Theory of random energy analysis for train derailment

XIANG Jun, ZENG Qing-yuan, LOU Ping
(School of Civil and Architectural Engineering, Central South University, Changsha 410075, China)

Abstract: Three fundamental problems in the calculation of train derailment abroad and at home were pointed out and the solutions to these problems were presented. The theory of random energy analysis for train derailment was suggested. The main contents of this theory are as follows: geometric criterion of derailment; method of random energy analysis of transverse vibration of train track system; mechanism of derailment and energy increment criterion for derailment evaluation; calculation of the entire derailment course of train. This theory is used to calculate a case of freight train derailment, which corresponds to an actually occurring accident. Another derailment test, in which the train is judged not to be derailed, is calculated and the maximum vibration response is well correspond to the test results. And the effectiveness and practicability of the theory are proved by the two calculated cases.

Key words: derailment; random energy analysis; theory; train; transverse vibration

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1 INTRODUCTION

Train derailment has been studied for more than one century both abroad and at home. A great number of achievements have been made, however, no satisfactory solution has been found. The basic reason lies in the fact that there still exist three fundamental problems in the calculation of train derailment [1-4]: 1) Proper solution to transverse vibration equation groups of the train track system cannot be obtained by separately establishing them of the train and track. 2) The transverse track irregularity is mostly treated as the exciting source of transverse vibration of the system. In fact, transverse vibration of the system may be caused by many factors, such as transverse track irregularity, conicity of wheel tread, defects of wheels and rails, eccentricity of mass and loading of cars and so on. Sole consideration of the track irregularity results in negligence of many other factors. 3) It is difficult to carry out random vibration analysis of the train track system as the theory of random vibration analysis for the system has not been established. The methods for solution of these problems, which are as follows: 1) The problem of the non-guaranteed uniqueness of the solution of equation groups for the transverse vibration of the system is solved by considering the train and track as a unitary system and establishing matrix equation of transverse vibration of the system. 2) The measured hunting waves of car bogie frames, which accurately reflect the influence of all factors that give rise to transverse vibration of the system, can be determined to be the exciting source of the transverse vibration of the system according to the homogeneous nature of the matrix equation of transverse vibration of the system. The standard deviation of the measured hunting wave of car bogie frame, which is expressed with $\sigma_e$, is also considered as the energy of transverse vibration sent into the system. 3) The problem of random analysis of the system is solved by the method of random energy analysis of transverse vibration of the system. Train derailment is the result of strenuous transverse vibration of cars. So, the analysis of train derailment can be carried out by the method of random energy analysis of transverse vibration of the train track system introduced in Refs. [5,6].

2 METHOD OF RANDOM ENERGY ANALYSIS OF TRANSVERSE VIBRATION OF TRAIN TRACK SYSTEM

A force produces vibration response of a
relationship between standard deviation $\sigma$ of bogie frame hunting wave of empty wagon C62, whose probability is 99%, and the train speed $v$, is shown in Fig. 1. Thus the car bogie frame hunting wave can be randomly simulated with the Monte-Carlo method on the basis of $\sigma$ [5]. The wave following the artificial earthquake wave is called the artificial hunting wave of car bogie frame.

Fig. 1 Relationship between standard deviation of hunting wave of car bogie frame and speed

3 THEORY OF RANDOM ENERGY ANALYSIS OF TRAIN DERAILMENT

3.1 Geometric criterion of derailment

Vertical up-jumping of the wheel from the rail and down-falling on the rail are not evaluated as a danger. A danger is evaluated according to the degree of transverse deviation of wheel from rail. When the relative transverse displacement between wheel and rail to the left and right sides is taken as the index, the dangerous circumstances of both derailment and turning-over may be evaluated with high precision [4]. The rolling test results of a single wheelset by China Academy of Railway Science (CARS) demonstrate that when the top of a wheel flange climbs up above rail top, full derailment will occur. On the basis of these research results, the geometric criteria for wheel derailment are formed as follows:

1) Wheel lift value $\mu$, is equal to the lift value $\mu_{\text{max}}$ when the flange top climbs up above rail top.
2) Transverse displacement $y_w$ of wheelset from rail is equal to the relative transverse displacement $y_{\text{wmax}}$ when the flange top climbs up above rail top.

Derailment occurs when conditions 1) and 2)