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High Frequency Flow-Induced Vibration of the 5x5 Test Bundle

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1. Introduction

Newly developed structural components of a nuclear fuel should be evaluated by the out-of-pile flow test prior to the in-core performance verification under a normal operating condition. KEARI has developed the hydraulic test facility [1](called FIVPET) which tested a 5x5 partial fuel assembly as a test bundle; a room temperature and low pressure water is used as coolant. From these test results, mechanical/hydraulic performances related to the design of a fuel component (such as spacer grid) can be compared and estimated.

High Frequency Vibration (HFV) of the 5x5 test bundle is a vibration of the strap and rod above 1500 Hz, which is caused by a coupling between the natural frequency of the strap and vortex shedding frequency induced from the strap thickness. In this study, the flow induced vibration test was performed to estimate the HFV of the test bundle and to compare the HFV amplitude between the 2 types of test bundles. These vibration test results will be used to select the final design of the spacer grid candidate for a commercial use and for preparing an input database for a future design.

2. Methods and Results

2.1 Test Facility, Bundle and Condition

Figure 1 shows a schematic diagram of the test facility and flow path. The water flows parallel to the test bundle inside the test section. Vibration of the strap and rod of the test bundle was measured by the Laser Doppler Vibrometer (LDV) through the transparent test section wall; Rod vibration located at the inner side of the test bundle is also measured by the embedded type accelerometer mounted inside the 2 instrument rod [2].

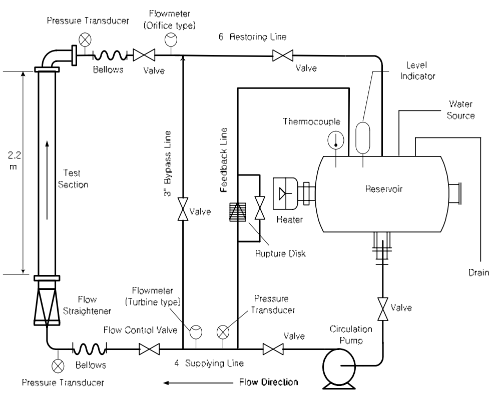

Fig. 1 Schematics of the Flow-Induced Vibration and Pressure drop Experimental Test (FIVPET) loop.

The test bundle is a 5x5 small-scale trial fuel assembly which consists of 23 dummy rods, 5 spacer grids and 2 guide tubes as illustrated in Figure 2. The flow tests were performed in the flow ranges of the inlet pressure of 1 ~ 6 kg/cm^2, mean flow velocity of 3 ~ 10 m/s which covers the PWR operating conditions of 4 ~ 5 m/s, and calculated Reynold numbers of 4.0E4 to 1.5E5 in the temperature range of 25 ~ 32 ^{o}C.

Figure 3 represents of the overall measurement process of the Flow-Induced Vibration (FIV) test. For the flow test, HP/VXI as a data acquisition device and MTS/IDEAS-PRO as the test data analysis software were used with the following data sampling parameters; maximum frequency of interest 5000 Hz, frequency resolution of 1.6 Hz, 50 times for the averages with the Hanning-broad window.

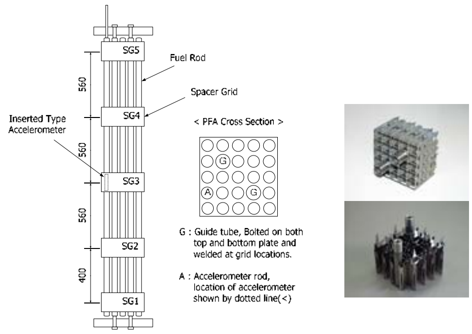

Fig. 2 Axial and cross sectional layouts of the test bundle and picture of the 5x5 spacer grids.

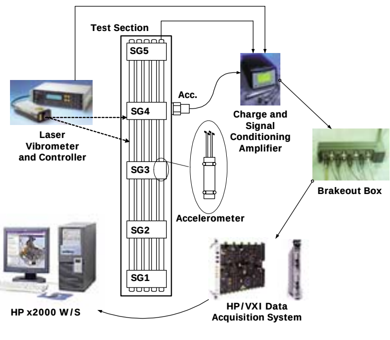

Fig. 3 Layout of a overall measurement process of the test.

2.2 Result

Figure 4 shows the vibration spectrum of the test bundles at the bundle flow velocities of 4 and 5 m/s. These spectrums are actually a vibration of the strap and rod in the test bundle measured at one point of the strap in the mid grid and another point of the rod in the third span of the test bundle. HFV of the strap and rod exists above 1500 Hz and their frequencies distribute over the finite frequency range (dominant HFV frequency group) of 0.5 ~ 1 kHz. The HFV frequency group also increases with the bundle flow velocity. HFV of the rod has a similar spectral energy profile with the strap HFV over the high frequency region, but has nearly a one-order lower magnitude than that of the strap. Magnitude of the HFV of the rod and strap are comparative or bigger than the low frequency vibration of the test bundle below 100 Hz, which correspond to the modal frequencies of the assembly and rod vibration modes. So, the HFV of the strap including the rod should be considered to estimate the fuel vibration and final fretting wear.

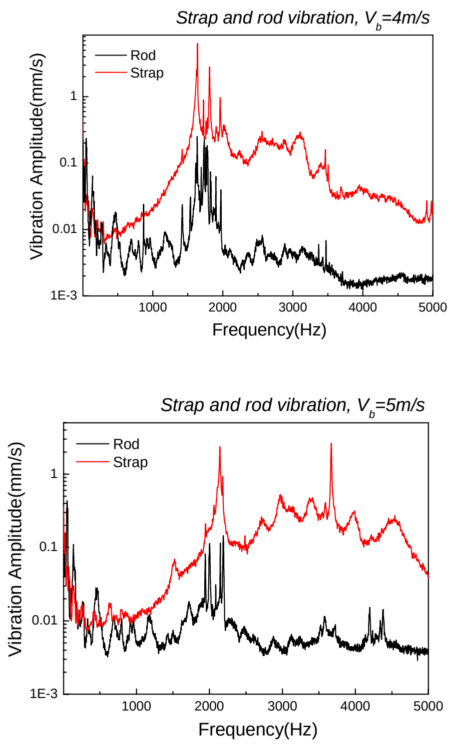

Fig. 4 Vibration spectrum of the test bundles at the bundle flow velocities of 4 and 5 m/s.

These HFV of the 5x5 test bundle is fundamentally caused by a coupling between the natural frequency of the strap and the vortex shedding frequency induced from the strap thickness [3]. Vortex shedding frequency of the grid strap can be estimated by the simple Strouhal number relationship by the following equation.

$$f_s = \frac{S_t U}{D} \quad (1)$$

Strouhal number(S_t) is a dimensionless proportionality constant between the predominant frequency of a vortex shedding(f_s) and the free stream velocity(U) divided by the characteristic length(D). The Strouhal number is a function of Re and can be changed according to the surface roughness, geometric characteristics of the flow cross section and inclination of the strap or rod against a flow direction. But from the calculation for the given flow velocity and peak in the measured HFV spectrum, St is around 0.19 to 0.21. Then, the shedding frequency corresponding to the flow velocities of 4 and 5 m/s is 1650 Hz and 2150 Hz, respectively.

Figure 5 represents the peak HFV amplitudes of the 2 different types of test bundles versus the bundle flow velocity. In the core flow range of the 4~5 m/s, HFV of the type B shows a clearly unacceptable HFV response when compared to that of the type A test bundle; Two test bundles have different shapes of spacer grids.

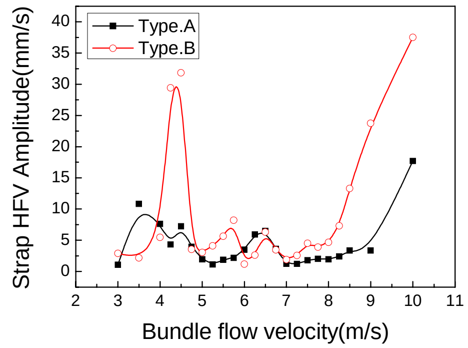

Fig. 5 HFV peak amplitude of the two different types of test bundle according to the bundle flow velocity.

3. Conclusion

The FIV test was performed to estimate the HFV of the test bundle and to compare the HFV amplitude between the 2 types of test bundles. From the aspect of the grid HFV, design of the A-type grid test bundle is superior to that of the type B. The test results will be used as further comparisons among the spacer grid candidates and for the preparation of the database for the future design.

Acknowledgement

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References

[1] H. S. Kang, K. H. Yoon, H. K. Kim, K. N. Song, Y. H. Jung, Development of the Flow-induced Vibration Loop for a 5x5 Partial Fuel Assembly, Proceedings of the KNS autumn annual meeting, 2002.
[2] Kang-Hee Lee, Heung-Seok Kang, Kyung-Ho Yoon and Kee-Nam Song, 2005, Flow-Induced Vibration (FIV) Test Using a Partial Fuel Assembly, Proceedings of the KNS spring annual meeting, Jeju, May 25-27, 2005.
[3] Kang-Hee Lee, Kyung-Ho Yoon, Kee-Nam Song and Jae-Yong Kim, Comparative Study on Flow-Induced Vibration of a 5x5 Partial Fuel Assembly for Design Verification of the Newly Developed Spacer Grids, Proceedings of the KNS spring annual meeting, Gang-Chon resort, May 25-26, 2006.