Sloshing of Fluid in Horizontal Steam Generator Generated by Horizontal and Vertical Seismic Motions

Karel Dach, Ladislav Pecinka
Institute of Nuclear Research, Rez (near Prague), Czechoslovakia
Pavel Drabek, Jiri Klatil
Technical University Plzen, Plzen, Czechoslovakia

INTRODUCTION

The nuclear power plants with WWER type reactors are characterized by horizontally situated steam generators (SG). During seismic event the horizontal and vertical ground accelerations induce fluid motion in directions of longitudinal and transversal axis. Resulting dynamical forces act on the SG attachement and could cause for example the failure of screws e.t.c. In obvious PSA scenario these phenomena are classified as a "indirect induced LOCA". In this paper the effects of transversal sloshing of fluid are analysed.

EQUATION OF MOTIONS FOR SMALL DEFLECTIONS

In Fig. 1a) is given an idealised schema of steam generator, the adequate pendulum model based on the mechanical analogy (Bashir et all, 1982; Budianski, 1960) is depicted in Fig. 1b).

The equation of motion has the form:
- for the pendulum

$$M_p l_p^2 \ddot{\Theta} + (g - z_0 \omega_e^2 \cos\omega_e t) M_p l_p \sin\Theta\cos\Theta + c_s l_s^2 \sin\Theta\cos\Theta = - M_p x_0 \omega_e^2 \cos\omega_e t \cos\Theta \qquad (1)$$

for the SG attachement

$$F = M_p l_p \ddot{\Theta}\cos\Theta - M_p l_p \dot{\Theta}^2 \sin\Theta + M_p x_0 \omega_e^2 \cos\omega_e t + c_s l_s \sin\Theta \qquad (2)$$

Introducing nondimensional parameters and coordinates

$$\Theta = \Theta \qquad \Omega_p = \frac{\omega_p}{\omega_e} \qquad \lambda_2 = \frac{x_0}{l_p} \qquad \beta = \frac{c_s}{M_p \omega_e^2}$$

$$\tau = \omega_e t \qquad \lambda_1 = \frac{z_0}{l_p} \qquad \lambda_3 = \frac{l_s}{l_p} \qquad \omega_p = \sqrt{\frac{g}{l_p}}$$

$$\varphi = \frac{F}{M_p l_p \omega_e^2}$$

we obtain the following system of equations

$$\ddot{\Theta} + (\Omega_p^2 - \lambda_1 \cos\tau)\sin\Theta = - \lambda_2 \cos\tau \cos\Theta \qquad (3)$$