EXCITATION SOURCES FOR FUEL ASSEMBLY VIBRATIONS IN A PWR[1]

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Introduction

Noise measurements from in-core neutron detectors have been utilized previously to monitor in-plant vibrations of pressurized water reactor (PWR) fuel assemblies.[1-3] Fuel assembly resonant frequencies and mode shapes were obtained from these in-core measurements by observing resonances in the neutron noise power spectral density (PSD) and then plotting the axial dependence of the root mean square (rms) neutron noise over frequency ranges containing these resonances. Based on this type of measurement, the resonant peaks in the neutron noise PSDs occurring at approximately 3 and 7 Hz have been associated with the first [$\mathrm{SIN}(\pi z/H)$] and second [$\mathrm{SIN}(2\pi z/H)$] natural bending modes of fuel assembly vibration.[2-3] However, recent studies of ex-core neutron noise have indicated that core support barrel or core support plate vibration reasonances may also be driving fuel assembly vibrations in the 6- to 8-Hz frequency range.[4-7]

In order to determine the fuel assembly mode shapes and their relationship to core barrel motion, we performed simultaneous measurements of in-core and ex-core neutron noise at the Sequoyah-1 reactor, a Westinghouse 1150 MW(e) PWR. Analysis of this data indicates that there are two different sources of vibrational excitation for the fuel in the 6- to 8-Hz frequency range.

Neutron Noise Measurements

Noise signals from four lower- and two upper-half (each 1.8 m long), ex-core, power-range, ionization chambers and one in-core, flux-mapping, fission chamber were recorded on 14 track FM analog tape. A series of measurements was made in a fuel assembly near the core center by positioning the in-core detector at each of seven axial grid spacer locations. All measurements were performed at full power and flow conditions and with a soluble boron concentration of 694 ppm. The noise recordings were Fourier transformed, and normalized PSDs (NPSDs) were calculated by dividing the raw PSDs by the square of the dc signal level.

Observations

The NPSDs of the in-core neutron detector over the 0- to 10-Hz range exhibit two resonances as shown in Fig. 1. The amplitudes of these resonances vary with the axial position of the detector in the fuel assembly as shown in Fig. 2. As observed previously,[1-3] the amplitude of the 3-Hz resonance is seen to vary sinusoidally with the detector axial position, which is characteristic of the fundamental fuel assembly vibrational mode with fixed end conditions. In the 6- to 8-Hz range, however, two distinct resonances are observed depending on whether the in-core detector is positioned in the upper or lower half of the core. A resonance is visible in the NPSDs only at 7-Hz when the detector is in the lower half of the core, whereas the detector response in the upper part of the core exhibits a resonance only at 6.5-Hz (see Fig. 1). A similar behavior was also observed in the upper- and lower-half ex-core neutron detector NPSDs. This evidence appears to contradict conclusions in previous works[1-3,7] that the resonances in the 6- to 8-Hz range are due to the second natural bending mode of the fuel assemblies. The rms method, as customarily applied, is unable to detect small shifts in frequency (like the ones observed in Fig. 1) because it is usually obtained by integrating the PSD over a frequency range that covers the two observed resonances.

Interpretation of Results and Conclusions

The observed axial dependency of the resonances (Fig. 2) suggests that the 3-Hz resonance is a vibrational mode of the fuel with fixed/fixed boundary conditions as previously reported but, contrary to previous works, the results in Figs. 1 and 2 show that in Sequoyah-1 there are two separate processes causing fuel assembly vibration in the 6- to 8-Hz range. This axial dependency suggests that the 7-Hz resonance is driven by vibrations of the core support plate while the 6.5-Hz resonance is driven by vibrations in the upper tie plate.

We conclude from this analysis that the rms neutron noise method may yield a false picture of fuel assembly vibrational modes because small shifts in resonant frequencies may be masked by the integration process. We also theorize that changes in the dynamic behavior of the core support plate, upper tie plate, or fuel (caused by aging or radiation damage) may lead to changes in the ex-core and in-core neutron noise similar to those observed in Sequoyah-1.[4,6]

Acknowledgment

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FIGURE CAPTIONS

Figure 1. Typical normalized power spectral densities of in-core neutron noise with the detector located in the upper or lower half of the core (274 and 91 cm from core bottom) at the Sequoyah-1 PWR.

Figure 2. NPSD amplitudes of 3.0-, 6.5-, and 7.0-Hz resonances as a function of axial in-core detector position at the Sequoyah-1 PWR.

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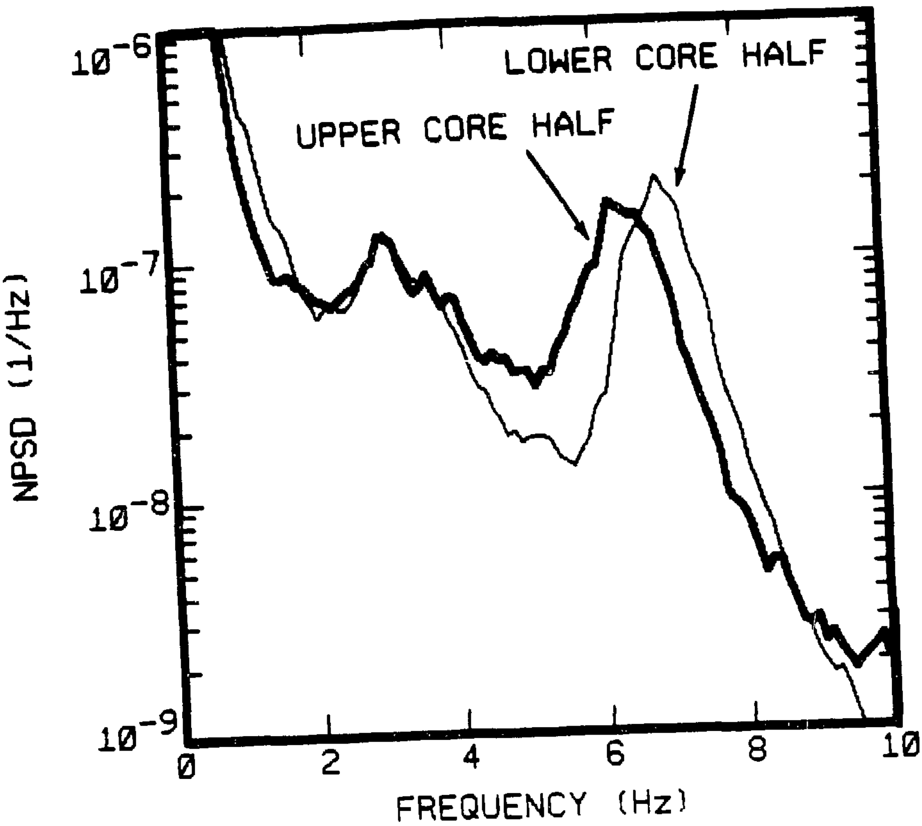
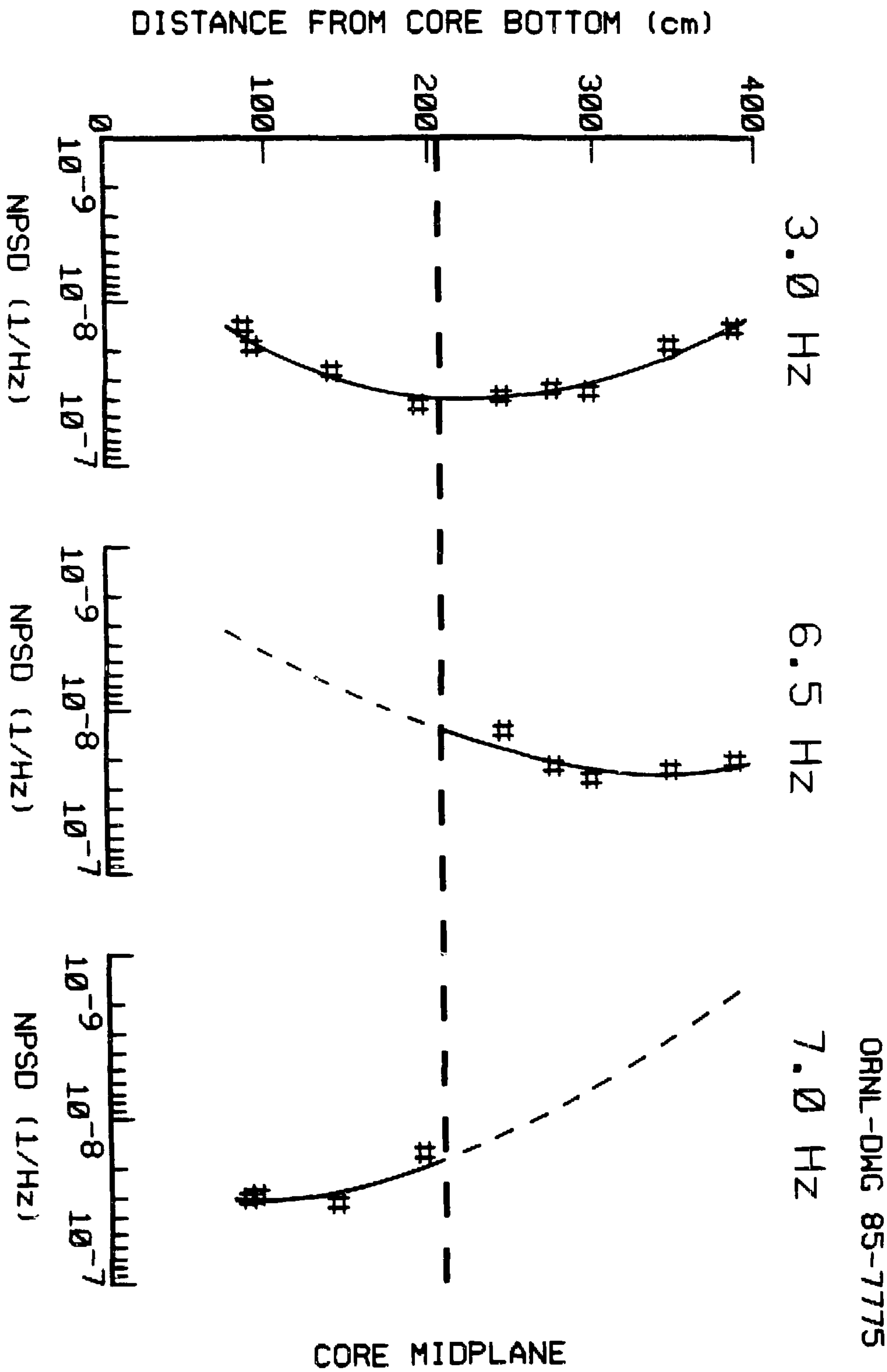

LOWER CORE HALF
UPPER CORE HALF
NPSD (1/Hz)
10^-6
10^-7
10^-8
10^-9
0
2
4
6
8
10
FREQUENCY (Hz)


DISTANCE FROM CORE BOTTOM (cm)
0
100
200
300
400
3.Ø Hz
6.5 Hz
7.Ø Hz
10^{-9}
10^{-8}
10^{-7}
NPSD (1/Hz)
CORE MIDPLANE
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