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Evaluation of Effect of Chamfer Shape of UO_2 pellet on Impact Resistance by Drop Impact Test

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1. Introduction

There are many ongoing research projects for improving the characteristics of PCI(Pellet-Clad Interaction) failure and applying it to commercial products in the world while nuclear power plants extending the fuel discharged burn-up and fuel cycle. Missing pellet surface(MPS) is one of deterioration caused by pellet-clad mechanical interaction(PCMI) mechanism of cladding in nuclear power plants and it results in reducing the product quality and integrity of nuclear fuels[1]. Thus, in order to increase the MPS resistance of UO_2 pellets, it is very important to improve the toughness and to change the shape of UO_2 pellet end-face[2]. Especially, changing the shape of UO_2 pellet end-face is able to effectively improve MPS resistance of UO_2 pellet. Therefore, this study selected candidate MPS resistance UO_2 pellet end-face shape by FEA(Finite Element Analysis) and then performed drop impact test using candidate MPS resistance UO_2 pellet.

2. Drop impact test simulation by FEA

In order to evaluate the impact resistance according to the chamfer angle of the UO_2 pellet's end-face, the impact test simulation by FEA was performed. As the results of FEA, Fig. 1 shows the relations between the UO_2 weight loss and first contact force with the chamfer angle of UO_2 pellet. As the chamfer angle increases, the weight loss of UO_2 decreased, but the weight loss gradually increased when the chamfer angle exceeds 18 degree.

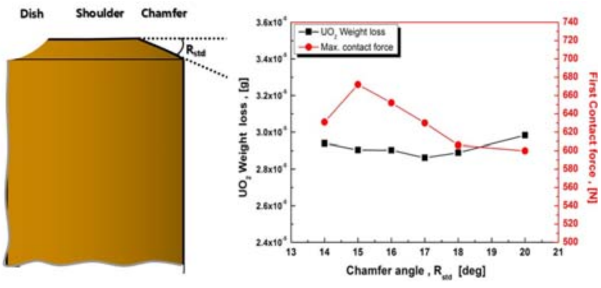

Fig. 1. Weight loss and contact force of UO_2 pellet with chamfer angle by FEM analysis

Also, the contact force of chamfer surface with the chamfer angle showed that at 15 degree of the chamfer angle, the contact force was the highest, and gradually decreased at 15 degree or more.

3. Experimental procedure

3.1. UO_2 pellet fabrication

Based on the results of the FEA, the candidate shapes of MPS resistance UO_2 pellet used as shown in Table. 1. The UO_2 pellets used the drop impact test were fabricated based on a commercial UO_2 pellet fabrication process. The starting materials were UO_2 powder produced through DC(Dry Conversion) process. These UO_2 powders were mixed with a tubular mixer for 4 hours. The prepared UO_2 powder mixtures were pressed into green pellets at 3 ton/cm^2. The green pellets were sintered at 1750℃ for 4h in flowing 100% H_2 gas. Fig. 2 shows UO_2 pellet of 5 types with various end-face shapes.

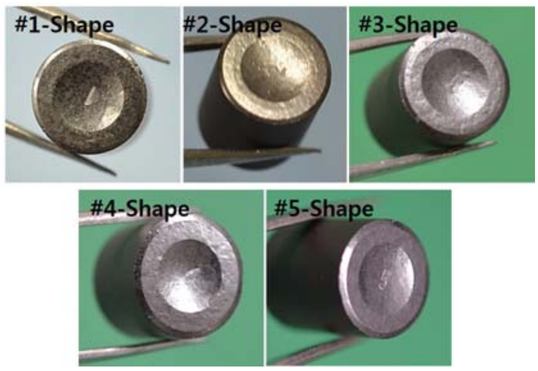

Fig. 2. 5 types of UO_2 pellet's end-face shape using commercial fabrication process

The sintered density of the fabricated UO_2 pellet was measured by the water immersion method. And then, sintered pellets was polished. The polished pellets were thermally etched at 1300℃ in CO_2 gas in order to examine their grain boundaries. The grain structures were examined by optical microscope and the grain size was determined by linear intercept method. The mean sintered density of all fabricated UO_2 pellets were 95 TD. % and mean grain size was 12 ㎛. Therefore, the quality of the all fabricated UO_2 pellets, such as microstructure and porosity, can all be evaluated to be the same.

Table 1. The end-face shape of candidate MPS resistance UO_2 pellet

ID. No.	End-face shape	Normalized Shoulder Length	1st chamfer angle $[R_S/R_{STD}(\Phi)]$	2nd chamfer angle $[R_S/R_{STD}(\Phi)]$
#1-Shape	Double chamfer	0.1734	1.1284	0.7529
#2-Shape	Double chamfer	0.5000	1.1284	0.7529
#3-Shape	Double chamfer	0.7500	1.1284	0.7529
#4-Shape	Double dish-chamfer	-	1.1284	0.7529
#5-Shape	Single chamfer	1	-	0.7529
Reference-Shape(STD)	Single chamfer	1	-	1.0000

3.2. Drop impact test

As shown in Fig. 3, the drop impact test used in this study is INSTRON's CEAST 9310 model, which applies very low impact energy to measure the impact fracture behavior of material in through data logger. The drop impact test was carried out for impact angles of 5, 25, 45, 75 and 85 degrees, respectively, and was applied to 0.07 joule. In addition, the impact tests were performed 20 times for each impact angle.

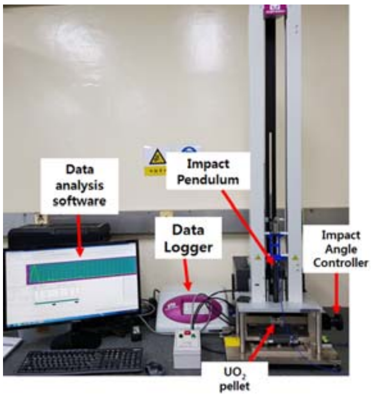

Fig. 3. The picture of drop impact tester

4. Results and discussion

Fig. 4 shows the chipping ratio of UO_2 pellet with various impact angle at impact energy of 0.07 joule by drop impact test. As shown in Fig. 4, at the impact angle of 45 degree, when the impact force was applied to the chamfer of the UO_2 pellet, impact force is transmitted perpendicular to the chamfer plane, and the impact force was absorbed in the UO_2 pellet so that it is judged that the chipping ratio was hardly occurred. On the contrary, the UO_2 chipping ratio was the highest at impact angle of 85 degree regardless of end-face shapes.

Meanwhile, the chipping ratio of #2-shape was not only the lowest (below 0.8%) at all impact angle but also had the highest impact resistance at the impact angle of 85 degree in severe test condition. In particularly, #2-shape is similar to #1 and #3-shape, but has a normalized shoulder length of about 0.5 and it is judged that the impact resistance of the UO_2 pellet by external impact is maximized.

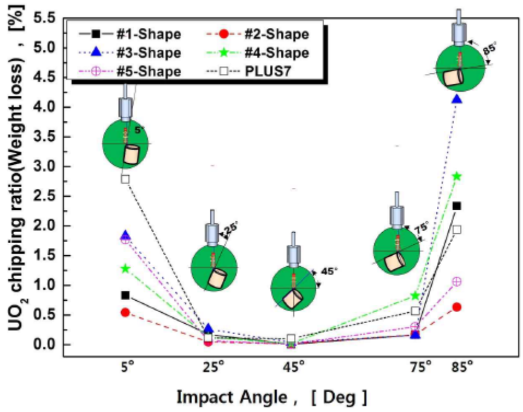

Fig. 4. The chipping ratio of UO_2 pellet with various impact angle at impact energy of 0.07 joule by drop impact test

5. Conclusion

In this study, in order to evaluation of MPS resistance with various end-face shape of UO_2 pellet, we were designed 5-types end-face shape of MPS resistance UO_2 pellets by FEM analysis, and then the drop impact test using fabricated 5-types candidate UO_2 pellet performed. Based on the above results, #2-shape among the 5-types candidate end-face shape was very superior impact resistance. Also, it is judged that the impact resistance of the UO_2 pellet by external impact is maximized when the normalized shoulder length is 0.5.

Acknowledgment

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