Establishment of a Lateral Impact Test Method for a PWR Fuel Assembly

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1. Introduction

Lateral impact test method by using FAMeCT(Fuel Assembly Mechanical Characterization Tester) is established to simulate an impact accident of a nuclear fuel to a core shroud. The purpose of the lateral impact test is to obtain the impact characteristics of fuel assemblies with the top and bottom nozzles constrained for a beginning of life (BOL) condition as shown in Fig. 1. In this paper, the developed method and some results of a fuel assembly lateral impact test are presented.

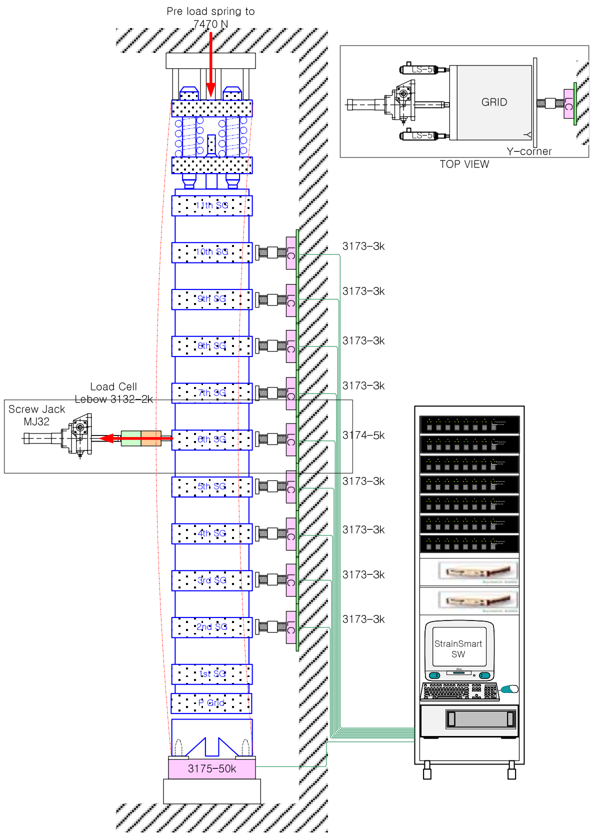

Fig. 1 A schematic diagram of the lateral impact test arrangement.

2. Lateral impact test method

2.1 test arrangement

A PWR fuel assembly is positioned vertically and restrained at the top and bottom nozzles by upper and lower core plate simulators. The fuel assembly is axially pre-loaded to approximately 7470 N by compressing the top nozzle hold-down springs to simulate the BOL hot condition [1]. Two types, linear sensors and load cells are used. Two linear sensors are installed at the 6th grid position to detect the initial lateral deflection of a fuel assembly and measure a displacement trace during a lateral impact. Totally 8 load cells (3 klbf each) are placed at the 2nd ~ 10th grid positions except 6th grid position. T-shape plates are installed in series with the load cells to simulate a core shroud. The gap between T-shape plates and spacer grids is adjusted as 3.8 mm. A 5 klbf-load cell is installed to monitor the impact force and duration time at the 6th grid position and a 2 klbf-load cell is used to measure the force during deforming the fuel assembly at same gird position. Because the lateral impact test is a kind of dynamic test, a data scanner of the 6000 series is used for data acquisition. To impact the fuel assembly instantly, a mechanical triggering device is specially designed as shown in Fig. 2. The fuel assembly is bent by using a screw jack.

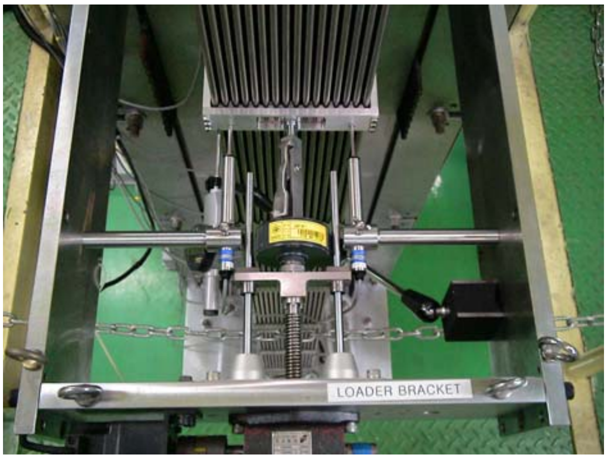

Fig. 2 A triggering device to initialize the lateral impact test.

2.2 *test procedure*

Firstly, the axial straightness between the UCP (upper core plate) and LCP (lower core plate) simulators is confirmed by using a plumb bob. Secondly, a full size PWR fuel assembly is settled. Thirdly, the fuel assembly is preloaded by about 7470 N axially by using the UCP simulator. Then, the gap between T-shpae plates and spacer grids is adjusted to 3.8 mm. Finally, all sensors are reset. The 6th (centeral) spacer grid of the fuel assembly is increasingly displaced from 5 to 40 mm at an interval of 5 mm. After the preparation steps above, the fuel assembly is suddenly released to collide with the T-shape plates by using the triggering device. The collected data are saved and post-processed [2].

3. Test results and discussion

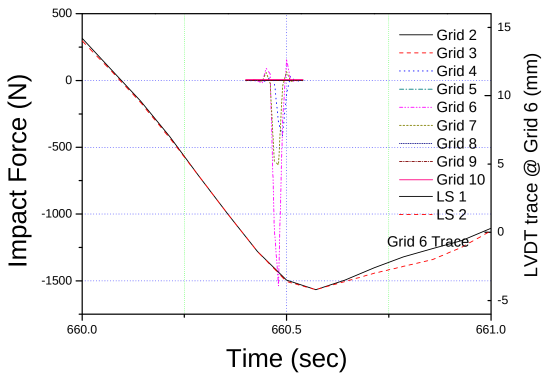

Fig. 3 Time versus impact forces and LVDT trace for the initial displacement of 15 mm.

The lateral impact test for an advanced PWR fuel assembly was conducted to verify the test performance. Fig. 3 shows an impact force at all spacer grids' positions and LVDT traces at the 6th grid position in the case of the initial displacement being 15 mm. In this case, the maximum impact force is obtained at the 6th grid position. This is reasonable because the maximum deformation must occur at that position. The impact duration time for this case is 0.02 seconds. Total lateral impact data such as impact force and duration time are summarized in Table 1. The maximum impact force was found 2100 N at the 6th grid position at the initial displacement of 40 mm. The average impact duration time varied from 0.01 to 0.03 seconds.

Table 1 Impact force and duration time for all initial displacements.

Initial displacement (mm)	Grid 4 impact force (N)	Grid 5 impact force (N)	Grid 6 impact force (N)	Grid 7 impact force (N)
5	1.6	0	110	0
10	1.6	0	840	77.8
15	1.6	1.6	1047.5	107
20	26	1.6	960	90.8
25	413.3	0	1537.5	632.4
30	673.6	44.6	1617.5	880.5
35	1080.4	106.6	2032.5	1089.7
40	1200.9	165.5	2100	1164.3
Initial displacement (mm)	Grid 4 duration time (sec)	Grid 5 duration time (sec)	Grid 6 duration time (sec)	Grid 7 duration time (sec)
5	0	0	0.	0
10	0	0	0.02	0.02
15	0	0	0.02	0.02
20	0.01	0	0.02	0.02
25	0.03	0	0.02	0.03
30	0.03	0.02	0.03	0.02
35	0.02	0.02	0.02	0.02
40	0.02	0.03	0.02	0.02

The lateral impact test data for the 5th position are lower than the other data. The impact forces at each grid position increase almost linearly with respect to the initial displacement of the 6th (central) structural grid as shown in Fig. 4.

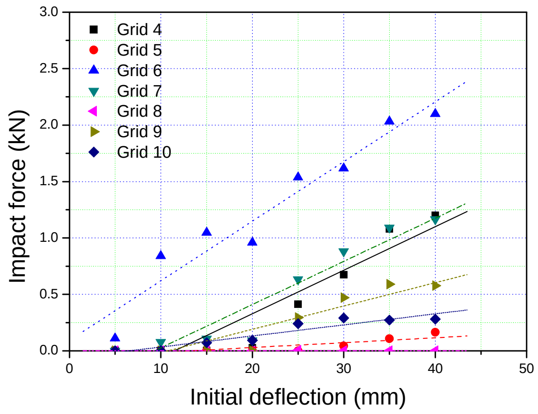

Fig. 4 Impact forces versus initial deflections.

4. Conclusion

A lateral impact test method and procedure of a PWR fuel assembly were established. A test was conducted for an advanced PWR fuel assembly. The results showed that the impact forces increased linearly. It is the same phenomenon as that has been presented previously. However, the maximum impact force was 2100 N, which was thought to be small compared with the previous results with a different fuel assembly. The reason will be studied by conducting repetitive tests with a varying test setup. However, it is meaningful to enable a lateral impact test of a full size fuel assembly domestically.

REFERENCES

[1] Kyung-Ho Yoon, Hyung-Kyu Kim, Tae-Hyun Chun, Lateral Bending Characteristic Analysis of a 16 by 16 type PWR Fuel Assembly using Test Method, Proceeding of KNS 2007 spring.
[2] J.Y. Kim et al., Test Procedure of Fuel Assembly Lateral Impact, FAMeCT-TP-03, (2008).