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OPTIMAL ELEVATION OF SEISMIC SUPPORT FOR CEDMs CONSIDERING DYNAMIC INTERACTIONS WITH RV OF A PRESSURIZED WATER REACTOR

CHOON-EON JIN, BEOM-SHIG KIM, SUNG-HO PARK
Korea Power Engineering Company,
Taejon, Republic of Korea

The optimal elevation of the seismic supports for the control element drive mechanisms (CEDMs) of a pressurized water reactor is determined by considering the dynamic interactions between the motions of the reactor vessel and the CEDMs. Fig.1 shows a schematic view of the unsupported CEDMs and the reactor vessel. Various support concepts can be investigated to have the system perform proper functions and retain structural integrity during seismic events. The dynamic interactions between the reactor vessel and the CEDMs are investigated with a mathematical model that idealizes the reactor vessel as a single mass primary system and the CEDMs as multiple secondary systems whose masses are different each other, as shown in Fig.2. The complex frequency response functions of the primary system and the secondary system are expressed, respectively, as;

$$H(\omega)_{p,d/a} = \frac{-(1+\mu_t) - \omega^2 \sum_{j=1}^{n} \frac{\mu_j}{\omega_j^2 - \omega^2 + 2i\varsigma_j \omega \omega_j}}{\omega_p^2 - (1+\mu_t)\omega^2 + 2i\varsigma_p \omega \omega_p - \omega^4 \sum_{j=1}^{n} \frac{\mu_j}{\omega_j^2 - \omega^2 + 2i\varsigma_j \omega \omega_j}} \quad (1)$$

$$H(\omega)_{s,j,d/a} = -\frac{\omega_p^2 + 2i\varsigma_p \omega \omega_p + \omega^4 \left\{ \mu_j \sum_{k=1}^{n} \frac{1}{\omega_k^2 - \omega^2 + 2i\varsigma_k \omega \omega_k} - \sum_{k=1}^{n} \frac{\mu_k}{\omega_k^2 - \omega^2 + 2i\varsigma_k \omega \omega_k} \right\}}{\left\{ \omega_p^2 - (1+\mu_t)\omega^2 + 2i\varsigma_p \omega \omega_p - \omega^4 \sum_{k=1}^{n} \frac{\mu_k}{\omega_k^2 - \omega^2 + 2i\varsigma_k \omega \omega_k} \right\} \left(\omega_j^2 - \omega^2 + 2i\varsigma_j \omega \omega_j \right)} \quad (2)$$

The mean square displacement responses of the system to the stationary random base excitation with constant power spectral density S_0 can be obtained from the following equations;

$$E\left[x_p^2\right] = S_0 \int_{-\infty}^{\infty} \left|H_p(\omega)\right|^2 d\omega \quad (3) \qquad E\left[x_j^2\right] = S_0 \int_{-\infty}^{\infty} \left|H_{S,j}(\omega)\right|^2 d\omega \quad (4)$$

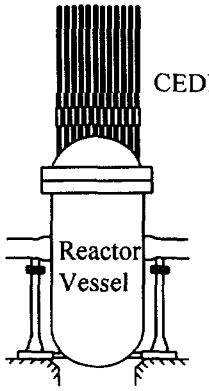

FIG. 1. Descriptive view of the reactor vessel and the free standing CEDMs of a pressurized water reactor.

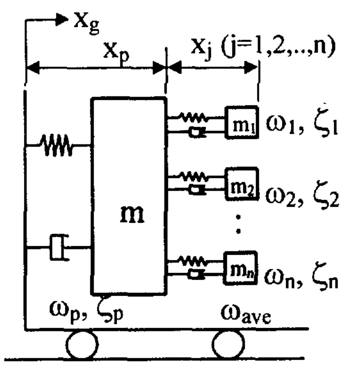

FIG. 2. Simplified mathematical model representing the reactor vessel and the CEDMs.

By defining the tuning frequency ratio f (= ω_{ave}/ω_p) and the frequency bandwidth of the secondary system β (= $(\omega_n-\omega_1)/\omega_p$), the responses of the system can be calculated as a function of f and β for a given mass ratio, the number of secondary systems and damping ratios. The optimal tuning frequency ratio f^{opt} and the optimal frequency bandwidth of the secondary systems β^{opt} are determined to minimize the response of the primary system [1]. If the seismic supports are added to the CEDMs as shown in Fig.3, the modal characteristics will be changed resulting in the change of dynamic interaction effect between the reactor vessel and the CEDMs. One of the dominant factors modifying the modal properties of the system is the support elevation h. Fig.4 shows the variation of f and β with the variation of the support elevation, h/l, which is obtained by performing modal analysis of the supported CEDMs with the reactor vessel uncoupled. It can be seen from Fig.4 that f^{opt} and β^{opt} (0.95 and 0.36, respectively, for μ_t=0.045, ζ_s=0.02 and n>15, from Ref.[1]) can be achieved at h/l= 0.83. The seismic responses are calculated to verify that the optimal support location determined from the idealized mathematical model subject to the random base excitation is applicable to the actual structural system, i.e., the reactor vessel and the CEDMs excited by seismic disturbances. The seismic response analysis for the coupled model of the reactor vessel and the supported CEDMs is performed using ANSYS 5.1 computer code[2]. Fig.5 compares the maximum seismic acceleration responses of the reactor vessel and the CEDMs for the variation of the support elevation. It can be confirmed from Fig.5 that the seismic acceleration response of the reactor vessel is minimized at the optimal elevation of the CEDM seismic support.

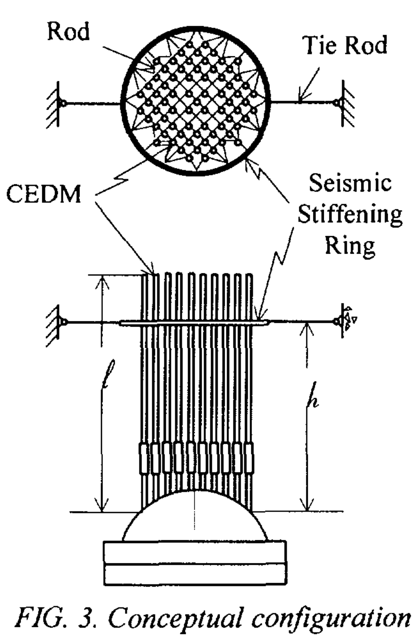

FIG. 3. Conceptual configuration of the seismic supports for the CEDMs.

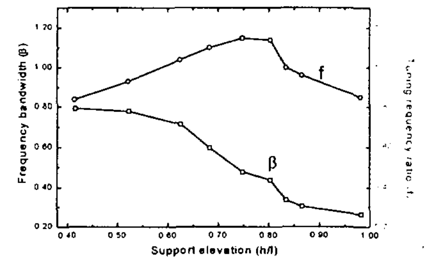

FIG. 4. Variation of tuning frequency ratio f and frequency bandwidth β with the variation of support elevation.

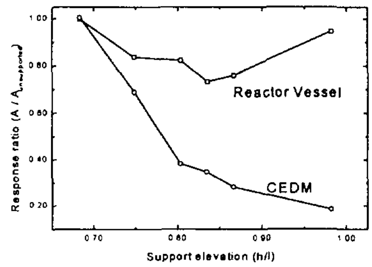

FIG. 5. Variation of the maximum seismic acceleration responses of the reactor vessel and the CEDMs with the variation of the support elevation.

REFERENCES

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[2] Swanson Analysis Co., ANSYS user's *manual*, Ver.5.1 (1996)