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# ETUDE DES VIBRATIONS ALEATOIRES D'ORIGINE HYDRODYNAMIQUE DE CERTAINES STRUCTURES DU BLOC REACTEUR PHENIX

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An important source of vibrations in the vessels of a reactor such as the sodium cooled fast French reactor Phenix is the turbulence of the liquid sodium flow. In fact, the random pressure pulsations may excite the natural modes of these structures if they are within the low frequency range. At the stage of the project, our purpose was to ascertain whether the vessels of the reactor were adequately stable and if not, to determine the necessary changes to achieve this aim. - Our investigation can be divided into three phases.

In the INSA Vibrational Laboratory in Lyons, the vibrational characteristics occurring in the vessels were measured on mechanical models at the scale of 1/10, in the air as well as in quiet water simulating sodium. In conjunction with these experiments, theoretical and experimental investigations for the breathing vibrations were done on the modal behaviour of various simple patterns of cylindrical immersed shells. The comparison of results led us to idealise the structures of the reactor to simple shell schemes easy to calculate.

In addition, pressure recordings carried out on hydraulic models at the scale of 1/4 were given to us. We analysed the statistical features of the pressure pulsations. On one hand, we studied on digital computer the power spectral density functions of the excitation pressure recorded by a pressure transducer located at various points of the vessel surface and on the other hand, the power co-spectral density functions relating to several pairs of pressure transducers located at more or less near intervals. The results show that on the surface of each vessel, the power spectral density function is practically independent on the measurement point and can be analytically represented in a simple manner.

Then, we calculated the response of the vessels analytically by using the theory of random vibrations of the shells which we developed to allow for the specificity of the problem and the experimental means. We determined a first upper bound of the response by using only the modal characteristics and the power spectral density functions. This was sufficient to guarantee the mechanical stability of certain structures.

On the other hand, it was necessary to develop a more elaborate calculation for other structures, taking the power co-spectral density functions into account. Of course, the sensitiveness of the method depends on the size of pressure transducers. Formulae have been established for this purpose.

Special attention was given to the estimate of fluid damping so that the damping ratios measured on the model can be applicable to the prototype. Basic damping studies were carried out.

In our opinion, these investigations permit to progress with the knowledge of the vibrations of nuclear reactors. However, the models necessarily present some distortions and all phenomena cannot be considered. Therefore, our results shall be checked during tests to be done after the erection of the reactor.

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## DISCUSSION

**Q** L. LAZZERI, Italy

1. How did you compute the added mass of the fluid ?
2. Did you find any coupling of the vibratory behaviour of the structures due to the interposed presence of the fluid ?

**A** G. PAYAN, France

1. The added mass of fluid was computed using a potential flow law of a perfect fluid. The same result is included in the more general calculation of laminar damping, using linearised Navier-Stokes equations, which was presented, with experimental verification, at the last AIRH congress in Paris (August 1971).
2. During the tests in quiet water, we observed no coupling due to the fluid. However, when the fluid is moving, some coupling must be considered between two modes of the same structure, according to calculation for ideal fluid with particular potential flow. We have used the calculations made by Casacci, correcting one mistake they contained and taken into account the possible effect of turbulence. We did not find here any danger of coupling. This work will be presented later.

**Q** J. KADLEC, Germany

1. What was the rms value of pressure fluctuations used for your calculations ?
2. What was the way of the use of the mentioned Schwartz inequality in calculating the response of the structure ?

**A** G. PAYAN, France

1. A few millibars.
2. If $W_p(A,B,\omega)$ is the cospectral density function relative to points A and B the Schwartz inequality leads to :

$$[W_p(A,B,\omega)] \leq (W_p(A,A,\omega)\, W_p(B,B,\omega))^{1/2}$$

As shown on the graphs, practically :

$$W_p(A,A,\omega) = W_p(B,B,\omega) = W_p(\omega)$$

on all structures considered, and for all points. Therefore :

$$|W_p(A,B,\omega)| \leq W_p(\omega)$$

The Powell integral being of the shape :

$$I = \iint W_p(A,B,\omega)\, \phi\phi'\, dS\, dS' \text{ with } I \geq 0$$

it is possible to write : $I \leq \iint |W_p(A,B,\omega)|\, |\phi\phi'\, dS\, dS'|$

Therefore, the final result we use : $I \leq W_p(\omega) \iint |\phi\phi'\, dS\, dS'|$

This calculation and application formula have been presented at the technical session of S. H. F. (April 1971) and should be published in "La Houille Blanche" in 1972.

**Q** E. OHLMER, JRC Ispra, Italy

Les structurations de pression, que vous avez mesurées dans votre maquette, ont été déterminées dans des zones où l'écoulement est établi, si j'ai bien compris. Pensez-vous qu'il faudrait tenir compte aussi des effets d'entrée de l'écoulement. En effet, les valeurs rms des fluctuations de pression dans de telles zones sont augmentées d'un facteur ~ 2, par rapport aux valeurs d'un écoulement établi.

**A** G. PAYAN, France

Looking at the design of this pool type reactor, it can be seen that, for all structures, the flow is really established. You will see in our paper that measurements have been taken at very different locations on the surface of the structures, so that we are rather confident in the data we used.