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Dynamic Buckling Behavior of Cell Setting & Normal Non-irradiated Spacer Grid using Pendulum Type Impact Test

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1. Introduction

The spent fuel pools will be filled with SNF (Spent Nuclear Fuel) in 2024, the research about dry storage for interim storage of low burnup SNF is still a work in progress. So far, any evaluation technique for material degradation and mechanical integrity change of SNF during dry interim storage period did not execute. In addition, it is essential to obtain relevant experimental data to confirm the retrievability of SNF for recycling or disposal according to the government decision after dry interim storage, which is an intermediate storage concept. Therefore, the mechanical integrity evaluation, pendulum type impact, test of the simulated spent nuclear fuel component, normal and clearance between the cladding and the spacer grid supports, non-irradiated spacer grid was established under the general test condition.

2. Pendulum Type Impact Test

2.1 Test specimen

The fuel rod cell size was enlarged due to the irradiation effect for operation period. The simulated cell size was enlarged about ⌀0.05 mm than the normal cell size. Even though all fuel rod cell size was not uniformly enlarged, every fuel rod cell size were uniformly set because the non-uniformity could not be exactly simulated. For the cell setting case, the cladding fragments for all fuel rod cell were inserted, but there were no inserted for the guide tube cell. On the other hand, all fuel rod and guide tube cell were inserted cladding and guide tube fragment for the normal spacer grid case.

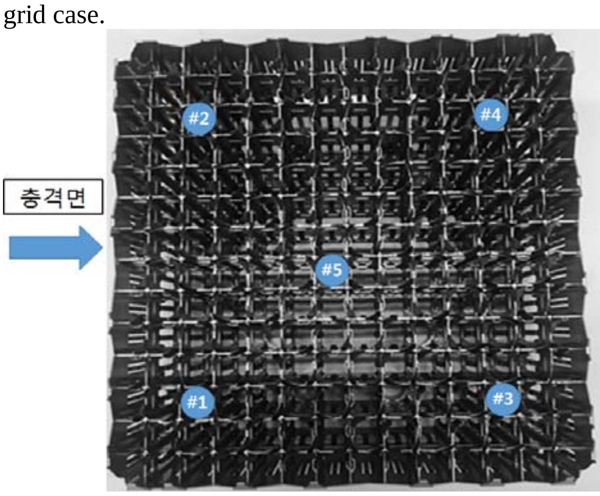


Figure 1. Cell setting spacer grid (14OFA).

In the Fig. 1, the numbers of blue circle are the position for five thermocouples, but they were not used for this test.

2.2 Pendulum type impact tester

The pendulum type impact tester (Fig. 2) was equipped and confirmed reliability using solid bar specimen. The measuring items of this tester are impact forces, initial impact angle, acceleration, temperatures, and strains (if needed). All sensors were calibrated through a certified calibrated laboratory for traceability. The mass and length of the impact hammer is 39 kg, and 0.88 m, respectively. The front small door of the chamber is actuated by pneumatic cylinder for reducing the heat loss. A stepping motor and brake system are provided to prevent the impact hammer from re-striking the specimen.

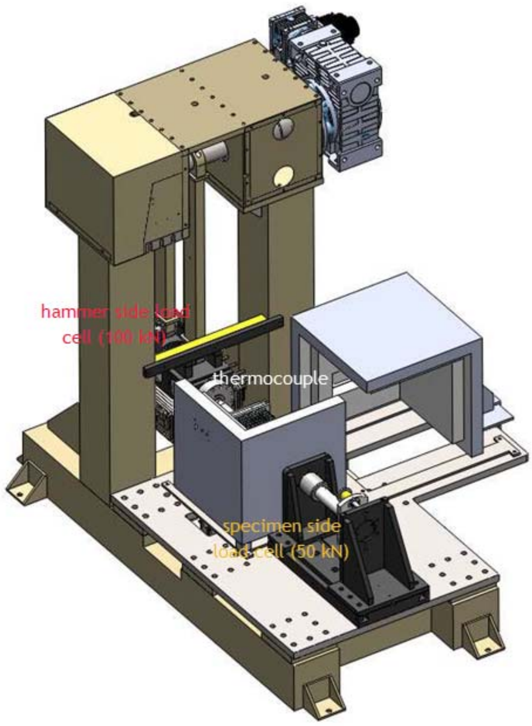


Figure 2. Pendulum type impact tester.

2.3 Dynamic impact test

The pendulum type impact test of the normal and cell setting non-irradiated spacer grid was executed under the room temperature condition. The initial impact angle was started from 25 degrees until buckling occurred at 1 degree intervals. Total number of test specimen was more than three.

Table 1 Impact test results of normal non-irradiated spacer grid

θ_i	Grid #1		Grid #2		Grid #3	
	Hammer side	Specimen side	Hammer side	Specimen side	Hammer side	Specimen side
25	31,748	34,924	-	-	-	-
26	33,580	36,188	-	-	-	-
27	34,780	36,851	34,424	37,277	32,472	36,225
28	35,568	37,689	36,058	37,680	35,281	37,840
29	36,898	37,649	34,960	38,626	36,821	38,697
30	**37,464**	38,692	36,865	38,325	38,427	39,922
31	33,694	38,753	**37,713**	40,106	39,292	40,613
32	27,885	34,460	26,215	34,652	**40,257**	41,571
33	-	-	-	-	39,798	42,218
34	-	-	-	-	28,217	33,584

Table 2 Impact test results of cell setting non-irradiated spacer grid

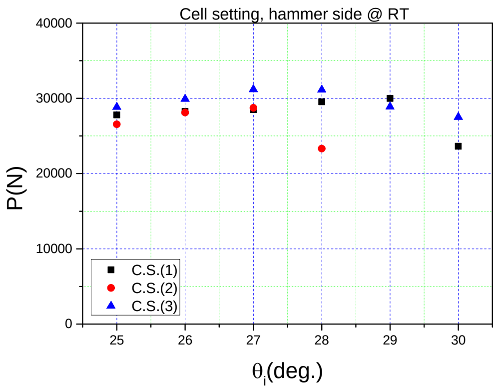
θ_i	Grid #1		Grid #2		Grid #3	
	Hammer side	Specimen side	Hammer side	Specimen side	Hammer side	Specimen side
25	27,811	33,816	26,556	33,010	28,846	34,386
26	28,275	34,518	28,111	34,029	29,914	35,931
27	28,506	34,609	**28,735**	35,233	**31,199**	37,466
28	29,544	35,640	23,331	29,790	31,137	37,616
29	**29,992**	35,441	-	-	28,898	32,776
30	23,634	29,465	-	-	27,517	35,270

2.4 Test results

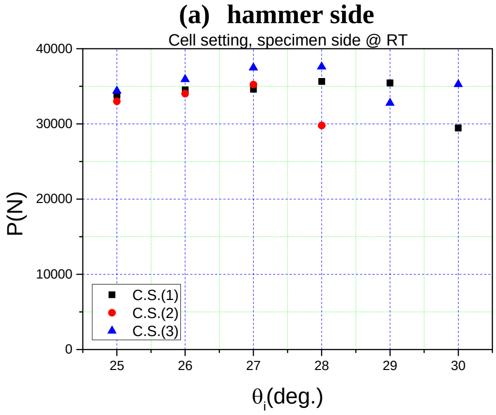
The pendulum type impact test results of normal and cell setting non-irradiated spacer grid specimen were summarized in Table 1 and 2, respectively. The average buckling strength and standard deviation of normal non-irradiated spacer grid at the hammer side were 38,478 N and 1,546 N, respectively. In similarly, the average buckling strength and standard deviation of normal spacer grid at the specimen side were 40,359 N and 1,746 N, respectively.

On the other hand, the critical buckling strength of cell setting non-irradiated spacer grid at the hammer and specimen side were 29,975 N and 36,163 N. respectively. Therefore, the critical buckling strength of the cell setting non-irradiated spacer grid was about 78 to 90% smaller than those of the normal spacer grid case. The dynamic characteristic curves of cell setting non-irradiated spacer grid at the hammer side was shown in Fig. 3(a). The dynamic characteristic curves of cell setting non-irradiated spacer grid at the specimen side was also shown in Fig. 3(b). The critical buckling strength was slightly larger on the specimen side than on the hammer side. It is assumed that if the impact acceleration was the same, the mass of fixtures to fix the specimen was added to the hammer mass. The critical initial impact angle was from 26 degrees to 29 degrees.

The impact force duration time before the buckling was about 6 ms, but this duration time becomes longer when the buckling occurs. In generally, the buckling occurrence was checked by decreasing the impact force, but it could be easier confirmed whether the buckling occurs by this impact duration time.



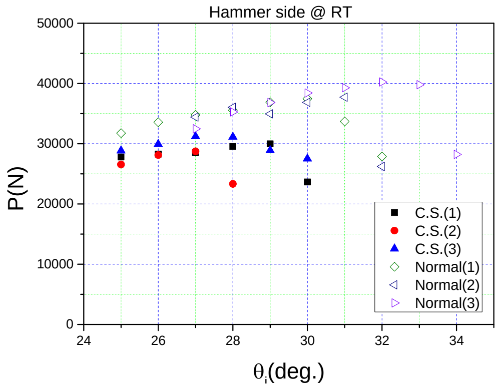
(a) hammer side



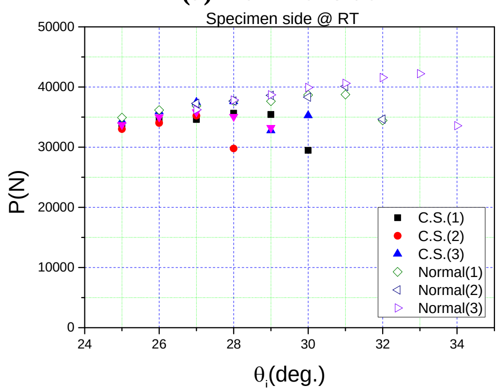
(b) specimen side

Figure 3. Dynamic characteristic curve of cell setting spacer grid.

The comparison results between the normal and cell setting non-irradiated spacer grid were shown in Fig. 4. As the results of the impact test, it was found that the residual frictional forces between the cladding and the spacer grid supports had significant influence on the impact strength of spacer grid.



(a) hammer side



(b) specimen side

Figure 4. Comparison results of dynamic characteristic curve between cell setting and normal non-irradiated spacer grid.

After two or three operation cycle, many fuel rods dropped on the top surface of the bottom end fitting due to the loss of the initial frictional force of spacer grid. Of course, not all fuel rods dropped onto the bottom end fitting. However, these gaps between the fuel rods and the grid supports eventually caused a reduction in the dynamic impact strength of the spacer grid itself. Therefore, this should be taken into account when dry interim storage work of spent nuclear fuel in the future.

3. Conclusion

For the low burnup spent nuclear fuel dry storage, a thin-plate structure pendulum type impact tester was used to evaluate the mechanical integrity of simulated nuclear fuel component. By using this tester, it is possible to perform the normal and cell setting non-irradiated spacer grid, which are used in 14OFA selected fuel assembly as the representative spent fuel. The test results of performing the mechanical integrity evaluation of the simulated spacer grid under the normal testing conditions were described. The critical buckling strength of the cell setting non-irradiated spacer grid was smaller than those of the normal spacer grids. Although there was a gap between the grid supports and fuel rods and the contact force was smaller than the normal spacer grid, these contact forces had a significant effect on the critical buckling strength.

ACKNOWLEDGEMENTS

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