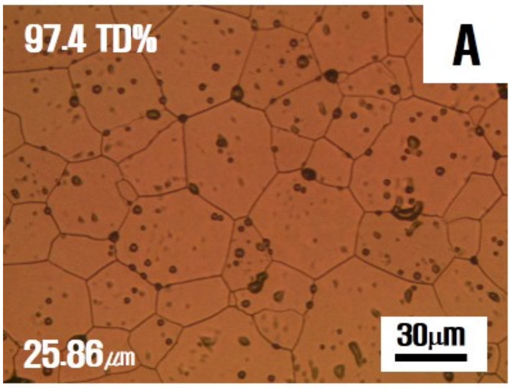
Fig. 1 shows that microstructure of Mn-Al doped pellets depending on the mixing method of UO_2 powder mixture. As shown in Fig. 1, the sintered densities of Mn-Al doped pellets according to the mixing process were nearly similar each other ranging from 97.3 TD% to 98.1 TD%. In addition, the grain size of all samples despite of the difference of mixing method was nearly the same.



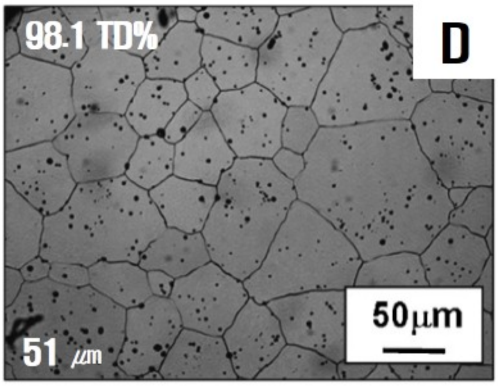
(a) tumbler mixing (b) rotary mixing (c) ball milling

Fig. 1 Microstructure of Mn-Al doped pellets depending on mixing method of UO_2 powder mixture

Fig. 2 shows that microstructure of Mn-Al doped pellets by an optical microscope. As shown in Fig. 2, the sintered density of Mn-Al doped pellets using the DC-UO_2 powder is 97.2 TD% and was nearly similar to the results of the Ref. 2 using the ADU-UO_2 powder which has sintered density about 98.1 TD%. Contrastively, the mean grain size of the sintered pellets using the DC-UO_2 powder is 26 μm and about half the size than results of the Ref. 2 using the ADU-UO_2 powder which has mean grain size about 51 μm. From the above results, it was considered that the sintering behavior of DC-UO_2 powder and ADU-UO_2 powder seems different. As a reference [3], linear shrinkage of green pellets with a DC-UO_2 powders during the sintering was much smaller than an ADU-UO_2 powder at a certain temperature. Thus, smaller agglomeration particles of ADU-UO_2 powder act as seeds during liquid phase sintering and the grain growth of Mn-Al doped pellets using ADU-UO_2 powder is accelerated faster than that of DC-UO_2 powder. Therefore, the mean grain size of Mn-Al doped pellets using the DC-UO_2 powder is much smaller than that of the ADU-UO_2 pellets, because the effect of grain growth on a liquid phase of Mn-Al during the sintering is less than those of the ADU-UO_2 powder.



(a) DC-UO_2 powder



(b) ADU-UO_2 powder [2]

Fig. 2 Microstructure of Mn-Al doped pellets according to the UO_2 powder types

4. Conclusion

In this work, to investigate the effect of UO_2 powder type and mixing method on the microstructure of Mn-Al doped UO_2 pellets, we fabricated the Mn-Al doped pellets using the DC-UO_2 powder. The measurement of sintered density and mean grain size for fabricated pellets was performed, and then the results of test was evaluated in comparison with a reference. As a results of test, the mean grain size of Mn-Al doped pellet using the DC-UO_2 powder is about half the size than that of Mn-Al doped pellet using the ADU-UO_2 powder. In addition, the sintered density of fabricated UO_2 pellet regardless of the UO_2 powder mixture mixing method was nearly the same.

In the future study, regarding preceding research or, if required, additional test needs to be carried out to support the experimental results.

ACKNOWLEDGEMENT

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