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Original Article

# STUDY OF CORE SUPPORT BARREL VIBRATION MONITORING USING EX-CORE NEUTRON NOISE ANALYSIS AND FUZZY LOGIC ALGORITHM

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ABSTRACT

The application of neutron noise analysis (NNA) to the ex-core neutron detector signal for monitoring the vibration characteristics of a reactor core support barrel (CSB) was investigated.

Ex-core flux data were generated by using a nonanalog Monte Carlo neutron transport method in a simulated CSB model where the implicit capture and Russian roulette technique were utilized. First and third order beam and shell modes of CSB vibration were modeled based on parallel processing simulation. A NNA module was developed to analyze the ex-core flux data based on its time variation, normalized power spectral density, normalized cross-power spectral density, coherence, and phase differences. The data were then analyzed with a fuzzy logic module to determine the vibration characteristics.

The ex-core neutron signal fluctuation was directly proportional to the CSB's vibration observed at 8 Hz and 15 Hz in the beam mode vibration, and at 8 Hz in the shell mode vibration. The coherence result between flux pairs was unity at the vibration peak frequencies.

A distinct pattern of phase differences was observed for each of the vibration models. The developed fuzzy logic module demonstrated successful recognition of the vibration frequencies, modes, orders, directions, and phase differences within 0.4 ms for the beam and shell mode vibrations.



## 1. Introduction

To achieve a high level of safety while maintaining a high level of plant availability, it is desirable to perform preventive measures instead of corrective ones. One of these measures is the monitoring of reactor internals vibration characteristics. Any change in the vibration signatures may indicate an anomaly in the reactor internals. A significant structure to be

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monitored is the core support barrel (CSB). One method to monitor the CSB's vibration is by analyzing the neutron flux sensed by ex-core detectors around it as demonstrated by Yun et al [1].

A typical pressurized water reactor (PWR) core schematic is shown in Fig. 1. The CSB is fixed to the vessel at its top section. The high-pressure coolant's flow creates flow-induced vibrations in the CSB. To limit the vibrations' effects, mechanical snubbers are installed at the bottom part of the CSB.

Much research has been done to monitor the CSB's vibrations. Song and Jhung [2] utilized the analytical finite element model to calculate the CSB's frequency response function and validated it experimentally with a modal analysis experiment on a scaled-down model of the APR1400's CSB. The modal analysis was done by a shaker test using vibration sensors attached to the CSB model. Further research conducted by Ansari et al [3] correlated the ex-core detector data and vibration sensors mounted on reactor structure and control rod drive mechanisms. As a result they were able to identify a particular control rod that had a different vibration signature. They also concluded that the use of ex-core neutron noise analysis (NNA) was more sensitive in determining the dynamic behavior of reactor internals compared to the vibration sensors. Additionally, the ex-core NNA method can also be used to monitor the condition of thermal shield systems attached to the CSB [4]. This was done by analyzing the correlation of the vibration monitoring results with loose-part monitoring data as performed by Lubin et al [4] on the St Lucie PWR nuclear power plant. The CSB could also be modelled through a finite element approach and be monitored using neural networks [5].

Standards and guides have been written on the conduct of ex-core detector data analysis for vibration monitoring. The American Society of Mechanical Engineers (ASME) published two similar guides in the ASME OM-S/G-2007 document [6]. Part 5 of this document focuses on specifically monitoring the core support barrel axial preload. Part 23 elaborates on the monitoring of reactor internals vibrations in general. The United States Nuclear Regulatory Commission specifically issued Regulatory Guide 1.20 on The Comprehensive Vibration Assessment Program [7].

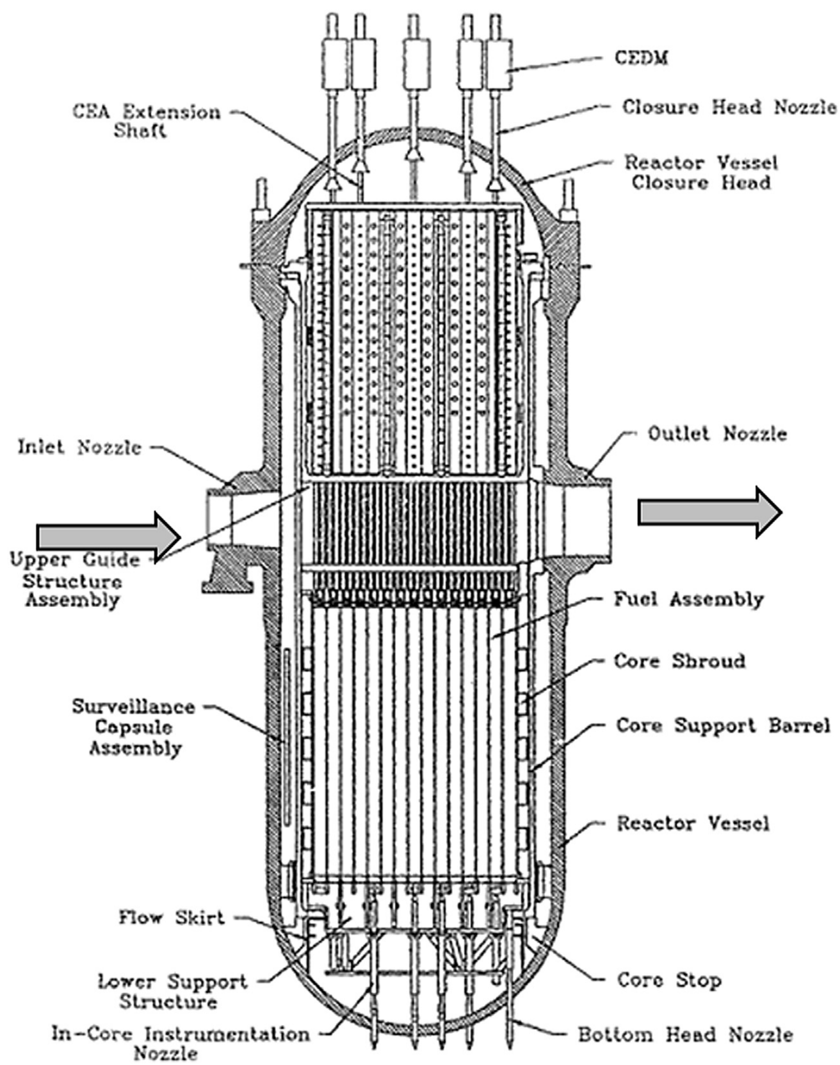


**Fig. 1 – Pressurized water reactor core schematic.**