KL-expansion-based Monte Carlo simulation for dynamic reliability of

structures subjected to non-stationary random excitations

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It is necessary to bring in certain assumptions for the analysis of system dynamic reliability of structures when using the power spectrum method, which will lead to a comparatively large influence on the calculation accuracy. Meanwhile, the computational efficiency of the power spectrum method is much lower when non-stationary random excitations are involved. In this paper, the feasibility of solving the problem in the time domain is investigated. Structural motion equations are first transformed into the form of state equations and solved by the precise time integration method. Closed-form expressions for structural random responses under non-stationary excitations with Karhunen-Loéve expansions are then deduced in the time domain. The computational effort for such explicit formulation is only equivalent to that required by two deterministic time-history analyses of the structure. Based on the above explicit expressions, an efficient Monte Carlo simulation method is proposed for solving structural system dynamic reliability under non-stationary random excitations with the first excursion failure criterion. As compared with the power spectrum method, the proposed method does not require a large amount of numerical integrals in both frequency and time domain. Furthermore, the assumptions are no longer required in the present approach with respect to the probability distribution of the excursion number and the correlation between different failure modes. Through numerical examples, the calculation accuracy and efficiency of the proposed method are compared with those of the conventional Monte Carlo simulation method, the Poisson process method and the Markov process method. Numerical results indicate that the proposed method has good accuracy and reasonably high efficiency.

Keywords: Dynamic reliability, System reliability, First excursion failure criterion, Non-stationary random excitations, Karhunen-Loéve expansions, Monte Carlo simulation