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VIBRATIONS OF THE SLENDER ROD INDUCED BY THE TURBULENCE IN THE COOLANT FLOW

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Abstract: *The theoretical model is presented. The vibrations are proposed to be random nature and are caused by random pressure fluctuation in the turbulent boundary layer surrounding the rod. The mean square of the amplitude of rod deflection is expressed using frequency response function to distributed loading and the spatial correlation density of the pressure fluctuations. The general expressions pinned-pinned.*

Keywords: ***Fundamental frequency, frequency response function, transverse forces, spatial correlation density.***

1. Introduction

In the operation of nuclear power plants the fuel assenblies are surrounded by the axial turbulent flow and in consequence of pressure fluctuations acting on its surface. The problem is this one of random vibrations. In general several types of forces exists as follows

- the pressure forces which are considered to be independent of rod motion.
- the damping forces which are dependent on the lateral velocity of the rod
- the inertie forces which are dependent on the acceleration
- the elastic restoring forces which are dependent on the stiffness.

2. Basic equations

Under the suppositions discussed in the previous chapter it can be shown that the mean square of the amplitude of deflection at the centre of the rod may be expressed as follows (Thomson 1965)

$$\langle y^2(t)\rangle = \frac{1}{M\omega_1^4}\int_0^{+\infty} H(f)H^*(f)df \int_0^L\int_0^L R_f(x,x',f)\phi_1(x)\phi_1(x')\,dxdx' \tag{1}$$

Where M ….. mass of the rod
ω_1 …. fundamentals circular frequency of the rod to distubuted loading
$H(f)$ … frequency response function of the rod to distributed loading
$H^*(f)$… komplex conjugate of $H(f)$
L …. length of the rod
ϕ_1 …. fundamentals mode of the rod
x, x' …. space variables
t …… time

$R_f = \langle F(x,t)F'(x',t)\rangle$ where $F(x,t)$ and $F(x',t)$ denote values of the transverse forces at points x and x´ respectively at time t.

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After evaluation of the spatial correlation R_f as the result we obtain

$$\langle y^2(t)\rangle = \frac{D_0^2\Psi_D^2}{M\omega_1^4}\langle p^2(x,t)\rangle' \int_0^{+\infty} H(f)H^\star(f)df \int_0^L\int_0^L e^{-\alpha|x-x'|}\cos\beta(x-x') * \\ * \varphi_1(x)\varphi_1(x')\,dxdx' \tag{2}$$

3. Application on the slender rod with boundary condition pinned pinned

In this case the double integral in eq. (2) takes the form

$$\Psi_L^2 = \int_0^L\int_0^L e^{-\alpha|x-x'|}\cos\beta(x-x')\sin\frac{\pi x}{L}\sin\frac{\pi x'}{L}\,dxdx'$$

and finally

$$\langle y^2(t)\rangle = \frac{L^2D_0^2}{M\omega_1^4}\Psi_D^2\Psi_L^2\langle\rho^2(x,t)\rangle\int_0^{+\infty} H_1(f)H_1^\star(f)df \tag{3}$$

Based on given boundary conditions, the integral in eq. (3) takes the form

$$\mathrm{I} = \int_0^\infty \frac{\Omega^4 + 4D^2\Omega^2\omega^2}{[(\Omega^2-\omega^2)+2iD\Omega\omega][(\Omega^2-\omega^2)-2iD\Omega\omega]}d\omega \tag{4}$$

As the result we obtain

$$\langle y^2(t)\rangle = \frac{L^2D_0^2}{M\omega_1^4}\Psi_D^2\Psi_L^2\langle\rho^2(x,H)\rangle\frac{\pi f_1}{4D} \tag{5}$$

4. Conclusions

This paper represent theoretical analysis of the effects of boundary layer turbulence on fuel rod vibrafon. Some results of experimental investigations has been used. We will continue in this effort as follows

- Numercial evaluation of the values Ψ_L^2
- Assessment of mean square of the rod amplitude for the fuel rod of fuel assembly TVSA-T
- Application on the fuel assembly TVSA-T of NPP Temelin.

References

Thomson W.T. (1965) *Vibration Theory and Applications* Prentice Hall, New Jersey.

Reavis J.R. (1967) WVI – Westinghous Vibration Correlation for Maximum Fuel Element Displacement for Parallel Turbulent Flow *Thirteen Annual Meeting Americal Nuclear Society, June.*

Gorman D.J. (1969) *The Role of Turbulance in the Vibration of Reactor Fuel Element in Liquid Flow* Advanced Engineering Branch, Chalk River, Ontario , Rept. No AECL-3371.

Prudnikov A.P. et al. (1981) *Integrals an Series* Nauka Publishing, Moscow, Serie Mathematics and Physics, in Russian Language only