Grid Cell Relaxation Effects on the High Frequency Vibration Characteristics

Joo-Young Ryu*, Kyong-Bo Eom, Sang-Youn Jeon, Jae-Ik Kim
KEPCO Nuclear Fuel Co., Ltd, Nuclear Fuel Technology Dept.
242, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: jyryu@knfc.co.kr*

1. Introduction

Nuclear fuel assembly in light water reactors is supported by thin plate structures such as grid straps which are subjected to the coolant flow. The average velocity of the coolant is approximately 5 m/s, and severe turbulence with hundreds of thousands of the Reynolds number occurs. The plate structure of the grid of fuel assembly is always exposed to serious vortex induced vibration[1]. Also, High Frequency flow-induced Vibration (HFV) is primarily generated by vortex-shedding effect[2].

When it comes to grid design as a fuel assembly component, HFV should be considered in advance since it is one of the critical factors. Excessive HFV has a possibility of making degradation of the fuel reliability that is directly related to the fuel robustness and operating performance[3].

KEPCO NF (KNF) has performed HFV tests with various grid designs. While studying the HFV characteristics through the HFV tests, it has been observed that HFV amplitudes show different levels according to grid cell relaxation. It means that the testing could give different interpretations due to the condition of grid cell. Since the amount of relaxation is different under operating conditions and environments in a reactor, test specimens should be modified as much as possible to the real state of the fuel. Therefore, in order to consider the grid cell relaxation effects on the HFV tests, it is important to use cell sized or non-cell sized grids.

In the present study, KNF carried out HFV tests to analyze the relationship between HFV amplitude and grid cell relaxation by using 5x5 grids.

2. Test Specimen

Fig. 1 shows 5x5 test assembly that is made up of actual size and components. Test specimen consists of one cell sized grid, rod support grids, rods, and one bottom nozzle.

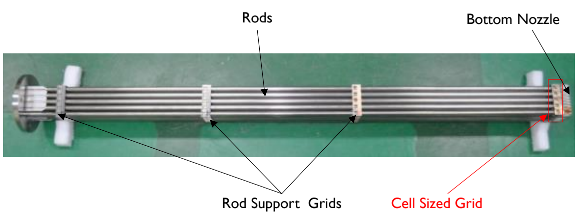


Fig. 1. Test specimen

2.1 5x5 Grid

For the HFV test, nickel alloy grid was selected. Each strap of this grid has a pair of dimples and a few slots. The array of grid was manufactured into the 5x5 grid as shown in Fig. 2 (a).

2.2 The Range of Cell Size

Cell size means cell setting distance from dimple to dimple or dimple to spring in one grid cell which is reshaped to a designated size by using adjustment tools. Precise pin gauges were used, as shown in Fig. 2 (b), for measurement to check that cell sizes are adjusted well.

(a) 5x5 grid (b) Pin gauge set

Fig.2. 5x5 grid and pin gauge

The 5x5 grid cell was adjusted and measured three times to make different grid cell relaxations. Fig. 3 shows the level of measured grid cell relaxations with min./nom./max. dimple heights. The first state is 0% relaxation of grid cell that is as-built. The second state is set as 33% relaxation of the grid cell that is quite similar with nominal height of the grid dimple. And, the third state is set as 92% relaxation of the grid cell that is almost loose state. The third state of cell sized distance is similar with the nominal diameter of the fuel rod.

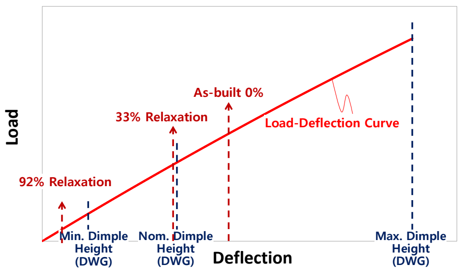


Fig. 3. Level of grid cell size

3. HFV Test

HFV tests were performed in Investigation Flow-induced Vibration (INFINIT) facility to investigate HFV amplitudes and its tendency according to grid cell relaxation. These were carried out under reactor operating conditions that is ± 15% of nominal in-core flow velocity and used with the 5x5 fuel bundle with actual dimensions, components and rods. The flow velocity range for the HFV test was applied from 15ft/s to 20ft/s in increments with 1ft/s. The 5x5 fuel bundle structure is generally used for the HFV test in INFINIT[4].

Additionally, since tendency of max HFV amplitude is commonly seen to appear on the top ligament of the grid strap based on the previous studies[3], the measurement point was selected on the top ligament that is upper most area of the grid strap as shown in Fig. 4.

3.1 HFV Test Configuration

The configuration of the test section is shown in Fig. 4. The 5x5 test assembly consists of one cell sized grid, rod support grids, rods, and one bottom nozzle for the HFV test. For minimizing other influences by abnormal flows, the measurement region is selected in the middle of INFINIT test section. In addition, measuring in the middle region of the test section can be worked well compared to end region of the test section.

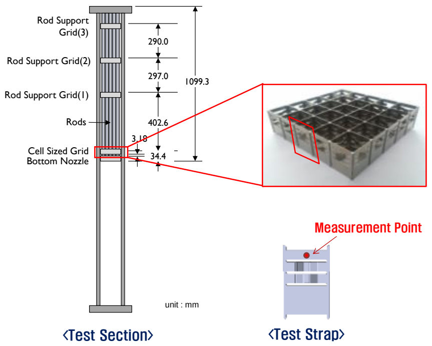
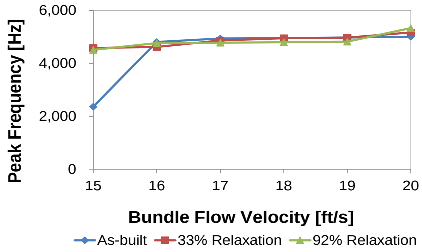


Fig. 4. Configuration of the test section in INFINIT

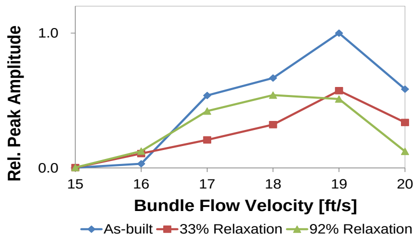
3.2 HFV Test Results

The HFV tests were performed twice for each case to confirm reliability and repeatability. The graphs of the HFV test results are shown in Fig. 5. In the two HFV data for each case, severe data was selected and plotted in one graph for evaluation. Fig. 5 (a) shows the comparison of peak frequency values, and Fig. 5 (b) shows the comparison of relative peak amplitude values at each flow velocity, respectively. Relative peak amplitudes were normalized based on the highest value among entire HFV test results.

Through the comparison of test results, it is observed that highest amplitudes occur at flow velocity of 18~19ft/s and measured frequency range is approximately 4,600~5,000Hz.



(a) Peak Frequency



(b) Peak Amplitude

Fig. 5. HFV test results

3.3 Analyses of the Results

The major HFV characteristics for the each case of grid cell relaxation in the case of nickel alloy grid are summarized in Table I and Fig. 6. Table I presents maximum values that are relative peak amplitude and peak frequency for each case of grid cell relaxation.

Fig. 6 shows the relationship between relative HFV amplitude and grid cell relaxation. It is noticed that 92% relaxation of grid cell has the lowest amplitude. Also, it is clearly indicated that HFV amplitudes show decreasing trend depending on the relaxation of grid cell size. Additionally, if the non-cell sized grid specimen is used for the HFV test, it can be assumed that test condition is more conservative than real condition.

Table I: HFV characteristics according to cell size

Cell Size	Relative Peak Amp.	Peak Frequency [Hz]	Flow Velocity* [ft/s]
As-built	1.00	4975.5	15~20
33% Relaxation	0.65	4970.0	15~20
92% Relaxation	0.54	4797.5	15~20

* In-core velocity range

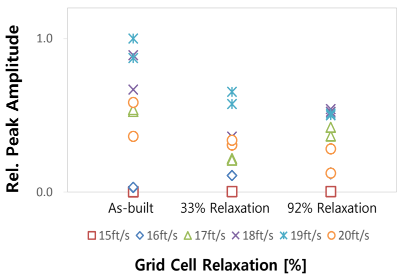


Fig. 6. Comparison of the relative HFV amplitudes

It is possible to predict the HFV amplitude when the cell size relaxation of 100% is occurred. The value can be predicted from the tendency of the test results that are maximum HFV values of each case as shown in Fig. 6. The curve shows saturated line. The expected value for 100% relaxation is about 54%. It is same level as 92% relaxation of the grid cell.

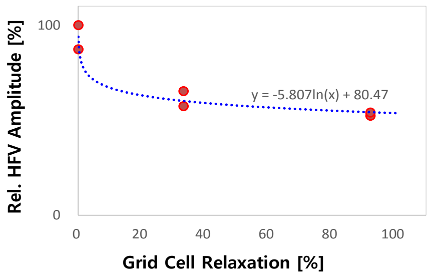


Fig. 6. Tendency of the HFV amplitudes

4. Conclusions

The main focus of this study is to find out how the HFV characteristics such as amplitude and frequency are affected by grid cell relaxation. Three cases of the grid cell sized specimen which is nickel alloy were prepared and tested. Through the comparison of the test results, it could be concluded that HFV amplitudes show decreasing trend according to the grid cell relaxation in the case of nickel alloy grid. It is also possible to expect the tendency of grid cell relaxation of a zirconium alloy grid based on test results. However, to find exact grid cell relaxation effects, it is additionally needed to perform HFV test with zirconium alloy grids.

For further investigation about HFV characteristic according to grid cell relaxation, it is required to study more related HFV tests, FEM analysis and theory approach.

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