Fuel Rod Vibration Measurement Method using a Flap and its Verification

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1. Introduction

Flow-induced vibration is a critical factor for the mechanical integrity of a fuel rod. This vibration can cause leaked fuel through the mechanism, such as grid to rod fretting.

To minimize the failures caused by flow-induced vibration, a robust design is needed which takes into account vibrational characteristics. That is, the spacer grid design should be developed to avoid any excessive vibration. On the one hand, if fuel rod vibration can be measured, an estimation of the excitation forces, which are a critical cause of rod failure, should be possible [1]. Therefore, by applying an external force, flow-induced vibration can be roughly estimated when the fuel rod vibration model is used.

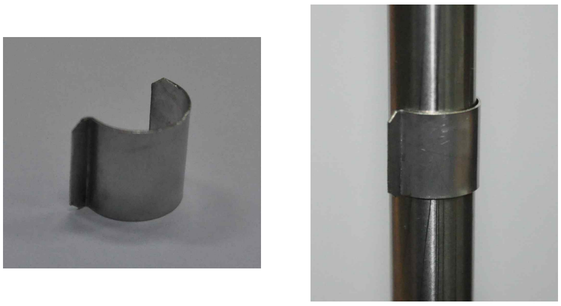
KEPCO Nuclear Fuel developed the test loop to research flow-induced vibration as shown in Fig.1. The investigation flow-induced vibration (INFINIT) - the test facility - can measure the grid strap vibration and pressure drop of a 5x5 small scale fuel bundle.

Fig. 1 Test Section of INFINIT Test Loop

Basically, using a Laser Doppler Vibrometer (LDV) [2], the vibration of a structure immersed in high speed fluid can be measured. Grid strap vibration is easily measured using an LDV. However, it is quite difficult to measure fuel rod vibration because of the round surface shape of the rods. In addition, measuring current method using the LDV, it was only possible to directly measure fuel rod vibration at the first row of the bundle as the rods behind the first row are obscured.

To solve this problem, a thin flap, as shown in Fig. 2(a) can be used as a reflecting target, gaining access to rods within the bundle. The flap is attached to the fuel rod, as in Fig. 2(b). As a result, most of the inner rod vibration can be measured.

Before using a flap to measure fuel rod vibration, a verification process was needed to show whether the LDV signal from the flap vibration provided equivalent and reliable signals. Therefore, impact testing was carried out on the fuel rod using a flap. The LDV signals were then compared with accelerometer signal to test for feasibility. The LDV measured the flap vibration velocity and an accelerometer adjacent to the flap measured fuel rod acceleration. Finally, additional investigations were performed to identify deviation between the two signals which could have been directly affected by the natural frequency of the flap.

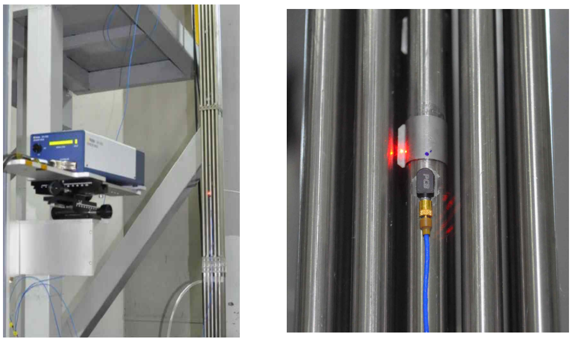


(a) a flap (b) clamped shape to rod
Fig. 2 View of the Flap

2. Comparison of the Two Signals

The impact test apparatus is shown in Fig. 3(a), and the flap is located relatively close to the accelerometer in order to compare the two signals. The fuel rod assembly which is used for the test is made up of small scale size of a 5x5 array.

An impact force was applied on the rod, and the LDV signal and the accelerometer signal were simultaneously processed using LMS Test.Lab, a data acquisition and analysis tool.



(a) set up for testing (b) two kinds of sources
Fig. 3 Test Apparatus

Fig. 4 shows the comparison power spectrum density (PSD) of the two signals. For a fair comparison, the LDV signal was converted to an acceleration spectrum. As shown in Fig. 4, at up to 5,200 Hz, the two kinds of data are very similar, except for a narrow frequency band. The frequency ranges around 3,100 Hz show some discrepancy between the two signals. It is thought that this inconsistency is caused by a resonance of the flap. Additional investigations of impact testing and simulation were performed to identify the source of the deviation.

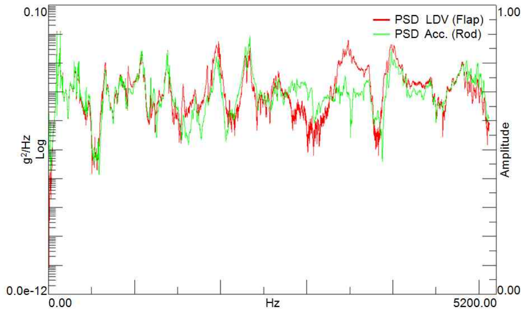


Fig. 4 Comparison of the LDV and Accelerometer Signals

3. Analysis of a Flap

To find the natural frequencies of the flap, impact testing and modal analysis were performed, using following methods.

3.1 Impact Testing

Fig. 5 shows the impact test configuration that was used to acquire the natural frequencies of the flap. For the implementation of free vibration conditions, a section of relatively flexible sponge was laid out and the flap was placed on top of it. The accelerometer was then positioned on the center of the flap.

The test results show that the resonance point occurs at 3,076 Hz, as shown in Fig. 6. This data explains why, around 3,100 Hz range, there was a discrepancy between the two sources of data.

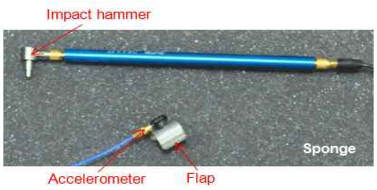


Fig. 5 Impact Testing for the Flap

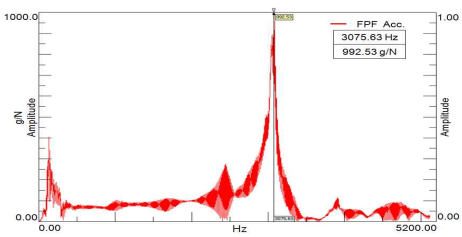
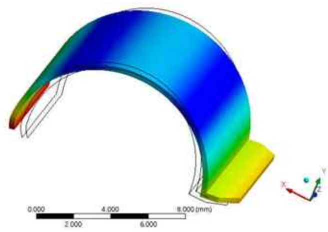


Fig. 6 Measured Response Function of the Flap

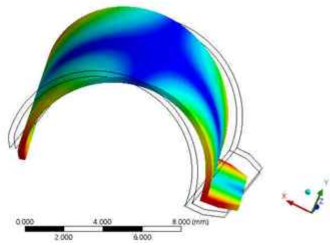
3.2 Simulation

To confirm this resonance frequency which occurs around 3,076 Hz, modal analysis was performed, using the commercial analysis program, ANSYS12.

Fig. 7 displays the mode shapes, and Table 1 lists the natural frequencies of the flap. It is found that the first natural frequency from the simulation is very similar to the resonance frequency shown in Fig. 6. The second natural frequency also exists within the 5,200 Hz range in simulation, but impact testing results show that there is in an insignificant related to this frequency. It is considered that the accelerometer positioned on the center of the flap might be unable to measure this particular frequency, because the amplitude of twisting motions could be decreased at this location.



(a) 1st mode



(b) 2nd mode

Fig. 7 Mode Shapes

Table 1 Simulated Natural Frequency

Mode	Frequency [Hz]
1	3,085
2	4,057

4. Conclusions

A flap to measure fuel rod vibration was suggested in the study. To verify the applicability of a flap, a series of tests were performed. According to these test results, over the entire range of testing, it is found that the flap signal provides almost equal results to that of the accelerometer signal. Therefore, it is concluded that a flap for fuel rod vibration is applicable and available.

REFERENCES

[1] N.G. Park, H.N. Rhee, J.K. Park, S.Y. Jeon, H.K. Kim, Indirect Estimation Method of the Turbulent Induced Fluid Force Spectrum Acting on a Fuel Rod, Nuclear Eng. And Design, Vol. 239, pp.1237-1245, 2009.
[2] Polytec Vibrometer User's Manual