Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Stress analysis of pellet as a function of its shape

Jin-Seok Lee, Ho-Sik Yoo*, Joon-Hyung Choi, Yoon-Ho Kim, Jung-Min Suh, Jong-Sung Yoo

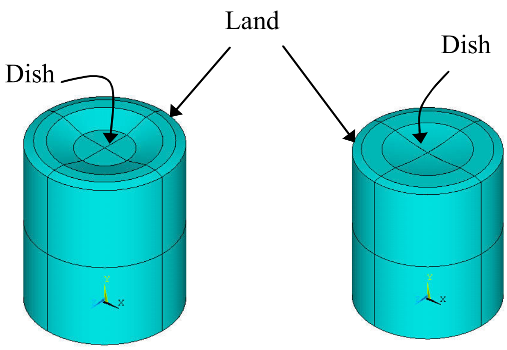
Korea Nuclear Fuel Co. Daejeon, 305-353, Korea

**National Nuclear Management& Control Agency. Daejeon, 305-732, Korea*

E-mail : jslee@knfc.co.kr

1. Introduction

Morphology of UO_2 pellet used as a nuclear fuel in the atomic plant is an important factor to determine the integrity of fuel rod during the operation[1-2]. Most of the commercial UO_2 pellet has chamfer and dishing even though their detailed dimension and shape are different according to the manufacturer. Both chamfer and dishing are given to pellet for preventing bambooing and for accommodating the expansion of pellet to the axial direction due to swelling during operation. Currently, two different dishing types are used such as truncated and cylindrical shape. The newly developed fuel, PLUS7^{TM}, has adopted cylindrical shape as its dishing morphology while the truncated shape has been used in the conventional fuel for KSNP reactor. In addition to the dishing shape, dimensions of the PLUS7^{TM} pellet are different from those of the conventional pellet as shown in Figure 1. Except for the dishing shape, the width of the land area is also one of the major differences between two pellets. The PLUS7^{TM} pellet has a wide land area in comparison with the conventional pellet. The effect of pellet shape on the stress distribution of the rod is an interesting subject but there has been no substantial attempt for analysis. In this study, the stress analysis on two different shaped pellets had been performed to figure out how differently the stress is distributed according to the pellet shape.

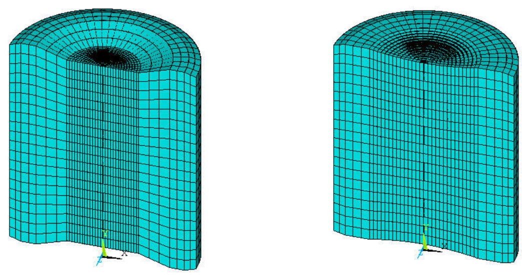


(a) Conventional (b) PLUS7^{TM}

Figure 1. Morphology of conventional and PLUS7 UO_2 pellets

2. Analysis

During the life time, the pellet experiences lots of loads from various sources such as thermal expansion, axial and radial compression, and fission gas pressure, etc. In this study, only axial compressive loads are considered to calculate the magnitude and distribution of stresses imposed on the pellet because their effects are dominant. The axial compressive loads consist of two different sources from the plenum spring that supports the pellet to prevent free movement during shipping to the reactor and the weight of stacked pellets. The resultant axial force amounts to approximately 30~40 lbs for both conventional and PLUS7^{TM} fuel rod designs at the initial loading. For this stress analysis, three dimensional elements (Solid45 in ANSYS) are implemented to simulate the behavior of the pellets. Figure 2 shows the finite element models for the stress analysis, which is composed of approximately 4900 elements and 5700 nodes. The axial compressive forces were applied to the land surface as pressure loads.



(a) Conventional (b) PLUS7^{TM}

Figure 2. Finite Element Models for Stress Analysis

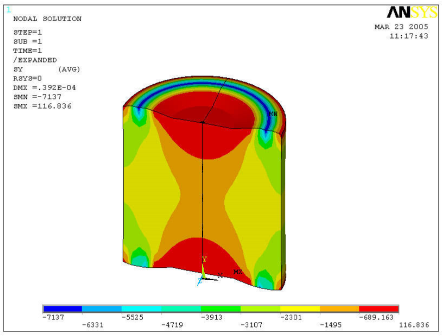
3. Results and Discussion

Table 1 shows the results of stress analysis on the pellet with two different shapes. The stress inflicted on the PLUS7^{TM} pellet is lower than that on the conventional pellet in both radial and axial direction. Differences of stresses in the axial and radial direction are 27%, 23%, respectively. Stress intensity value that determines the susceptibility of fracture of pellet is also lower in PLUS7^{TM} pellet than in the conventional one. Figure 3 shows the axial stress distribution of pellet and it can be clearly seen the high concentration of compressive stress at the land area.

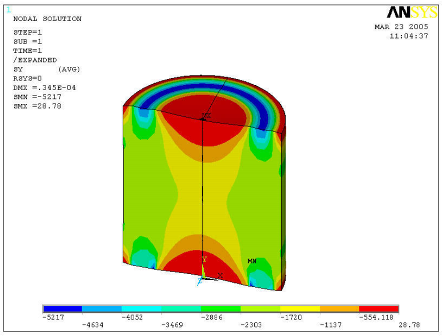
Table 1. Results of stress analysis

Items		Conventional	PLUS7^{TM}
Geometry	Diameter (inch)	0.325	0.3225
	Height (inch)	0.390	0.387
Stress Result (psi)	Radial	-3,224	-2,473
	Axial	-7,137	-5,217
	Stress Intensity	6,442	4,633

However, there is no significant stress change at the dishing area between two pellets.
At first, we had supposed that dishing shape might be the main factor to decide the level of stress inflicted on pellet. But the land area at which two pellets meet plays a decisive role in determining the stress as can be seen in Figure 3. All the loads imposed on the pellet are transmitted to the land area so that pellet with wide one is able to dissipate them easily compared to thate pellet with narrow one.



(a) Conventional



(b) PLUS7^{TM}

Figure 3. Axial stress distribution for the conventional and PLUS7 pellets

Consequently, it can be said that the morphology of the PLUS7^{TM} pellet whose land area is wider than the conventional pellet is more adjustable to mitigate stress level of the pellet.

4. Conclusion

Stress analysis was performed using ANSYS program on two different shaped pellets. Dimensions of the pellet currently supplied to the commercial nuclear plant were used for this analysis. Applied load was 40 pound and the other conditions were assumed to be the same. The results showed that the radial and axial stresses applied to the PLUS7^{TM} pellet were lower than those to the conventional pellet. In addition, the PLUS7^{TM} pellet showed lower stress intensity factor. From the stress analysis, it could be figuring out that the stress inflicted on the pellet was not determined by the dishing shape but by the land area.

5. Acknowledgement

This work is performed for the “Development of Export-Driving High Performance Fuel” under the R&D program led by Ministry of Commerce Industry and Energy(MOCIE). The author would like to express the thanks to MOCIE for its financial support of this development.

REFERENCES

[1] G. Delette and Ph. Sornay, “Finite element modeling of the pressing of nuclear oxide powders to prdict the shape of LWR fuel pellets after die compaction and sintering”, IAEA-TECDOC-1416, pp21-30, 2004
[2] R. Baccino, F. Moret, “Nuclear modeling of powder metallurgy processes”, Materials and Design, 21, pp359-364, 2000