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Fuel Rod Modal Testing and Some Technical Difficulties

Nam-Gyu Park,a Joon-Kyu Park,a Jin-Sun Kim,a Jung-Min Suh,a Chong-Chul Lee,a
a Nuclear Fuel Tech. Office, R&D Center, nkpark@knfc.co.kr

1. Introduction

Fretting wear is one of the catastrophic failure mechanism in nuclear fuel assemblies. Since the mechanism is mainly caused by continual vibration of fuel rods in a reactor [1], it is essential to know dynamic properties of a fuel rod. Though reactor conditions cannot be exactly simulated in test facilities, we usually predict approximate fuel rod behavior based on test results. Especially, fuel rod vibration test in water condition is very limited, because measurement technology or technique under water is not developed well compared to in-air vibration test. The study discusses fuel rod vibration test in-air condition and some difficult problems of the test.

2. Fuel Rod Modal Testing

2.1 Test Configuration

The test fuel rod of 0.36 inch outer diameter consists of lead pellets and fuel tube with end plugs. Fuel spring is also installed in the plenum space. The fuel rod is supported with 9 6x6 mid grids and top and bottom grids. Figure 1 is schematic view of the test facility. All the grids are clamped to the rigid stand as shown in Figure 1, thus movement of grids is not allowed. Since it is thought that turbulence intensity is not high enough to move respective fuel assemblies, it is reasonable to restrict grid movement. The exciter in the figure excites the fuel rod at the 6-th span from the bottom. Impedance head which is installed at the tip of the steel stinger in the exciter measures exciting force and acceleration of the point. An accelerometer measures acceleration of the mid point in each span. LabVIEW™ [2] processed the measured signal, and the results are stored in a computer.

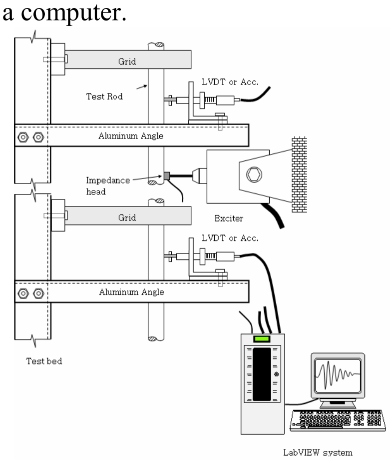

Figure 1. Schematic View of Full Size Fuel Rod Test

2.2 Test Procedure

A fuel tube with the same size as fuel rod is also tested to obtain reference data. The fuel tube is much lighter than fuel rod, because it does not contain lead pellets. At first, as usual modal testing process, random force excited the fuel tube, but coherence level is very low as shown in Figure 2. It means that fuel tube is not a linear system. Since dynamic contact or friction between fuel tube and spacer grid springs can be occurred in spacer grid supports, the system is not linear anymore. Afterwards, instead of the random excitation, sinusoidal test which is useful for nonlinear system was performed to achieve available data for all tests.

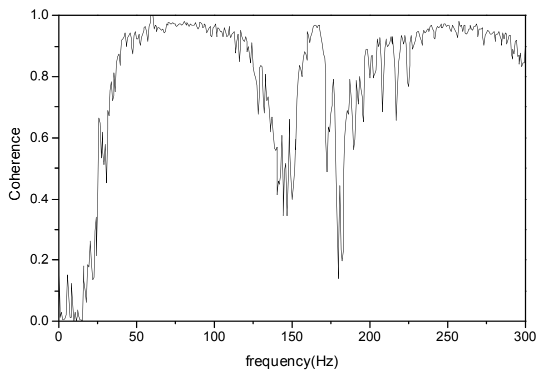

Figure 2. A coherence function of the fuel tube

To investigate adjacent rods' effects on the target fuel tube or rod, hundreds of short tubes of 100 mm length are prepared. Thus 4 categories of test were performed, that is 2 fuel tube tests with and without neighboring short tubes, and 2 fuel rod tests with and without neighboring short tubes. When performing a test with short tubes, the short tubes are inserted in every cell of all 6x6 grids except the cells of fuel rod and fuel tube locations.

3. Test Results

3.1 Fuel Tube Test Results

Fuel tube test without adjacent fuel tubes was performed at first. Then, the test with surrounding tubes was fulfilled to examine neighboring tubes' contribution to the fuel tube vibration. Figure 3 shows two different test results. Point frequency response from the first test is overlaid with that of the second test. Distortion around 1.1 kHz was observed, but no big difference was made.

Rather than point response, cross response shown in Figure 4 shows low level of signal beyond major modal frequencies. It is thought that gird support friction and dynamic contact hindered force transmission. It was observed that the first natural frequency is around 160 Hz. It was also shown that many modes are clustered in small frequency band below 300 Hz.

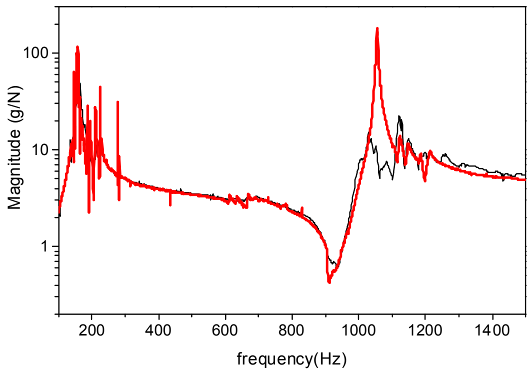

Figure 3. Point Frequency Response Function of Fuel Tube; gray line : w/o adjacent tubes, black line : with adjacent tubes

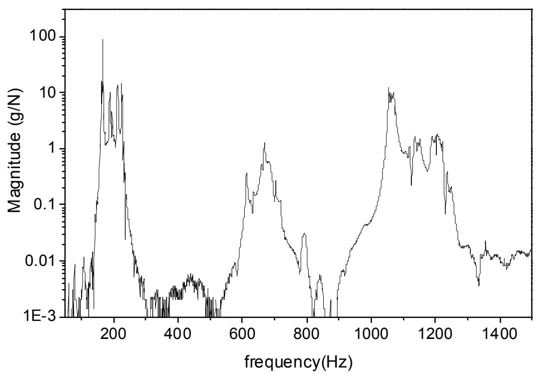

Figure 4. Cross Frequency Response Function

3.2 Fuel Rod Test Results

Because lead pellets exist in the fuel rod, they make another noise considering pellet to clad interaction. Increasing the level of input sine signal, we hear chattering sound caused by pellet to clad interaction. The noise makes the system nonlinear and signal analyses difficult. Like Figure 4, Figure 5 shows two different test results.

Since the rod weight is heavier than tube, we observed lowered natural frequencies. Based on Figure 5, we see that no severe change of dominant frequencies was made between the two cases. Considering lead pellet, amplitude level is also lower than that of fuel tube and it seemed that signals are noise contaminated. With the noise contaminated signal, it is thought that further analysis reliability will be low.

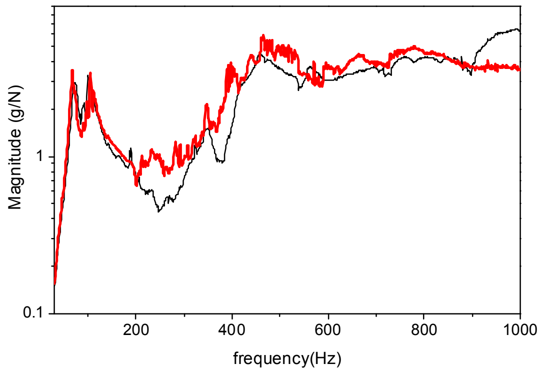

Figure 5. Point Frequency Response Function of Fuel Rod; red line : w/o adjacent tubes, black line : with adjacent tubes

4. Conclusion

This study discussed fuel rod modal tests and some difficulties. To investigate dynamic properties of a fuel rod, 4 categories of test were accomplished. Since the fuel tube motion cannot be rigidly restricted by dimples and spring in each grid, we can only obtain noise contaminated signal when random excitation, which is very normal exciting method, is applied. Above all, pellet to clad interaction makes the system more non-linear. And it is concluded that adjacent tube effects are not significant. According to the author's knowledge, sinusoidal excitation with weak intensity will minimize pellet to clad interaction, but input force level should be large enough to acquire reasonable S/N ratio. Since input force cannot be transmitted well due to friction at spacer grids, using multi input test will be more helpful.

ACKNOWLEDGEMENT

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[1] M. K. Au-Yang, Flow-induced Vibration of Power and Process Plant Components, Professional Engineering Publishing, 2001.

[2] LabVIEW^{TM} 7 Express, National Instruments, 2005