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Vibration Pre-characterization of Partial Fuel Test Assembly

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1. Introduction

To check applicability to a conventional reactor core and compatibility with a present fuel design requires hydraulic vibration testing for the annular fuel design in the form of a fuel bundle. Objective of the hydraulic vibration testing (or flow induced vibration testing) is to understand vibration behavior of an oscillating structure submerged in fluid flow and find out relationship between vibration responses of a structure and flow characteristics. Along the same line, a partial fuel test assembly (PFTA) was made in 4x4 arrays with 12 dummy annular fuel rods and 5 combination-type spacer grids of cantilever and vortex dimple spring as shown in Fig. 1. To be more focus for effects of the inner channel fluid mass on the dynamics of an annular fuel test assembly, mass-equivalent simulated lead pellets were eliminated in dummy fuel rods. A series of vibration testing using UMAP (underwater modal test equipment) in ambient and under still water were performed to identify dynamic characteristics of PFTA and evaluate the effects of test parameters and conditions. Objective of the test is to evaluate UMAP performances and prepare backup data for future response analysis of hydraulic vibration testing.

Fig. 1 4x4 dual-cooled partial fuel test assembly mounted on the UMAP.

2. Methods

Classical modal testing and modal analysis method [1, 2] were applied to the pre-characterization for PFTA. A feedback controlled electro-magnetic shaker was installed at mid port of UMAP back plate and excited PFTA to vibrate under given input force (amplitude, excitation waves, covering frequency range) and boundary conditions (axial compressive force). Stinger installed at the end of shaker carried the excitation force to the PFTA through a force sensor. Underwater accelerometers with sealed plug connection were mounted on 5 grids' outer plates by adhesive bond and measured forced vibration responses of PFTA. Water (23 ^{o}C) was filled up to upper-most spacer grids' elevation. Measured input and response signals during the testing were processed to get the frequency response functions using IDEAS/TDAS software. Fig. 2 shows hardware configuration of the vibration testing.

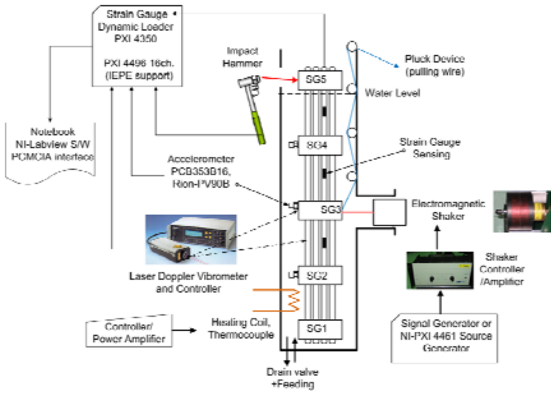
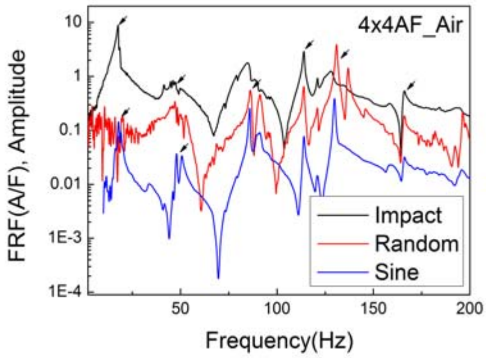


Fig. 2 Hardware configuration of UMAP for PFTA modal testing.

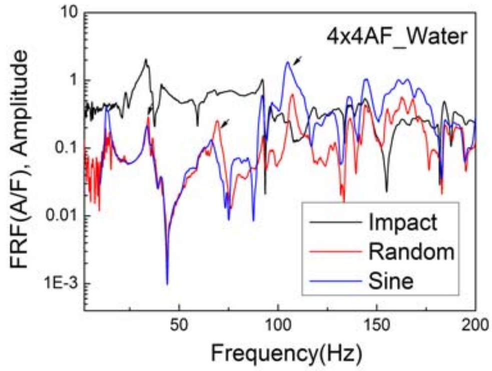
3. Results

Fig. 3 shows in-air and under-water frequency response function (FRF) of PFTA tested by 3 types of excitation: impact, random and sinusoidal. Except test environment of still water, method applied to under-water modal test was identical to that of the in-air test. However, frequency responses in the under-water test FRF were not as clear as the measured realization from in-air test. Additional fluid damping surely contributes this ambiguity in frequency response, especially in the high frequency region. Frequency softening and damping increasing (sideband expansion near or at peak) due to added mass were appeared in the results under-water test FRF against in-air test FRF. Six natural frequencies in in-air test FRF could be identified within 200 Hz of frequency interest and 3 bending vibration modes were confirmed by the post modal analysis (as shown in the Fig. 4); overall modes of vibration in Fig. 3(a) look well separated.

It can be said that each modes of vibration in in-air test FRF corresponds to frequency peaks in under-water test FRF. In in-air test FRF, frequency responses by random excitation represents better realizations in modal sharpness at peak, resonance and anti-resonance features than those by the impact excitation, but frequency response by sinusoidal excitation shows more descriptive and clearer modal characteristics especially in fundamental mode than that by random excitation.



(a) In-air test FRF



(b) Under-water test FRF
Fig. 3 FRFs of 4x4 dual-cooled PFTA; Arrows indicate natural frequency of vibration modes.

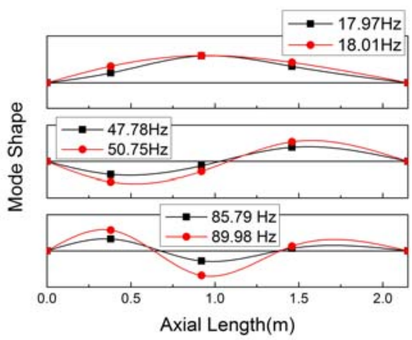


Fig. 4 Vibration mode shape of 4x4 dual-cooled PFTA

Fig. 4 shows bending vibration mode shapes of PTFA identified from modal analysis. Each lower mode represents nearly "dual mode characteristics" whose two independent modes with slight frequency difference are located and influences each other. Normal mode vibration assumption and mode separation which are crucial in linear dynamics are not allowed to these dual mode situation. This can also lead to beating problems when fuel assembly is vibrating under operating condition. Dual mode characteristics is originated from PFTA's inherent asymmetry to the direction of own diagonal axis.

In-air test FRF of PFTA with all inner channel water filled showed no obvious differences against in-air test FRF of PFTA without addition of inner channel fluid mass. This was because inner channel fluid mass was much light compared to the net mass of PFTA, thus has rarely influence on the dynamics of test assembly.

4. Summary

A series of vibration testing for PFTA was carried out using newly constructed UMAP. Objective of the test was to evaluate UMAP performances and identify dynamic characteristics of sample PFTA. Six natural frequencies of 4x4 annular PFTA within 200 Hz was identified from modal testing and analysis and fundamental frequency of PFTA was 18 Hz in air and 13 Hz under water. Frequency differences between in-air and under-water test was mainly from the fluid added mass and damping effect. Local vibration modes of PFTA have dual mode characteristics from the mode shape analysis. Inner channel fluid mass seems rarely influence on the overall dynamics of rod assembly.

ACKNOWLEDGEMENT

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