compared to those with no raining. The magnitudes of the total cross force and overturning moment increase as the rainfall intensity increasing, but the total lift decreases only slightly. The underneath flow characteristics of the real shape of high-speed trains were studied with the unsteady numerical simulation method, and the influence of the rotating structures of bogies on the flow characteristics at the bottom is comparative analyses. The aerodynamic drag of the underneath components of the train is one of the important parts for aerodynamic drag of the whole train, and the aerodynamic load of the train bottom has a significant influence on the vehicle aerodynamic load. The rotating of bogies may seriously influence the unsteady characteristics of the train aerodynamic load. A constraint multi-objective aerodynamic shape optimization of the high-speed train nose with is done based on the surrogate model and multi-objective genetic algorithm. Firstly, we use incremental superposition parametric method for parametric design of high-speed train head. Then we get the Pareto front of the aerodynamic drag of the whole train and the aerodynamic lift force of the trailing car.

Key Words: High-speed train; Aerodynamic effect; Wheel rotation; Rainstorm; Optimization design; Tunnel effect

气动作用下高速列车响应特性研究

黄晨光

(中国科学院力学研究所)

摘　要:该研究的总体研究目标是弄清楚在气动作用下高速列车整车与关键零部件的动力学响应特征以及对运行速度提升后出现的新现象的规律分析与总结。前期主要研究工作是针对气动-轮轨联合作用条件下高速列车动力学响应分析建立分析方法与仿真模型,分析、整理与总结实车实测数据规律,发现新现象,为计算分析模型提供相关的验证数据与条件。后期研究主要是对分析方法与计算模型的改进、完善与检验,对出现的新现象规律进行总结。后期的4项研究内容为:(1)考虑流固耦合的列车刚体动力学分析模型研究;(2)考虑流固耦合的列车刚柔体动力学分析模型研究;(3)气动载荷作用下高速列车车体振动行为及动态响应研究;(4)关键结构疲劳可靠性分析。该研究主要阐述2013年度取得的主要研究进展与阶段性成果。针对上述研究内容,主要研究成果包括:建立了高速列车流固耦合、刚柔耦合仿真模型;建立考虑一系悬挂质量效应与车体弹性的动态响应仿真模型;提出了增量谐波平衡法与线性频响函数法相结合求解高速列车系统稳态解的方法及轨道动态不平顺模拟方法;分析了考虑轨道不平顺作用下,气动载荷对高速列车直线与曲线通过时的动力学响应的影响;获得了高速列车车体振动响应随运行速度的变化特征;对高速列车系统中的内共振现象进行解释与分析;研究了高速列车侧窗受交会压力波作用下的动态响应;分析了高速列车裙板结构在气动载荷作用下的动态响应及颤振行为。

关键词:高速列车　流固耦合　刚柔耦合　响应特性　交会压力波

Reseach on the Chracteristic of the Response of High Speed Vehicle Under Aerodynamic Loads

Huang Chenguang
(Institute of Mechanics, Chinese Academy of Sciences)

Abstract: The overall research objective of this topics is to figure out the chracteristic of the response of high speed vehicle and the key components under aerodynamic loads and to analysis the objective law of the new phenomen appeared with the increase of the running speed. The main research work done before is to establish the simulation method and model of the vehicle for the analysis of the dynamic response of the high speed vehicle system and to analyz, sort and summary the measured data of the real vehicle. Later research is mainly on the improvement and the inspection of the simulating methods and models and the summary of the law of new phenomena. The later research content are: (1)research on the analysis of the dynamic response of the high speed vehicle system adtopting rigid body model and considering the fluid solid coupling effects; (2) research on analysis of the dynamic response of the high speed vehicle system considering the rigid-flexibility and the fluid solid coupling effects; (3)research on the vibration behavior and the dynamic response of the car body of high-speed train under aerodynamic loading; (4)fatigue reliability analysis of the key structure. This report mainly describes the major progress and achievements on above research contents in the 2013. The main research achievements include: Considering fluid solid coupling, rigid-flexibility coupling, the model for the analysis of the dynamic response of the high speed vehicle system are established. The numerical model of high speed vehicle system taking into consideration the carbody flexibility and the dynamic effects of the primary suspension have been presented. An approximate harmonic approach formed by incorporating the Incremental Harmonic Balance method with frequency response function for solving the dynamic steady response of railway vehicles is presented. The track dynamic irregularity simulation method is also put forward; Considering the effect of aerodynamic loads and track irregularities, the dynamic responses of high-speed railway train in straight and curve track are analyzed. The characteristics of the car body vibration with the increasing of running speed are obtained. The internal resonance phenomenon on high speed train system is analyzed. The dynamic response of the side window of the car body under crossing pressure wave are investigated. The dynamic bahavior and the flutter phenomenon on the apron board structure of high speed train are studied.

Key Words: Fluid solid coupling; Rigid-flexibility coupling; Stationarity; Internal resonance; Crossing pressure wave; Apron board; Futigue

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