

Coupling vibration research on Vehicle-bridge system

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Abstract. The vehicle-bridge coupling system forms when vehicle running on a bridge. It will generate a relatively large influence on the driving comfort and driving safe when the vibration of the vehicle is bigger. A three-dimensional vehicle-bridge system with biaxial seven degrees of freedom has been establish in this paper based on finite numerical simulation. Adopting the finite element transient numerical simulation to realize the numerical simulation of vehicle-bridge system coupling vibration. Then, analyze the dynamic response of vehicle and bridge while different numbers of vehicles running on the bridge. Got the variation rule of vertical vibration of car body and bridge, and that of the contact force between the wheel and bridge deck . The research results have a reference value for the analysis about the vehicle running on a large-span cabled bridge.

1. Introduction

The coupling vibration of vehicle-bridge system while vehicle running on the bridge will generate a relative influence on the driving safety, running comfort, and the safety of bridge structure itself. Especially for the large coupling vibration of vehicle-bridge system, it will cause the serious consequences while vehicle running. Most of the earliest analysis are on the basis the differential equation of the whole system for the vehicle-bridge coupling vibration, and then apply the analytic method to solve.

The high-speed vehicles will generate certain impact on structure, which will affect the structure working status and service life. Meanwhile, the vibration generated in the process of vehicle running will affect the comfort and security of the vehicle. With the more and more large span bridge being constructed, the structure incline to more and more soft with the characteristics of stiffness and lower damping. So, it is more sensitive of the influence between the large span bridge and vehicle. This paper mainly researches the vehicle-bridge system coupling vibration respectively consider the driving speed, vehicle quality, vehicle number, and vehicle spacing.

2. Analysis model

The vehicles are being under the action of irregular track and external load in the process of running. The interaction of force and displacement will be generated between the components of vehicle model system. So, the reasonable vehicle model establish can properly reflect the vibration characteristics of vehicle system. The model in this paper simplify the dynamic vehicle model as the car body, vehicle frame, vehicle wheel. The components of vehicle are all be counted as rigid bode and connect with



elastic and damping elements between components. Meanwhile, adopting damping system arrange between vehicle wheel, car body, and road surface. The established numerical simulation vehicle model for two biaxial four wheels are shown in Fig. 1

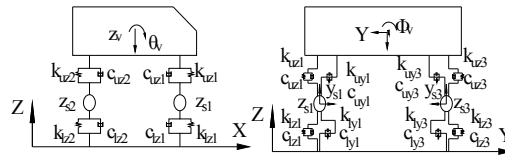


Fig. 1 Two axis dynamic analysis model

Where, the numerical vehicle model is simplified as rigid car body, elastic and damping synthesis device, and four rigid wheels. This paper adopts biaxial seven degree of freedom model for numerical vehicle model. Based on a large-span cable stayed bridge, this paper considers the structure geometric nonlinearity as following for the finite element numerical simulation of the bridge structure. The cable appears sag effect because of curve form as the results of the influence of gravity of cable and pretension of cable. The main tower and main girder anchorage cable are considered by equivalent modulus of elasticity.

3. Analysis method

The numerical simulation is conducted by the finite element software ANSYS. The vehicle-bridge coupling system are studied with numerical simulations. This paper does not consider the influence of the deck roughness on vehicle-bridge system coupling vibration. Where the entity cell was used to imitate the main girder of cable stayed bridge, cable cell was used to imitate the cable, COMBIN14 cell was used to imitate the spring and damping of vehicle, the contact element CONTA174 and target element TRAGE170 were used to imitate the contact between the vehicle wheel and bridge deck. The established meshing finite element numerical model diagram are shown in Fig. 2

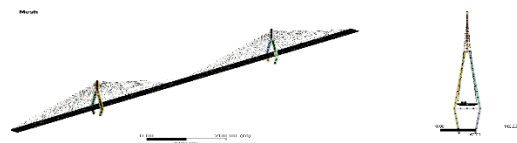


Fig. 2 Numerical analysis model of vehicle-bridge system

4. Results and discussion

The effect of vehicle numbers on coupling vibration response of vehicle-bridge was studied with the two cars horizontal in the first and second lanes, longitudinal respectively has one row, two rows, three rows, and four rows. The case was adopted to conduct the study by 5m in the before and after spacing of vehicle, 100km/h speed running from the start of the bridge to the end of the bridge.

4.1. dynamic response of vehicle

The car body vertical displacement increases with the vehicle number and the amplitude of fluctuation increases with car quality, as shown in Fig.3.

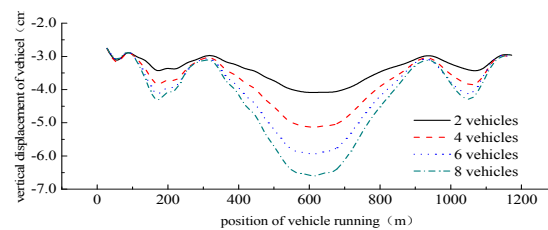


Fig. 3 Vertical displacement of car body

The change rule of vertical displacement of vehicle and contact force of vehicle wheel are as shown in Fig.4~5. Where L side wheel contact force on the behalf of the average contact force of two wheels near bridge centerline side, R side wheel contact force on the behalf of the average contact force of two wheels near bridge edge side, car body vertical displacement on the behalf of centroid place of car body vertical displacement.

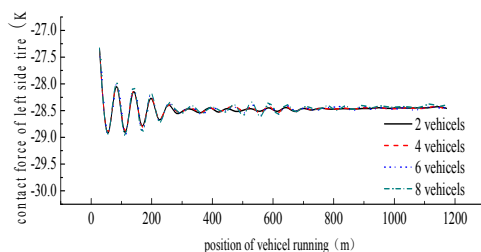


Fig. 4 Contact force of outside wheels

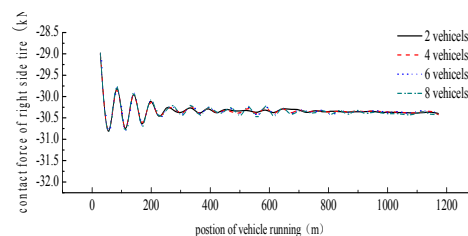


Fig. 5 Contact forced of inside wheels

There is a small difference in the fluctuation amplitude of the wheel vertical contact force with the increasing numbers of vehicle when vehicle running on the bridge. The contact force of vehicle wheel appears a slight vibration with the running distance increasing, as shown in figure. The car body vertical contact force fluctuates in a narrow range while vehicle running on the mid-span cross for the case only two cars running on the bridge. The contact force fluctuation is large with the vehicle number increasing. That phenomenon can illustrate the more number of vehicle the more vibration of bridge.

4.2. dynamic response of bridge and impact factor

the vertical displacement change rule of the vehicle running are shown which are in the section of side span, subside span, main span, and 1/4span. Meanwhile, the change rule of angel rotation of mid-span cross-section is also shown as followings.

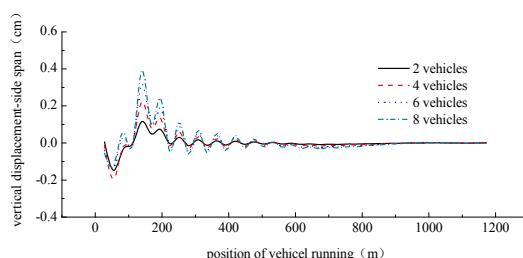


Fig. 6 Vertical displacement of mid-span cross of side span

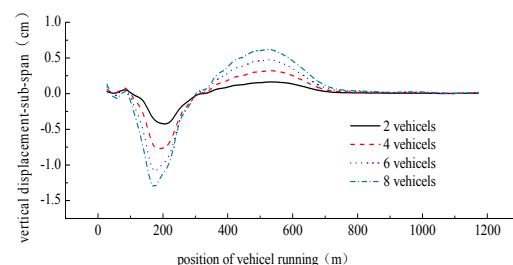


Fig. 7 Vertical displacement of mid-span cross of sub-side span

The vertical displacement of side span cross-section and subside span increase with longitudinal vehicle number, as shown in Fig.6~7. There is relatively large fluctuation amplitude for the vertical

displacement in the side span cross-section and subside span cross-section when more number vehicle running on the bridge.

The vertical displacement of 1/4 span cross-section, vertical displacement of mid-span cross-section of bridge main span, and the torsion angle deformation of mid-span cross-section of bridge main span are all increase with the vehicle number in the process of the different longitudinal multi-vehicle running into the bridge and out the bridge, as shown in Fig.8~10.

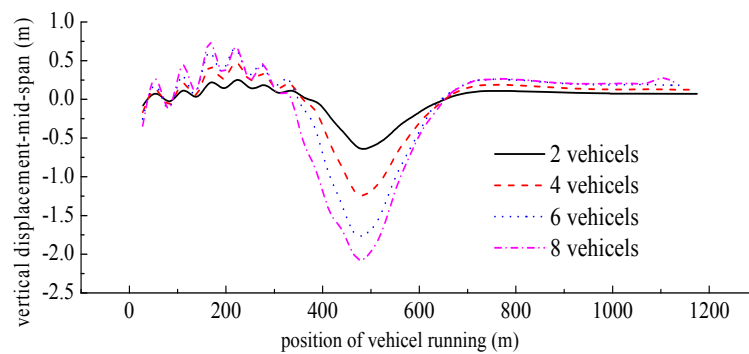


Fig. 8 Displacement of 1/4 span cross section of main span

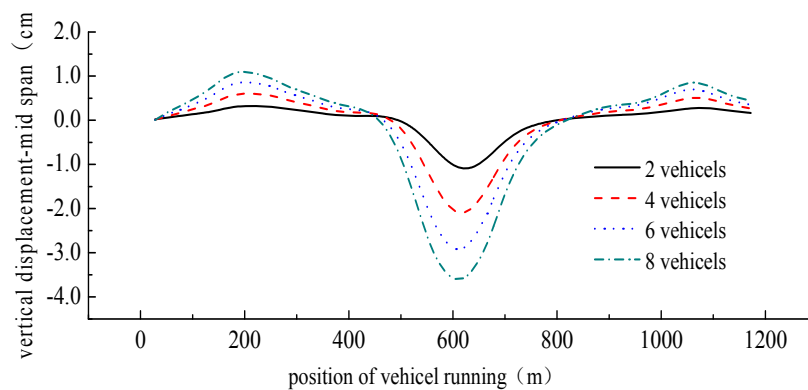


Fig. 9 Displacement of mid span cross section of main span

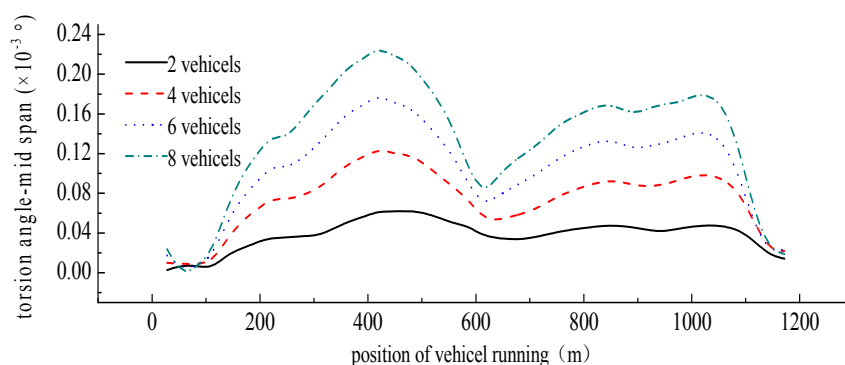


Fig. 10 Torsion angle of mid-span cross section of main span

In the process of vehicle running from the starting of bridge to the end of bridge, there are two vertical displacement in zero for mid-span cross section of bridge main span, and there are three vertical displacement in zero for car body. The vertical displacement of mid-span cross section of

bridge main span appears the second zero besides starting point. The displacement of vehicle and bridge demonstrate some delay lag which can be illustrate by the phenomenon that the location of car body vertical displacement appearing zero is behind the location of vehicle running at. The torsion angel deformation of mid-span cross section of bridge mid span demonstrates two large peaks, but the location of peak appear both are not in the position of mid -span cross section when longitudinal multi-vehicles running on bridge.

The impact coefficients of the cable stayed bridge each cross section are shown in Tab.1 When the vehicle driving side by side, the quality of each vehicle is 12T, the longitudinal spacing of vehicle is 5m, the vehicle running at 100km/h on the bridge.

Table 1. impact coefficients of different number of vehicles

Section position	2 vehicles	4 vehicles	6 vehicles	8 vehicles
1/8 span	1.120	1.128	1.121	1.142
2/8 span	1.107	1.122	1.128	1.146
3/8 span	1.021	1.032	1.057	1.122
4/8 span	1.040	1.020	1.041	1.061
5/8 span	1.043	1.051	1.045	1.098
6/8 span	1.100	1.105	1.125	1.142
7/8 span	1.173	1.160	1.166	1.174

The impact coefficients of mid span cross section of bridge main span do not increase with the number of vehicle when the vehicle divided into two column side by side move on the bridge.

5. Conclusion

(1) Numerical value analysis shows that the bigger the vehicle quality, the more obviously vertical the displacement and torsion angle deformation of mid-span cross section of bridge vary.

(2) The vertical displacement and torsion angle of mid-span cross section of bridge main span increase in synchronously with the number of vehicle increase.

(3) The contact force of vehicle four wheel always fluctuates with a small region because of the coupling vibration of vehicle-bridge system when the vehicle travel on the bridge with different speeds. The contact force of outside wheels is bigger than that of inside wheel due to the road cross-sectional slope.

Acknowledgments

This work was financially supported by Jilin Education Science Programming Project GH150487.

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