An Overall Rail-Vehicle Carbody of a High-Speed Train FE Model Validation

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Keywords

vehicle dynamics, air spring, frequency-dependent nonlinear, finite element model validation, uncertainty

1. Introduction

The precision and reliability of the overall rail-vehicle system dynamics model of a high-speed train accounts significantly as the prerequisite for the calculation of vibration and comfort. Varieties of stiffness and damping elements, such as the primary air spring, the secondary mental spring, rubber joint, etc., the performance of which have significant effect on NVH. Due to the influence of manufacturing and assembling errors, obvious uncertainties lay in the stiffness and damping properties of connecting components. Experience shows that the stiffness difference in the primary air spring is more than 5% and the secondary mental spring reaches more than 3%. Besides, the stiffness and damping of some connecting components also show nonlinearities in frequency domain because of the vehicle speed variation and quality changes in operating state. Based on the model validation[1] and Multistage calibration, this article focused on the model validation and calculation of nonlinear change and uncertainty distribution of important connecting components' vibration response (such as air spring),by building the vehicle's FE model.

2. Basic Theory

2.1 RSM Based Calibration for Selective Parameters

The method includes the following main steps: Compute response features of every design point in the space spanned by the parameters according to DOEs (Design of Experiments)[2]. Then a high order polynomial model (or other RS model) is regressed ; Then the updating problem can be expressed as a optimization procedure. The optimization problem can be solved by traditional optimization method.

2.2 Distribution Estimation of the Response Features Prediction

The direct solution to compute the Distribution of response features is LHS [3,4]. (Monte Carlo simulations) integrated with RS models. The parameters were treated as norm distribution and intervals [1, 5].

3. Experimental Case Study

3.1 Identification and Calibration of the Key Parameters.

According to the process of model validation, we obtained accurate parameter distribution of stiffness and damping during the study of each air spring and mental spring. The typical nonlinear characteristics and stiffness distribution characteristics of air spring is shown in Fig.1 and Fig.2, which is considered in the establishment of nonlinear FE model of the vehicle. Both mental spring and air spring uncertainties are obtained through individual test, then the probability distribution was fitted by probability distribution testing.

3.2 Experimental Modal Analysis of the Whole Vehicle.

Vehicle modal experiment is a critical challenge work which requires proper excitation and acceleration-testing distribution of measured points, as well as advanced EMA identification method and software to process the data. We excited multi-points on the vehicle at the same time to conduct modal test, and the main modal are identified in 0-40Hz.

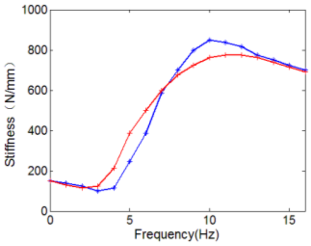

Fig.1 Effect of different excitation frequency and amplitude for dynamic stiffness

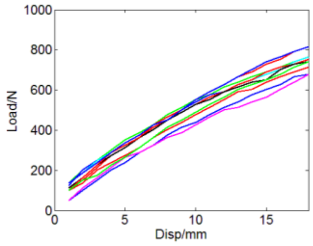

Fig.2 Static stiffness curves of 11 air springs

3.3 Verification of the FE Model of Overall Rail-Vehicle Car-Body with EMA Results.

During the simulation, air springs were set as frequency-dependent nonlinear and other connecting members were set as linear uncertainty parameters. Then the modal parameters calculation is conducted by obtained distribution their characteristics. The distribution is given through the calculation of RSM and Monte Carlo simulation. Finally, compared with the modal experiment results, the FE model of vehicle satisfies the verification conditions within the specific frequency band.

Fig.3 The FE model of vehicle in overall conditions

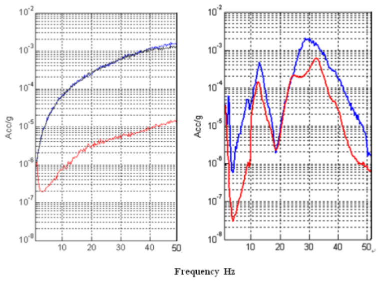

Fig.4 Road-spectrum of rail-vehicle and the experimental response spectrum

3.4 Response Prediction of the Vehicle under the Typical Excitation Spectrum.

Put forward the FEM response prediction of the vehicle under the typical excitation spectrum，using the approximate road-spectrum of rail-vehicle and the experimental response spectrum shown in Fig.4. This paper presents the prediction of the vehicle response spectrum distribution in the typical excitation spectrum.

4. Conclusions and Remarks

The validation method of FEM we used is advanced in dealing with the uncertain parameters and the nonlinear response analysis effectively. We will evaluate and optimize the vehicle vibration and comfort through the optimal design and robust design in the future.

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