NUCLEAR REACTOR SURVEILLANCE — NEUTRON NOISE MEASUREMENTS AND VIBRATION ANALYSIS ON FRENCH PWR INTERNAL STRUCTURES

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In a reactor, the internal structures are submitted to vibrations mainly induced by the turbulent excitations of the primary flow. These structures are an important component of the system and to prevent any incidents, it is necessary to follow the vibration behaviour of the reactor.

The first thing to do is to define a reference, which consists in the initial signature of the structure motions, then to follow from time to time the evolution of the behaviour, and verify that it does not exist abnormal changes of the signature due to particular phenomena.

So, we must find criteria for vibration monitoring, i.e. to give some limits of variations of the main vibration parameters corresponding to a normal behaviour(variation domain for frequencies and maximum levels allowed for amplitudes).

It is not simple to reach this step, because for a given reactor, the normal vibration behaviour itself can changes with time, due to variation of many mechanical parameters : fabrication tolerancies, gaps which close, contacts between vessel and core barrel.

It is also necessary to performe a lot of measurements on several plants to obtain data, to compare a reactor to an another, to get statistics.

In parallel calculations can explain some evolutions of frequencies (introduction of contacts).

The experimental program undertaken consists in neutron noise and external accelerometers measurements on several reactors.

1. Introduction

This paper deals with some interesting results about the vibration monitoring of reactor internals. These results were obtained by means of external accelerometers located on the vessel and also by neutron noise measurements on four plants : TIHANGE 1, FESSENHEIM 1 and 2, BUGEY 5.

2. Description of hardware

2.1. Accelerometers

The reactor vessel is equiped with 7 high sensitivity (200 pc/g) and high temperature resistant accelerometers installed on the head flange and on the bottom (see fig. 1). In addition to the displacement of the vessel these sensors are able to "see" the motion of the internals.

2.2. Neutron noise

The neutron noise measurements are made on the flux signal delivered by eight excore half-chambers located around the core. The fluctuating signal is then adequatly filtered and amplified.

2.3. Data analysis

The neutron noise and the signals delivered by the accelerometers are analyzed by means of a classical Fast Fourier Transform computer code which gives the direct and cross power spectral densities as a function of the frequency.

We suppose that the fundamentals of neutron noise are well-known. Let us simply recall that the neutron noise analysis is a powerful tool for the survey of the displacement of the internals.

3. Analysis of results

3.1. Basic characteristics of PWR internals behaviour

The vibratory behaviour of PWR internals equiped with cylindrical thermal shield is characterized by its beam mode and to a less extent by first shell modes.

The beam mode n = 1 is of most importance on a safety point of view. The monitoring of frequency and amplitude associated with this mode allows to verify the vibration integrity of the strucutres.

Let us recall that experimental ref. [1], [2], [3], and analytical studies have permitted a whole understanding of the behaviour of structures and to estimate their displacements.

Depending on the positionning of the core barrel in the vessel and the pumps in operation the results of these studies show that the core barrel :

- vibrates in a cantilever mode with no contact at the radial support,
- vibrates in supported mode with constant contact at one or more radial supports.

3.2. Results of accelerometers measurements

The measurements carried out on four plants show that, in addition to the rocking mode of the vessel which very distinctively appears on all the accelerometers around 14 to 16 Hz, peaks also appear which are related to the internals motion. Among these peaks the beam mode is the easiest to "see" from the outside of the vessel. However the type of this mode is different from one plant to another :

- the cantilever beam mode around 7,5 Hz is typical of FESSENHEIM 2 and BUGEY 5 (see fig. 7&2).
- the supported beam mode around 11 Hz is typical of TIHANGE 1 and FESSENHEIM 1 (see fig. 6).

3.3. Results of neutron noise measurements

The neutron noise spectra are in accordance and confirm the results of the accelerometers The conclusions that can be drawn on the beam modes are the same (see fig. 3, 4, 5).

3.4. Comparison between neutron noise and accelerometers (see fig. 6 & 7)

By comparison with the neutron noise spectra it can be concluded that the frequencies seen by the external accelerometers are the same as those included in the neutron noise, this is a confirmation that these frequencies are related to the internals motion.

The super-imposition of neutron noise and accelerometer spectra is very interesting.

These findings are also confirmed on a quantitative point of view by the cross-spectrum analysis of neutron noise and accelerometers. Coherence values and phase relationships appear especially clearly on the beam mode.

4. The future

The final purpose of these studies is to determine criteria for the vibration monitoring of reactor internals.

On the experimental level, an important test program is under progress on a great number of plants.

On the calculation level, an analytical model of the internals and vessel will provide for the relationship between the displacements inside the vessel and those measured outside.

This model will be calibrated by the results of the tests and especially of vibration tests carried out on instrumented reactor internals.

Finally in what concerns the neutron noise, fundamental studies have been undertaken in order to understand the relationship between the displacements of the internals and the magnitude of the peaks appearing on the neutron spectra.

5. Conclusion

Our program is still under progress ; we think that the multiplication of measurements on several reactors, the vibration calculations, the synthesis between experimental data and calculated results will permit us to understand the internals behaviour and to define criteria for vibration monitoring.

REFERENCES

[1] R. ASSEDO, A. EPSTEIN, R.J. GIBERT, M. LIVOLANT, "Synthesis of Vibration Studies on a Three Loop PWR Internals Model", 4th Conf. on Structural Mechanicsin Reactor Technology, San Francisco, U.S.A., (15-19 August 1977).

[2] J.C. CARRE, R.J. GIBERT, F. JEANPIERRE, R. ASSEDO, "PWR Internals Vibrational Mode Shapes Calculation and Tests", S.M.O.R.N. Conference, Gatlinburg, U.S.A., (19-23 September 1977).

[3] R. ASSEDO, A. EPSTEIN, R.J. GIBERT, F. JEANPIERRE, M. LIVOLANT, "Hydroelastic Model of PWR Reactor Internals Safran 1 - Validation of a Vibration Calculation Method", Vibration in Nuclear Plant Conference, Keswick, U.K. (May 1978).

VESSEL INSTRUMENTATION ACCELEROMETERS

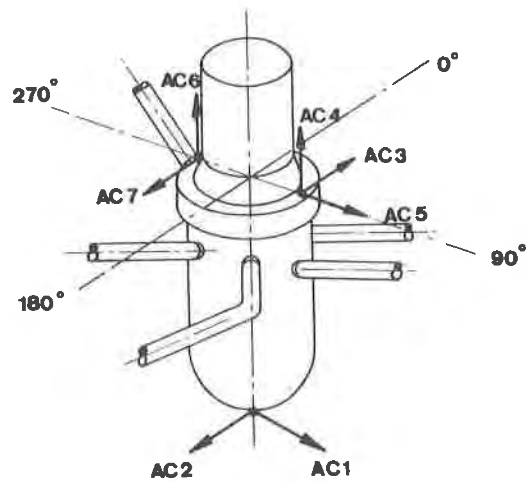

Figure 1 - VESSEL INSTRUMENTATION ACCELEROMETERS

BUGEY 5
HEAD VESSEL ACCELEROMETER PSD

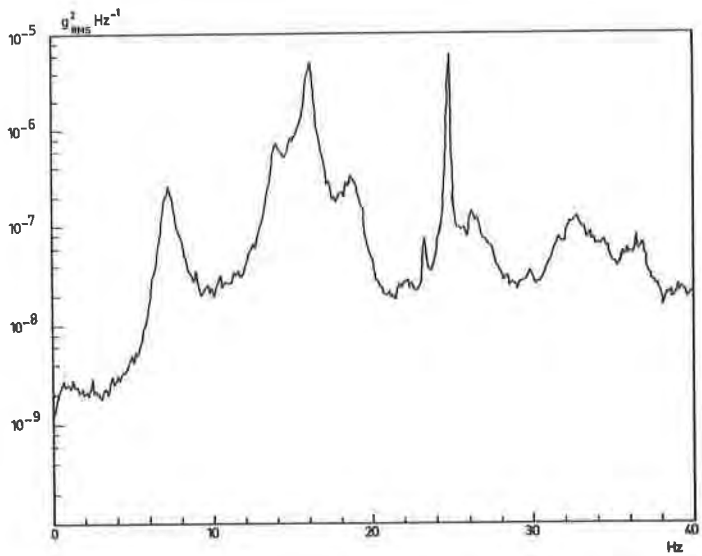

Figure 2 - BUGEY 5 - HEAD VESSEL ACCELEROMETER PSD

F 2/2

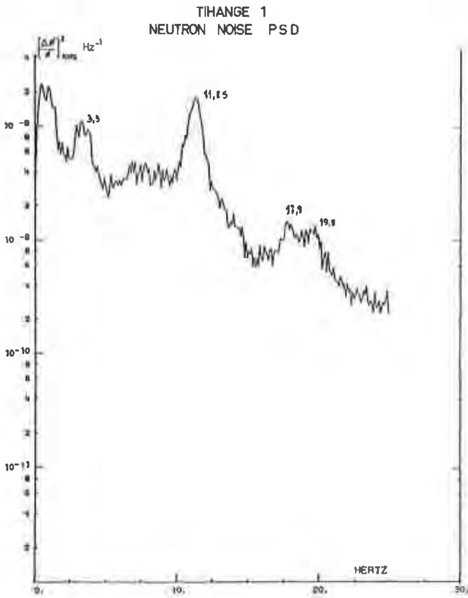

Figure 3 - TIHANGE 1 - NEUTRON NOISE PSD

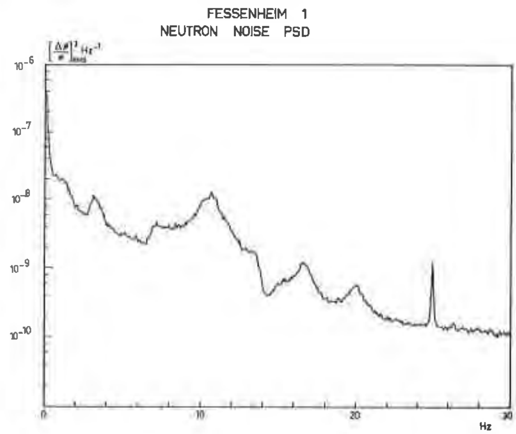

Figure 4 - FESSENHEIM 1 - NEUTRON NOISE PSD

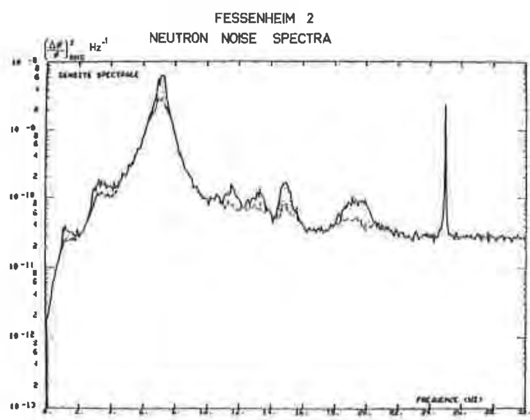

Figure 5 - FESSENHEIM 2 - NEUTRON NOISE SPECTRA

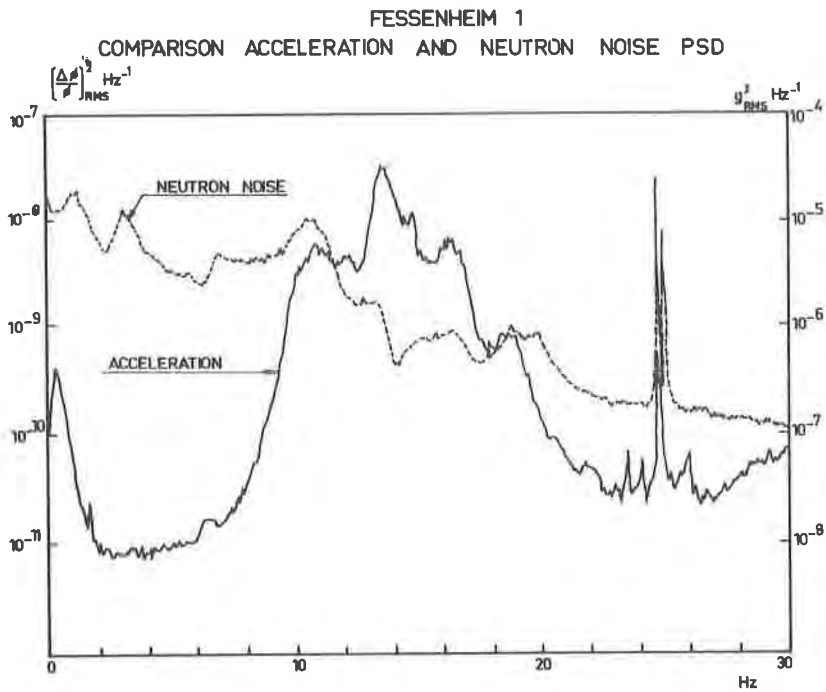

Figure 6 - FESSENHEIM 1 - COMPARISON ACCELERATION AND NEUTRON NOISE PSD

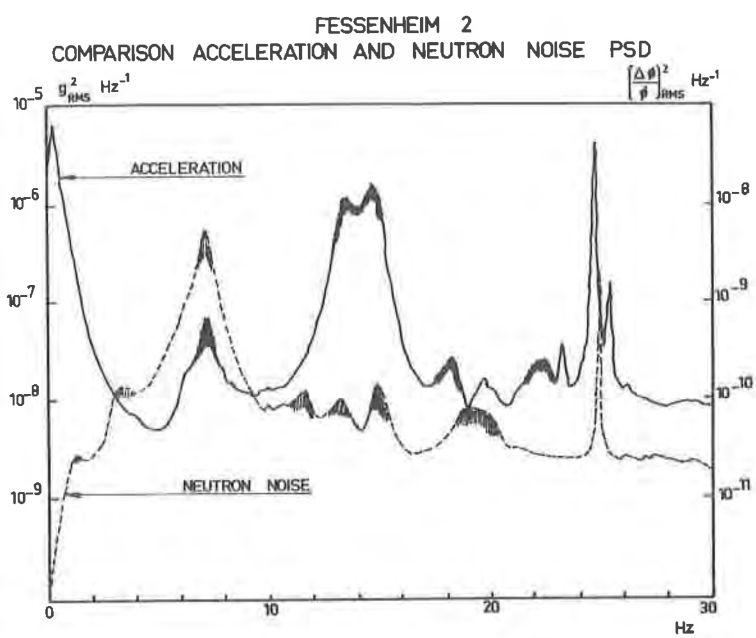

Figure 7 - FESSENHEIM 2 - COMPARISON ACCELERATION AND NEUTRON NOISE PSD