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Structural Vibration of Core Support Barrel Assembly for Yonggwang Nuclear Unit 4

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Abstract

Core support barrel (CSB) assembly is one of the most important reactor internals structures supporting and protecting the nuclear core during normal operation and faulted events.

For Yonggwang 3 and 4 (YGN 3&4), the adequacy of the analytical response prediction of reactor internals for flow induced vibration was demonstrated through the comprehensive vibration assessment program (CVAP) performed during hot functional test. Besides, the vibration characteristics of the CSB of operating nuclear power plant can be examined via the excore neutron noise monitoring signal.

In this paper data from YGN 4 analyses, CVAP, and neutron noise monitoring system are compared and evaluated. In general, the results are comparable each other and conservative enough to ensure sufficient design margin and structural integrity. Further investigations on the modelling and analyses procedure are recommended to utilize the experimental results to the maximum extent. And collection of the neutron noise data is desired to serve as a baseline information.

1. Introduction

YGN 3&4 is the first nuclear power plant built in Korea under the self-reliance program. During the hot functional test, the limited vibration measurements, which are the first Korean experience, on reactor internals was carried out to show the design validity per U.S. NRC regulatory guide[1].

YGN 3&4 are also equipped with neutron noise monitoring system which enables online surveillance of reactor internals vibratory motion during plant operation.

In this paper, design analyses and measurement data are compared and evaluated under various operating conditions. With this information the designer can better understand the motions occurring inside reactor vessel and therefore can make design improvement if desired.

2. Finite Element Analyses

A free vibration analysis was performed to obtain the system's natural frequencies and associated mode shapes. The natural frequencies and mode shapes of the core support barrel (CSB) assembly, which form the basis for the forced response analysis, were obtained through the use of an axisymmetric shell finite element computer program ASHSD[2]. This computer program is capable of obtaining natural frequencies and mode shape of complex axisymmetric shells; e.g., arbitrary meridional shape, varying thickness, branches, multi-materials, orthotropic material properties. An inverse iteration technique is utilized in the program to obtain solutions to the characteristic equation, which is based on a diagonalized form of consistent mass and stiffness matrices developed using the finite element method. Four degrees of freedom are taken into account in the analysis, giving rise to coupled mode shapes and corresponding frequencies. The core support barrel (CSB) is modeled as shown in Fig. 1. The structure is fixed at the upper flange to determine the beam modes and frequencies. The shell modes and frequencies are found by considering the upper flange fixed and the lower flange pinned. The frequencies in water are computed utilizing the computer code HYDRO[3]. The code is based on a approach to the hydrodynamic effects of two concentric circular cylinders.

3. Measurement - Neutron Noise Monitoring

In YGN 3 and 4 the vibration of the core support barrel under normal operations can be taken from excore detector signals. Since the fluctuation in current delivered by the detector is proportional to the displacement between internals and the excore detector, this signal yields an information of core support barrel motion. Fig. 2 shows the sketch of the neutron noise monitoring system.

The data acquired were analyzed using spectrum analysis technique; traditional Fast Fourier Transform (FFT) routine is utilized to get coherence, phase, and the auto and cross power spectral density (PSD) of the vibration signal of CSB for YGN 3&4. Signals are reduced to the range of 0-50 Hz, since the major CSB signal lies in that low frequency region.

4. Measurement - Comprehensive Vibration Assessment Program

The objective of comprehensive vibration assessment program is to obtain the data to confirm predictions at operating conditions of steady state and transient normal operation.

The measurement was made on 18 different operating modes with 30 sensor locations during hot functional test. Pressures, stresses and accelerations were measured at locations that are decided thru prediction analyses.

Data on the core support barrel was obtained using the instrumentation at snubber block of CSB. The data acquisition was performed at two different frequency ranges - high (0-500 Hz) and low (0-50 Hz) frequency ranges. Sketches of the vibration measurement system is shown in Fig. 3.

The power spectral densities were reduced in the 0-500Hz frequency range for all instruments at all test conditions. In addition, the cross PSD's, Coherence and Phase results were reduced in the 0-500Hz frequency range for selected combinations of instruments at all test conditions. Similar data reduction was completed for 0-50Hz to see low frequency range in more detailed manner.

5. Results and Discussions

The frequencies for the beam mode and for the shell modes are given in Table 1 for the typical condition of 564F. The pertinent beam mode shapes are plotted in Fig. 4. The shell modes are cos(mθ) ring distortions and as an example the first four modes are shown in Fig. 4. The first beam mode frequencies found are 8.1 Hz and 6.92 Hz, without-core case and with-core case respectively.

The PSD spectrum analyses of the acquired neutron noise signal were made for Yonggwang nuclear unit 3 and 4. The resulting PSD from YGN 4 is shown in Fig. 5 showing the peak found at 8.6 Hz as the first beam mode.

Typical PSD plot of the acceleration transducer at CSB is shown in Fig. 6 for CVAP test condition of normal operation. These are used to identify beam mode shapes, frequencies and snubber response displacements. First peak frequency is found at 7.1 Hz.

To see the numbers provided above, comparable agreements are made to the magnitude of natural frequencies.

Stress results from both prediction analysis and CVAP test meet the ASME stress and fatigue criteria[5] with prediction values being more than ten times higher than measured values.

From the measured data it seems that the weight of the core does not affect the system frequencies,that is, addition of mass seems to increase the natural frequency of the system. In YGN 3 neutron noise data, however, shows the peak at 7.6 Hz, still the core does not affect the natural frequencies. This phenomenon can be explained by introducing axial load stiffening effect and/or uplifting of core due to flow resistance, but frequency drop due to the mass addition of core is found by the similar study[6].

6. Conclusion

The analysis results are in agreement with the measured data and conservative enough to ensure sufficient design margin and structural integrity. Further investigations on the modelling and analyses procedure are recommended to utilize the experimental results to the maximum extent. And collection of long-term neutron noise data is suggested to serve as a baseline information.

References

1. U.S. NRC regulatory guide 1.20, 1976,"Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing"
2. Ghosh and Wilson, ASHSD-Dynamic Stress Analysis of Axisymmetric Structures under Arbitrary Loading, EERC U of Calif., Berkeley.
3. HYDRO: ABB-CE proprietary code.
4. ABB-CE report, Aug.22.1995, A Comprehensive Vibration Assessment Program for Yonggwang Nuclear Generating Station Unit 4.
5. ASME Boiler and Pressure Vessel Code, Section III, 1989 ed.
6. A.Trenty,1995, "Internals structure vibratory monitoring of 54 French PWRs", Trans. of the 13th International Conference on SMiRT.

Table 1. Predicted Natural Frequencies of Core Support Barrel

		Circumferential Mode No.			
		m=1	m=2	m=3	m=4
Axial Mode No.	n=1	8.1 (6.92)	26.9 (21.57)	35.6 (28.89)	54.8 (57.5)
	n=2	16.6 (35.4)	41.5 (53.6)	70.6 (48.3)	103.4 (64.4)
	n=3	22.3 (40.2)	38.6 (89.0)	63.4 (78.7)	92.9 (82.8)
	n=4	48.9 (70.2)	53.9 (126.6)	69.0 (113.2)	91.6 (109.1)

* pre-core (post-core) in Hz

Fig. 1 ASHSD Finite Element Model of CSB

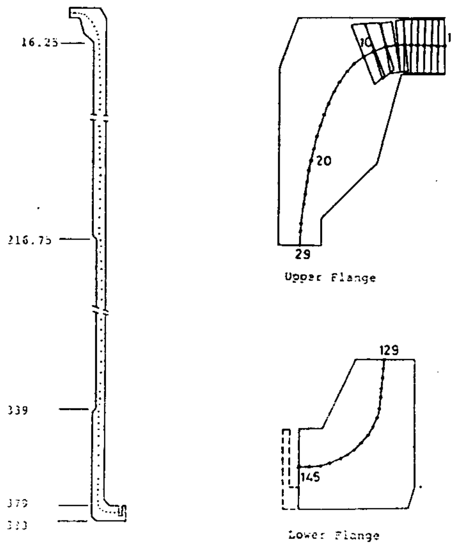

Fig. 2 Schematic Diagram of Neutron Noise Monitoring System

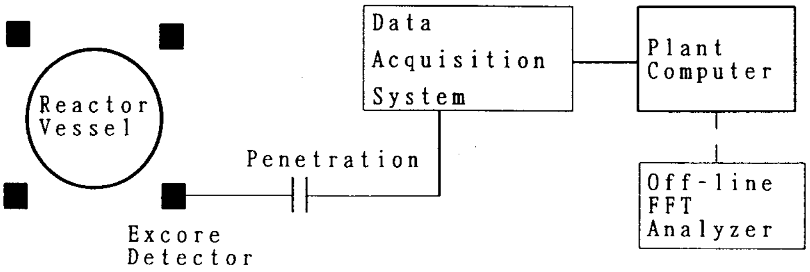

Fig. 3 Schematic Diagram of CVAP Measurement System

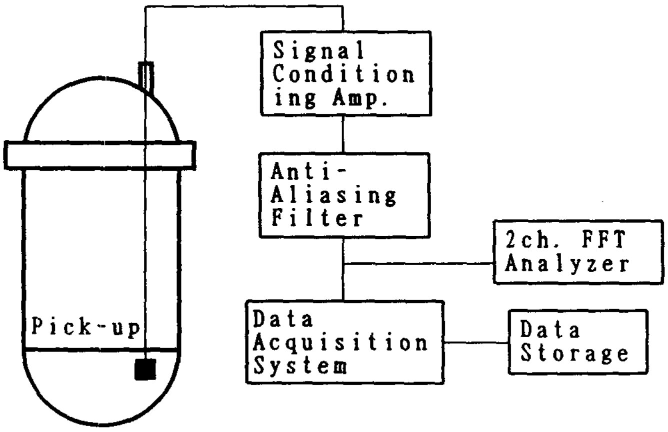

Fig. 4 Typical Beam and Shell Mode-shapes

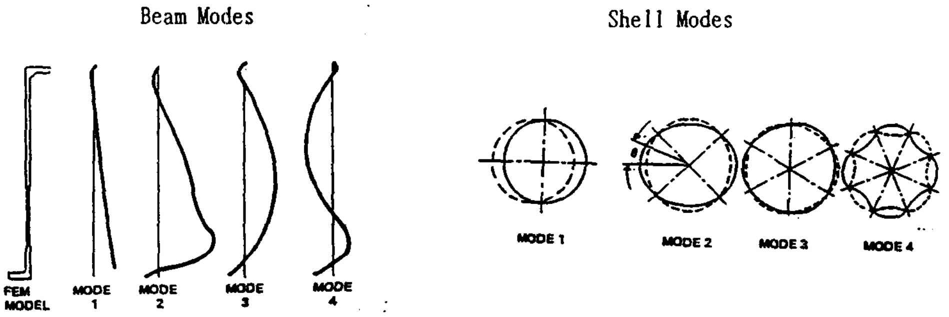

Fig. 5 Power Spectral Density (Neutron Signal)

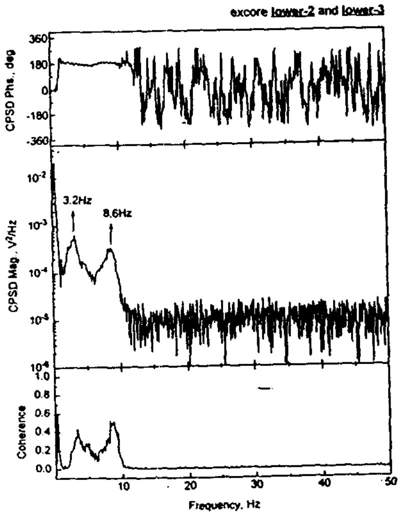

Fig. 6 Power Spectral Density (CVAP)