Correlation between Strain and Buckling of Spacer Grid by Side Impact

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INTRODUCTION

The purpose of this study is to establish the correlation between the strain and buckling of a spacer grid (SG) by side impact. Since the spent fuel is brittle, there is an increased risk of breakage when subjected to external loads during handling, storage and transport. In order to evaluate the damage, it is necessary to determine the relative force of the fuel rod. The function of the spacer grid of a fuel assembly is to serve as the impact surface should the assembly undergo large lateral deflections. The lateral strength of the spacer grid must be sufficient to withstand a condition II seismic incident (operating basis earthquake, OBE), or condition IV seismic incident (safe shutdown earthquake, SSE). For this, a pendulum type impact test of the spacer grid is executed, and the strain data at the side plate of the grid and surface of the fuel rod are obtained.

THROUGH GRID TEST

Pendulum Tester

The through-grid test is executed using a pendulum type tester, which is shown Fig. 1. The SG specimen is fixed at the rear side by a pneumatic fixture, and the impact hammer is locked and released by a servo motor.

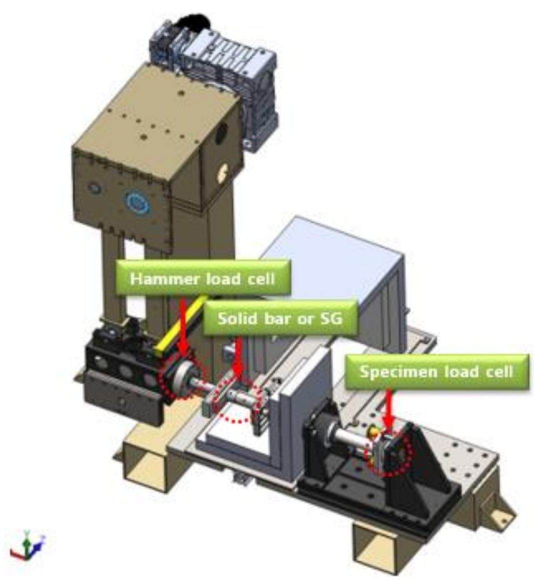

Fig. 1. Pendulum type impact tester.

Test Specimen

A 14 by 14 spacer grid test specimen is fabricated with Zircaloy sheet material. In addition the fuel rod and guide tube (GT) fragments are inserted at each fuel rod and GT cell. The cross points between inner plates and the contact edges between the inner and outer plates are welded using a laser welding method.

Test Condition for Impact Test of SG

The test data are acquired using two load cells (front & rear side), rotary variable differential transducer (RVDT), and uni-directional strain gage. These strain gages are attached on the side plate of the SG and surface of the fuel rods, which are shown in Fig. 2. All strain gages are 350 Ω, and the gage factors are about 2.0.

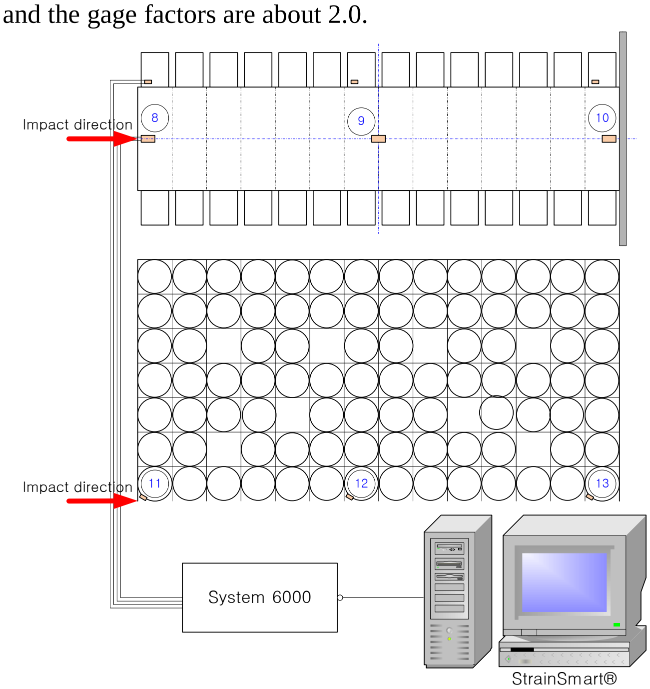

Fig. 2. Strain data acquisition diagram for impact test.

The initial impact angle is started from 5 degrees until buckling from a vertical plane, and the impact angle increment is 2 degrees. The mass and arm length are 39.0 kg,

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and 0.88 m, respectively. Test data sampling rate is 10,000 points per second.

TEST RESULTS

Basic Results of SG

The lateral impact test results are summarized in Table 1. The critical impact force occurred at 27 degrees, and the maximum impact forces of the hammer and specimen side are 33,762 N, and 37,505 N, respectively. In addition, the duration time is about 5.1 ms.

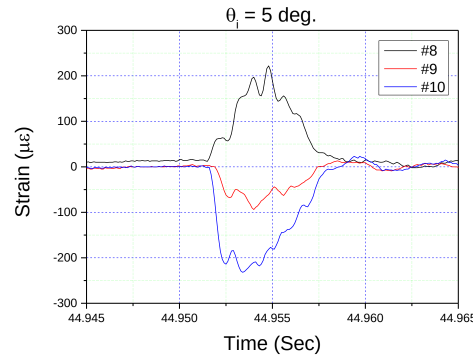
Table. 1. Impact test results summary

Angle (deg.)	Impact energy (J)	Impact velocity (m/s)	Duration (msec.)	Impact force (N)	
				Hammer	Specimen
5	1.28	0.26	5.50	5,406	7,115
9	4.14	0.45	4.83	10,452	13,217
13	8.62	0.66	4.75	15,384	19,169
17	14.69	0.86	4.92	19,656	25,057
21	22.34	1.06	5.25	20,600	25,973
25	31.51	1.26	5.00	31,765	33,980
27	36.66	1.36	5.08	33,762	34,889
29	42.17	1.46	6.08	33,583	37,505

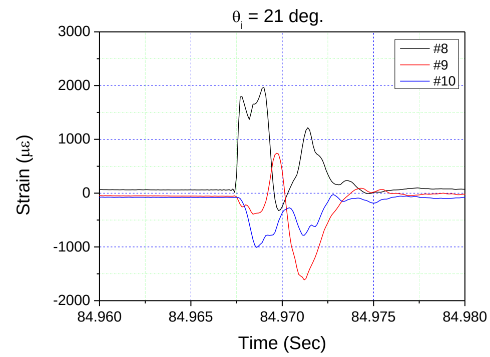
Strain Results of SG

The strain value of the side plate (⑧, ⑨, ⑩) appeared to be 2,190 με at the front gage position. In the strain viewpoint, the maximum strain is shown at the initial 21 degree angle, and the maximum strain is then decreased with respect to the initial impact angle. On the other hand, the strain curve appears differently between the pre-buckling and post-buckling. The strain characteristic curves of pre-buckling are single curve (a), although they have tensile or compression properties as the gage position. However, the strain characteristic curves of post-buckling are double curves (b). In addition to this, the strain curve of the mid-position is changed based on the tensile and compression properties. The buckling characteristic of the spacer grid by lateral impact was mainly governed by the side plates. It is believed that the side plates can withstand a lateral impact load until buckling occurs, but when buckling occurs, these side plates collapsed. Therefore, these side plates were found to be very important for buckling behavior of a spacer grid.

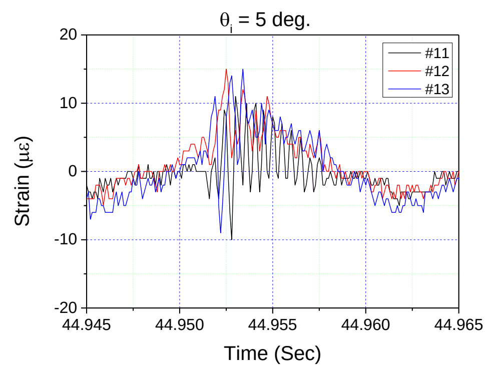
Contrary to this, the strain data of the fuel rods (⑪, ⑫, ⑬) showed negligible values. There was simple vibration behavior by the ringing phenomenon of the inner plates. Of course, the maximum strain value was shown at an initial angle (d) of 21 degrees. This seemed to be due to the fact that all plates were responsible for most loads when an external impact load was applied. Therefore, it was confirmed that the spacer grids functioned well.



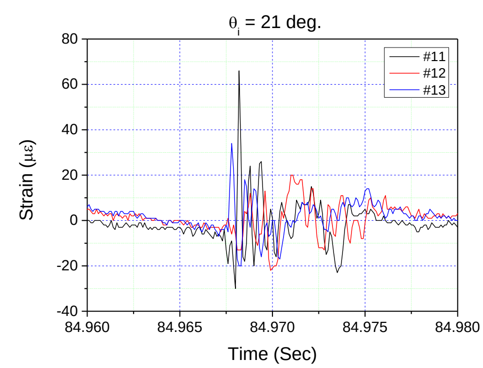
(a) pre-buckling of side plate



(b) post-buckling of side plate



(c) pre-buckling of rod



(d) post-buckling of rod

Fig. 3. Strain characteristic curve of side plate and rod of SG.

Buckling Mode Shape of SG

The buckling mode shape of SG is shown in Fig. 4. In this figure, the front region of side plate is deformed in outward direction, but the rear region of side plate is deformed in inward direction. So, the tensile strain (positive signal) is shown in the front region, and the compression strain (negative signal) is shown in the rear region.

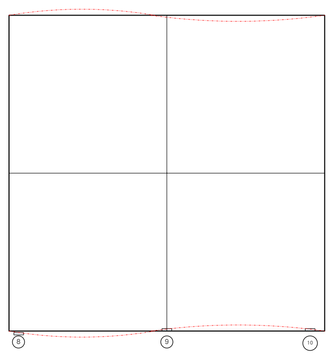


Fig. 4. Buckling mode shape of SG by impact test.

CONCLUDING REMARKS

A pendulum impact test was executed to evaluate the buckling behavior of a spacer grid. From a conservative point of view, it was found that it is more rigorous to evaluate the strain values rather than maximum force by the load cells. Most of the external impact load was absorbed by all plates, and the impact force acting on the fuel rods was insignificant.

The same test will be carried out using the spacer grid extracted from spent fuel and an assessment will be made of the structural integrity of the spent fuel.

ACKNOWLEDGMENTS

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