Structural Dynamic Reliability Evaluation Under Consideration of Fuzzy Strength and Fuzzy Stress

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Abstract

A new dynamic reliability analysis under repeated or multiple series fuzzy loads and fuzzy strength is proposed in this paper. The proposed prediction models of structural dynamic fuzzy reliability with and without strength degeneration are established by using fuzzy theory and stress-strength interference theory. The fuzzy reliability is converted to probability reliability. The results have shown that the proposed model is feasible and practicable.

Keywords: Fuzzy load, Fuzzy strength, Dynamic reliability, Strength degeneration

1 Introduction

The reliability of engineering structures is an important indicator to evaluate their structural performance. Structural reliability analysis can be obtained using traditional random probabilistic reliability model such as direct integration method or the First Order Second Moment Method (FOSM)[1–6]. In classical methods, probability distribution functions of structural strength and applied load are assumed to be known and its parameters are normally determined based on a large volume of data. Moreover, the prediction of structural reliability is very sensitive in terms of the accuracy of probability distribution parameters. Large error in computed reliability can be produced if probability distribution parameters contain minor error[7]. Monte Carlo simulation is also widely used in engineering for reliability analysis[8–11]. In addition, other advanced approaches such as dynamic reliability, subset simulation, gamma process, etc have also been studied[12–17].

In engineering practical applications, there are a lot of fuzzy uncertainty situations, for example fuzzy mechanical systems were studied in the articles[18–20]. Structural reliability analysis under random load and fuzzy strength were studied in the article[21]. The fuzzy uncertainty was converted to random uncertainty by using equivalent normalization method and thus structural reliability index could be obtained using the FOSM method[22]. On the other hand, stress is not immutable in engineering practical problems. A reliability method has been improved and the algorithm has been simplified to analyze reliability of bar structure under random stress and fuzzy strength in the articles[23,24]. However, the proposed approaches in the above articles were only applied for the case of single continuous load without fuzzy strength degeneration. In fact, during the service period of engineering structures, the applied fuzzy loads are normally repeated or multiple series and structural strength is often degraded due to vibration, shock, fatigue, corrosion, aging, as well as other uncertainty inherent and external factors. Therefore structural reliability is changing over time. Structural non-probability dynamic reliability was studied in the article[25]. Besides that, structural dynamic reliability under three different types of random loads and based on the probability density evolution method were studied in the articles[26,27]. It has been shown that dynamic failure rate is similar to the well-known "bath-tub" shaped failure rate. Structural dynamic reliability under repeated or multiple series loads was studied in the article[28].

In this paper, multiple series fuzzy loads and structural fuzzy strength, which are often met in engineering practice, are analyzed by using the fuzzy theory. The prediction model of structural dynamic fuzzy reliability is established in accordance with the stress-strength interference theory. Two cases with and without strength degeneration over time are considered. Finally, it is illustrated that the proposed model is feasible and practicable.

2 Prediction Model of Structural Dynamic Fuzzy Reliability

2.1 Structural Dynamic Fuzzy Reliability without Strength Degeneration

During the service period, structure is not subjected to single continuous fuzzy load, but repeated or multiple series of fuzzy loads. According to the order statistic method, it is assumed that if a structure does not fail under the maximum fuzzy load,

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