Reliability Evaluation of Bridge Fatigue Life through Refined Statistical Analysis of Stochastic Traffic Flow Monitoring Data

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Abstract

To evaluate the reliability of the fatigue performance of key bridge components under stochastic vehicle loads, a prediction and evaluation method for the fatigue life of bridges based on elaborate statistical analysis of traffic flow and strain influence line identification is established in this paper. Firstly, The two-step clustering (TSC) method is applied to distinguish the different traffic states with the clustering numbers to be determined objectively. The elaborate stochastic traffic flow is simulated by random sampling of vehicle feature probabilistic models for each traffic state. Secondly, the actual bridge strain influence line inverted based on the fatigue detail measured strain data is used to be loaded by the stochastic traffic flow, and the stress time history under the stochastic traffic flow is calculated. The Monte Carlo method is applied to predict fatigue life. Finally, a real bridge is taken as an example to verify the effectiveness of the proposed method.

Keywords: vehicle load monitoring; stochastic vehicle flow; cluster analysis; influence line identification; fatigue reliability.

1 Introduction

In the process of long-term service, the bridge structure is repeatedly loaded by vehicle loads of variable amplitudes, which leads to the continuous accumulation of fatigue damage. The high cycle fatigue problem of bridge components, such as steel bridge decks, is very prominent and seriously affects bridge safety in its design service life [1]. Therefore, it is necessary to evaluate the fatigue performance and predict the fatigue life of a bridge during the operation period by considering the influence of vehicle loads. The vehicle-induced bridge fatigue damage is related to the stress amplitude and stress cycles. The traffic flow per unit time affects the number of stress cycles, and the axle weight and distance affect the stress amplitude. Therefore, it is critical to obtain the vehicle load information for the evaluation of vehicle-induced fatigue.

SHMS can monitor data, such as vehicle load and structural strain under the actual operating conditions of the bridge. Monitoring data-based fatigue evaluation of bridges has attracted considerable attention. Research in this area can be divided into two categories as follows.

The first group of studies mainly focused on fatigue damage evaluation based on structural strain monitoring data [2-3]. The field strain measurement-based fatigue evaluation has the following two shortcomings: i. The field-measured strain is produced by multiple actions, including vehicles, wind and temperature; ii. There are limited strain measuring points for the SHMS,

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