ARTICLE IN PRESS

Mechanical Systems and Signal Processing xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

Reliability analysis of random vibration transmission path systems

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ARTICLE INFO

Article history:
Received 30 June 2016
Received in revised form 24 April 2017
Accepted 27 June 2017
Available online xxxx

Keywords:
Transmission
Transfer path
Random
Transmission reliability
Reliability sensitivity

ABSTRACT

The vibration transmission path systems are generally composed of the vibration source, the vibration transfer path and the vibration receiving structure. The transfer path is the medium of the vibration transmission. Therefore, the uncertainty of path parameters influences the system reliability greatly. In order to avoid the resonance failure, the transmission reliability analysis and the reliability sensitivity analysis are both very important. Based on the reliability theory, the absolute value difference of natural frequency and excitation frequency of random vibration transmission path system was limited and the reliability pattern of the resonance problem was defined in this paper. Applying the generalized second moment technique of vector-valued functions and the stochastic finite element theory, the theoretical analysis method of the transmission reliability and reliability sensitivity was presented. The corresponding vibration transmission path system with uncertain path parameters including mass, stiffness and path position was analyzed theoretically and computed numerically, and then the correlated mathematical expressions were obtained. Thus, in practical project, most of uncertain factors in the vibration systems can be analyzed so that the effective way can be given to avoid resonance failure.

1. Introduction

In the modern industry, the problem of vibration and noise has always been concerned widely by technical personnel. The suitable control method for the system vibration and noise is of great theoretical value and economic benefit. Generally speaking, the vibration system is composed of three parts, the vibration source, the vibration transfer path and the vibration receiving structure. The transfer path is a specific medium, through which the vibration sources are transferred to the system receiving structure. In order to control the vibration and noise effectively, it is necessary to recognize and analyze the vibration transfer path accurately. At present, many researchers used the transfer path analysis (TPA) and the statistical energy analysis (SEA). TPA is the method of solving the vibration problem by connecting the contribution of the transfer path and the response of the receiver based on the corresponding experiments, which is usually associated with the partial contribution. The method is more used to deal with the low frequency problems [1–3]. SEA is the method of studying vibration and noise from the viewpoint of energy based on the concept of the subsystem, which researches the transfer and balance of the energy in the different subsystems by statistical method. This method is a tool of solving the dynamics problem in high frequency domains for the complex systems. However, due to the large workload of statistical energy analysis, many researchers usually used the power flow theory to solve the practical problems [4–6]. These two methods can be applied in the later

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http://dx.doi.org/10.1016/j.ymssp.2017.06.037
0888-3270/

Please cite this article in press as: W. Zhao, Y.-M. Zhang, Reliability analysis of random vibration transmission path systems, Mech. Syst. Signal Process. (2017), http://dx.doi.org/10.1016/j.ymssp.2017.06.037

stage of product development and are closely related with the support of various experimental methods. Overall, the research on the prediction and the randomness of the parameters is limited.

It is generally known that, the uncertain factors will appear inevitably in the vibration system. The random nature of the path parameters will change the system's vibration transmission characteristics, and ultimately affect the output of the system, which can bring out the system reliability problem. In many fields, the reliability problem has been concerned widely by the scholars. Lv et al. [7] used the response surface method combined with the finite element method to analyze the vibration stability of vehicle disc brake system with uncertain parameters based on the theory of reliability analysis. This technique can realize the sensitivity analysis of system parameter to the function. Liu et al. [8] introduced dynamic structural system reliability analysis into the chatter vibration prediction of the turning process system with the uncertain structural parameters. Chatter reliability represents the probability of stability for the turning process system.

According to the actual working condition, the research on the reliability problems of vibration transmission path system can be made in two ways. On the one hand, it can be studied when the transfinite is looked as the measure indicator about the path transfer force or transfer rate. This kind of research is based on the system responses and depends on the random response analysis for the random systems. Zhu et al. [9] defined the reliability mode assuming that the maximum amplitude peak of unbalance response should be no more than the allowable amplitude peak based on the explicit relationship expression between random response and original random variables. In this research, they applied finite element method combined with artificial neural network technique. Xia et al. [10] developed a vibration reliability analysis method, in which the study of peak beyond was the basis of the failure criterion for the evaluation of vibration reliability. The development of these methods is related closely with the stochastic response analysis of the system. On the other hand, the study can be finished according to the structural failure coming from the resonance or potential resonance, which exists widely in the various structures with uncertainty factors. When the system is in a state of resonance, the dynamic stress is very large and the service life can be shortened greatly, which will influence the performance of mechanical equipment. Based on the vibration theory, Wang et al. [11] established a limit equation about structure resonance fatigue according to the natural frequency distribution. He et al. [12] provided the general resonance reliability analysis model considering the randomness of the structure size, the material properties and the external excitation. The fuzzy resonance theory was used to describe the close degree of the structure natural frequency and the external excitation. In this paper, our works focus on the transmission reliability and reliability sensitivity of the vibration transmission path systems applying the generalized second moment technique of vector-valued functions and the stochastic finite element theory. Considering the uncertain path parameters such as mass, stiffness and path position, we derived the correlated mathematical expressions and demonstrated the validity of the theory with the numerical examples.

2. Vibration transmission path system model

In most vibration systems, there are several transfer paths between the vibration source and the receiving structure and the excitations are transmitted in the corresponding ways. For example, the car body vibration comes partly from the force and torque generated by the engine. In this system, the engine mount is transfer path [13,14]. Based on the typical structure, we built the vibration transfer path system models with three parallel paths, as shown in Figs. 1 and 2. The difference of two models is in the vibration sources. The system in Fig. 1 is excited only by the vertical force and the system in Fig. 2 is excited not only by the vertical force but also by the moment. Thus, the parameters that affect the path transmission characteristics include not only the quality, stiffness, damping, but also the installation location of the transfer path. Fig. 1 shows a 5-DoFs

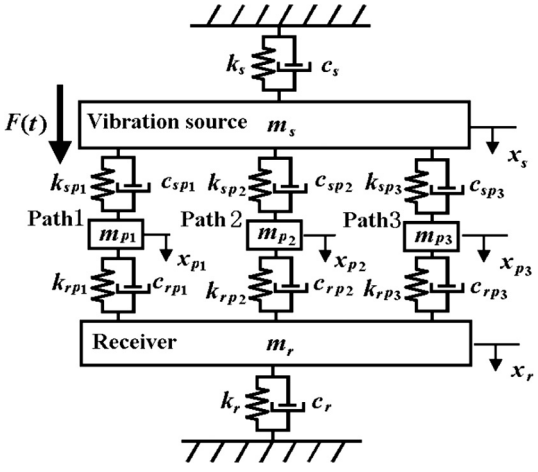

Fig. 1. Vibration transfer path system model with vertical force excitation.

Please cite this article in press as: W. Zhao, Y.-M. Zhang, Reliability analysis of random vibration transmission path systems, Mech. Syst. Signal Process. (2017), http://dx.doi.org/10.1016/j.ymssp.2017.06.037