A review of the current status of structural dynamic reliability theory

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Abstract

The theory of structural dynamic reliability plays an important role in the building structure, especially in the complex large span space structure and the anti-seismic and wind resistance of the high-rise building structure. The three key problems of structural dynamic reliability analysis are stochastic analysis of structures, determination of structural failure boundary or failure criteria, and calculation of reliable probability of structural dynamic response. This paper summarizes the research status of the methods to solve the above problems, and finally puts forward the prospect of the future development direction of the research field.

Keywords

Structural dynamic reliability; random response; structural failure mechanism.

1. Introduction

As a research field of edge crossing, the theory of structural dynamic reliability is involved in many subjects and needs to be studied widely. In general, the research of structural dynamic reliability mainly includes two aspects: structural random response analysis and structural dynamic reliability calculation. The following are the development and present situation of the two aspects.

2. Research status of random response analysis of structures

2.1 Random response analysis of linear systems

At present, the basic theory of linear random vibration system has been mature. The basic method of stochastic response analysis of single-degree-of-freedom linear system can be attributed to the time domain analysis method based on Duhamel integral and frequency domain analysis method based on Fourier transform.

Another effective method to solve the problem of linear stochastic vibration is modal analysis, and the modal analysis method includes real modal analysis and complex modal analysis. Single-degree-of-freedom linear system under white noise excitation [1], cosine noise excitation [2] and conjugate complex exponential random excitation [3] are analyzed by Tong Fang; The random response of multi degree of freedom linear system under limited band white noise excitation [4] has also been analyzed. The complex modal analysis method is used in paper [5] to obtain the response spectral moments, based on the response covariance function according to the relation between time domain parameters and frequency domain parameters. Xiyuan Zhou.etc [6] use the complex mode theory to study the dynamic response analysis method of the general non orthogonal damping structure under the action of the earthquake. The new method of structural random response analysis-the virtual excitation method proposed by Chinese scholar Jiahao Lin.etc [7,8] improves the computation efficiency. Also the stochastic response analysis of time invariant linear system can be completed efficiently and accurately by using the method. However, it should be pointed out that the present virtual excitation method is only suitable for the stochastic response analysis of the time invariant linear system.

2.2 Random response analysis of nonlinear systems

Structural nonlinearity is generally divided into two types, geometric nonlinearity and material nonlinearity, which are mainly manifested in damping terms and stiffness terms or both coupling

terms. Since the 60s of last century, nonlinear random vibration has been paid much attention. Up to now, many methods have been developed to predict the response of nonlinear systems.

(1) The FPK equation method. It's a method by solving the FPK (Fokker-Planck- Kojimoropob) equation to obtain the random reaction of the structure. (2) Statistical moment truncation method. Due to the nonlinearity of the system, the system response function to meet the moment the moment equations constitute an infinite series, in order to get the solution of this moment equation, some approximate methods must be used in the series truncation (3)Stochastic equivalent linearization method. Equivalent linearization method is proposed for the first time in Caughey in 1963, after the continuous improvement of the Bobori, Kaul, Penzien and Wen et al, the method can be used to solve the problem of nonlinear calculation of strong and weak. (4) Stochastic perturbation method. Perturbation method, also known as small parameter method, has been widely applied to deterministic nonlinear problems. But for uncertain problems, it's proposed by Crandall [9] . (5) The stochastic averaging method. Under certain conditions, the dynamic response of nonlinear system in non white noise can be approximate descripted by Markov diffusion process, the drift and diffusion coefficients of FPK equation of the approximate diffusion process can obtained by appropriate random average of state equation of a given system . After solving the average, the approximate response of the original system can be obtained by the FPK equation. This is the stochastic averaging method. (6)Numerical simulation method. The input of a lot of simulated dynamic loads is generated by artificial method, and the calculation of reaction time history is repeated. (7) Other combination methods.

3. Research status of structural dynamic reliability analysis method

A simplified structural calculation model is usually used in existing studies, and the analysis of structural dynamic reliability is based on two basic failure criterion: the First transcendental failure criterion (FTFC) and the fatigue failure criterion (FFC).

3.1 Dynamic reliability analysis based on FTFC

Although the FTFC is a relatively simple and ideal model, it gives the basic idea of dynamic reliability analysis, so it is a model which has been paid much attention and studied much.

Now, the FTFC has developed analysis basic method can be divided into two categories: the first category is analyzing the probability beyond the boundaries of the response directly from the the random dynamic response system; the second is solving the FPK equation of the state reaction from the random state equation of the system.

3.2 Dynamic reliability analysis based on FFC

At present, more research has been done on the reliability of structural fatigue. The analysis of fatigue reliability includes the fatigue performance of structural or structural materials, the statistical counting of repeated loads, the fatigue cumulative damage criterion and the reliability analysis method.

The study of fatigue reliability has a very rich content and a large number of research results. It should be pointed out that a lot of research results come from the field of machinery. In this kind of problem, the classical method is the linear accumulation damage theory of Miner. When the relationship between the stress amplitude S of the structural dynamic response and the cycle number N(S-N diagram) is known , the fatigue reliability of the structure is obtained according to the probability mode of accumulating damage or fatigue life. In the aspects of bending fatigue and shear fatigue of reinforced concrete members, many studies have been done. It is generally considered that the fatigue life of a structure obeys Weibull distribution or lognormal distribution. Although the Weibull distribution is more reasonable from the perspective of risk rate, lognormal distribution is more convenient for further analysis and application.

Structural dynamic reliability theory is mainly used in the analysis of wind resistance and aseismic reliability of structure.

4. Research prospect

(1) The development process and research status of structural dynamic reliability theory are summarized in this paper. Through one's own analysis and research, the future research direction of structural dynamic reliability theory is expected to have the following aspects:

Research on basic theoretical. The main purpose is to find a solution to the exact solution of many problems in mathematics.

(2) The structural dynamic reliability analysis should take into account various factors, including the service life of the structure, the use condition and its variation, the probability and combination of all kinds of random loads, especially the uncertainty of the structure itself. Recently, some studies have shown that the stochastic variability of structural parameters can lead to a large change in structural stochastic response. The factors that consider the randomness of structures are still lacking.

(3) Dynamic reliability analysis of multi degree of freedom and continuous system, such as large-span spatial structure and high-rise building structure, is the focus of structural dynamic reliability. The dynamic reliability analysis of multi degree of freedom and continuous system is very difficult, for example, the safety area is multi-dimensional space, and the correlation of each particle's dynamic response and the cross spectrum analysis are all very complex problems. If the nonlinearity of the system is considered, the dynamic reliability analysis will be more complex. Therefore, it is necessary to strengthen research on the problems in this area and solve many problems in this area.

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