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Investigation of Grid Strap Vibration Subjected to Axial Flow Condition

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1. Introduction

It is important to indentify static and dynamic characteristics for every structure from the viewpoint of structural evaluation. In addition, when the structure is subjected to special design conditions, the mechanical performance should be evaluated for safety operation. Especially, the fuel assembly is exposed to turbulent flow condition. Therefore, the dynamic behavior of the fuel rods including grid strap should be examined. Grid strap vibration caused by flow induced is one of the critical elements to fuel cladding wear. To analyze these phenomena, grid strap are examined under the free and forced vibrations.

Grid configuration is pretty complex, since the spring and dimple design should be implemented within the limited space. This paper measures local vibration on the strap in one cell. For full sized spacer grid, the dynamic characteristics will be different from that of the small scale grid in the view point of global geometry. Therefore, one cell vibration is considered rather than a global vibration. And one cell of the strap has one spring and two dimples. This paper presents dynamic characteristics of the strap in a grid at several conditions. First, modal analysis of the strap is performed by Finite Element Method(FEM). And modal testing is followed with a 5x5 grid to identify the dynamic characteristic considering real conditions in air. Finally, flow induced vibration for 5x5 small scale fuel bundle is completed in INFINT™ facility that is a test facility to evaluate flow induced random vibration.

2. Investigation of Grid Strap Vibration

2.1 Modal Analysis of a Strap

Usually, modal analysis can be performed with FEM. But, it's very difficult to analyze full-sized grid structure, since the finite element model requires immense degrees of freedom.

Therefore, only one strap is dealt in this work. By using ANSYS Workbench 12, modal analysis of the strap is performed. For more realistic boundary condition, tack welding at each corner is implemented using fully coupling with the other straps. Every side of the crossing straps to the target strap is constrained with elastic support. That is, since the sides of the crossing strap are connected to the grid assembly, artificial elastic supports are introduced.

Under the above conditions, modal analysis results shows that first natural frequency is denoted as ω_1 in Table I.

Table I: modal frequencies

Mode	Frequency
1^{st}	ω_1
2^{nd}	$2.8\ \omega_1$
3^{rd}	$6.3\ \omega_1$
4^{th}	$7.9\ \omega_1$

2.2 Operational Modal Testing of 5x5 Grid

It is known that two methodologies of modal testing can be performed. One way is impulse test by using impulse hammer. The other way is sine wave or random wave test by using exciter. During modal testing, a force transducer at a reference location is needed, but the strap in one cell is very small compared to diameter of a force transducer. Thus, it is difficult to directly measure force within the restricted surface, because the measured signal can be distorted with relatively heavy force transducer.

To avoid such difficulties, Operational Modal Analysis(OMA) can be used[1]. Force transducer is not needed for OMA. The test methodology is shown in Fig. 1. A 5x5 grid rather than 1x1 grid used in this test for fairly realistic condition. Random signal is generated in LMS Test.Lab, and the signal is transferred to the exciter. Velocity response at each point is measured using Laser Doppler Vibrometer(LDV), and the test result is shown in Fig. 2. Where the resonance frequency and its amplitude are normalized by ω 1 and maximum amplitude, respectively. As shown in Fig. 2, the first resonance mode occurred at $1.4\ \omega_1$ (first peak point). The second peak mode shape is similar to the third peak shape. So, it can be considered second modal frequency.

Modal analysis results using FEM show some deviation at the first natural frequency compared to OMA test result. It is thought that the boundary condition in the simulation model does not match to the real condition.

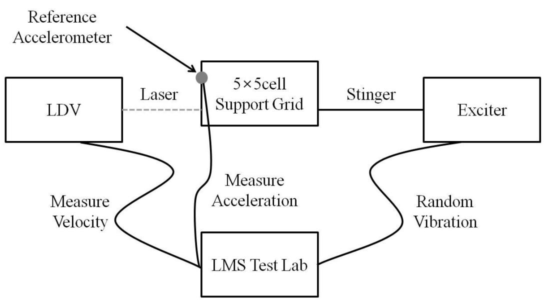


Fig. 1. Test method of cell vibration using OMA

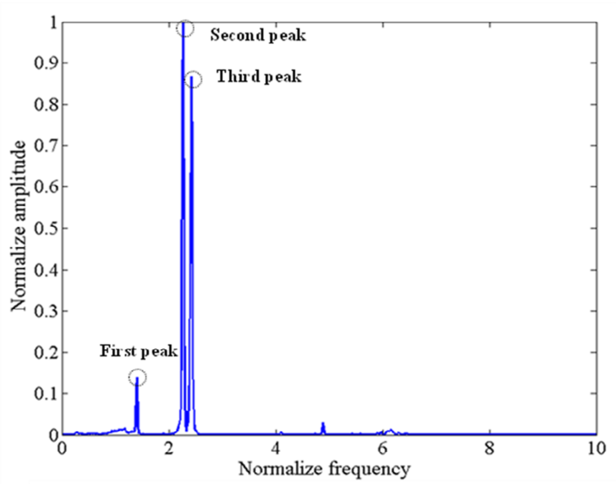
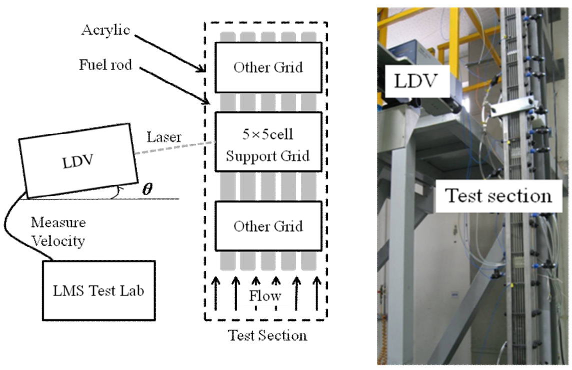


Fig. 2. Power spectrum density at the strap

2.3 Flow Induced Vibration of 5x5 Bundle

The nuclear fuel in reactor always subjected to random vibration caused by turbulent coolant flow. INFINT^{TM} had been built to identify vibration behavior of a grid. A schematic of the test and its picture are shown Fig. 3. LDV measures velocity of a point at the target strap in the center of 5x5 grid. To discard unwanted reflected signals including housing vibration, as show in Fig. 3, a specific angle is implemented in the LDV[2]. The flow velocity in the bundle can be controlled from 0m/s to 12m/s using inverter. Actually, for commercial reactors, the coolant velocity varies from 5 m/s to 6 m/s. Under the same flow condition, a typical strap vibration spectrum is delineated in Fig. 4. Based on the test results, it is seen that the first resonance occurred at around 6.7 ω_1.

It is clearly shown that resonance frequencies in lower frequencies range are not appeared. The strap vibration is occurred at very high frequency when the coolant flow is provided. It is thought that the vortex shedding frequency causes high frequency vibration.



(a) Schematic of LDV measurement (b) INFINIT facility

Fig. 3. Flow induce vibration facility

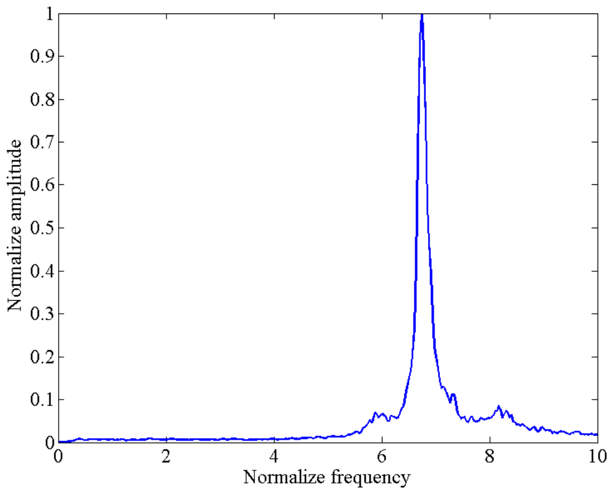


Fig. 4. Power spectrum at the strap

3. Conclusions

This paper discussed behavior of one strap in a grid under several conditions. While developing a new grid design, to evaluate whether the grid design shows good performance, every simulation including flow-induced vibration should be considered. This paper introduced evaluation method and showed the general procedure in the dynamic evaluations.

REFERENCES

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[2] D. G. Ha, N. G. Park, J. M. Suh, K. L. Jeon, and W. J. Lee, Optimal Experiment Environment for Flow-induced High Frequency Vibration Test Facility, Transaction of the Korean Nuclear Society Spring Meeting, p. 313-314, 2011.