

APPLICATION OF SIMPACK MULTI-BODY SYSTEM ANALYSIS SOFTWARE IN DYNAMICS ANALYSIS OF RAILWAY FREIGHT VEHICLE

Yang Guangwu, Xiao Shoune and Jin Dingchang

National Key Laboratory of Traction Power, Southwest Jiaotong University, Chengdu, 610063, China)

Abstract: Dynamics performance of freight vehicle with swing bolsters is simulated through using SIMPACK multi-body system analysis software. The spring plank is considered as spring, stiff body with spring and flexible body by means of finite element method (FEM) and Hook law. The effect of these three cases on dynamics response is evaluated in dynamics analysis. Method that handles with thin plate component reasonably is found out in dynamics analysis.

Keywords: Multi-body system, SIMPACK, freight vehicle with swing bolsters, spring plank

1. Introduction

In traditional dynamics analysis of railway vehicle, it is general that DOF (degree of freedom) of each stiff body in vehicle is manually verified firstly. Then their dynamics differential equations are listed according to Newton's second law and solved with some integral methods. Finally, by handling with integral results of displacement, velocity, acceleration of each stiff body and their interaction forces, dynamics global performance of vehicle such as riding index, stability and safety is obtained.

Many new techniques occur along with development of modern railway vehicle. Interconnection of components in vehicle is more complicated. It is difficult that their dynamics differential equations are manually listed. What is more, effect of flexibility of lightweight component on global performance can't be neglected. Therefore, it is important how to consider these factors elaborately for vehicle dynamics research.

In China, because passenger car and freight vehicle are mixed to run in the same railway, freight vehicle with three-piece truck has seriously hindered to raise transportation efficiency of whole railway due to its slow running velocity and low transportation safety. Application of freight bogie with swing bolsters^[1] makes it possible to raise velocity in railway. Freight bogie with swing bolsters adds a spring plank between left and right side frames based on three-piece truck. Bolster springs and wedge springs are laid on spring plank. The spring plank connects with left and right swing bolsters that connect with left and right side frames and can swing along with x-axis of side frames. So the side frames can swing along with x-axis. The improvement greatly increases freight vehicle's velocity and decreases wear between wheel and rail.

Dynamics performance of freight vehicle with swing bolsters is simulated with SIMPACK multi-body system analysis software^{[2][3]} in this paper. In simulation spring plank is equivalent to spring, stiff body with spring and flexible body. Through comparing effect on vehicle dynamics responses between these three cases, method that handles with thin plate component reasonably is found out in dynamics analysis.

2. Multi-body System Simulation

The model of multi-body system of half vehicle is shown in figure 1. The whole vehicle consists of one car-body, two bolsters, four side frames, eight wedges, four swing bolsters, two spring planks, eight adapters, four wheel-sets and bolsters springs. In multi-body analysis, component is connected each other by joints, constraints and force elements. In global reference frame, x-axis corresponds with running direction of vehicle, y-axis is lateral direction and z-axis is downward. DOF of joints and constraints in each body refers to coordinate of interconnection point. In order to obtain friction caused by normal force, DOF of normal direction in both contact areas is constrained especially. The SIMPACK model of vehicle is shown in figure 2.

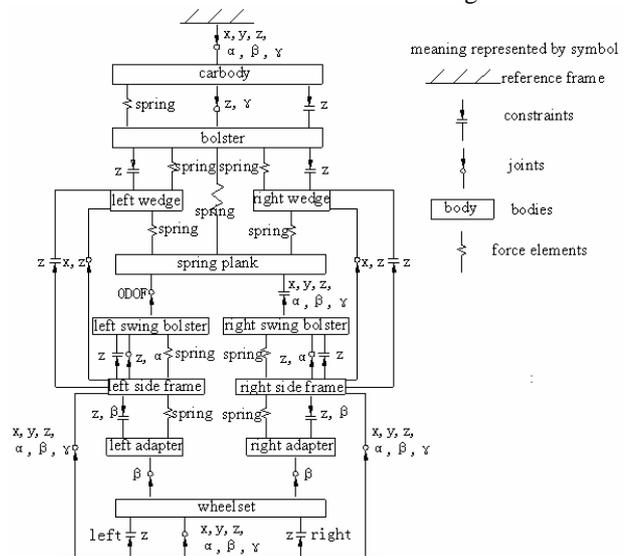


Figure 1. The model of multi-body system of half swing freight vehicle

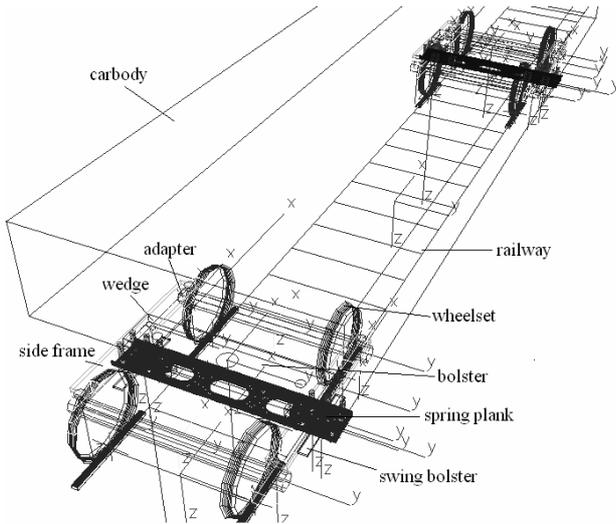


Figure 2. The SIMPACK model of vehicle

3. Equivalent of Spring Plank

3.1. Spring Stiffness Equivalent of Spring Plank

In simple model, spring plank is considered a spring having translation stiffness and rotation stiffness. It is connected between Left swing bolster and right swing bolster in dynamics analysis. Equivalent of the spring plank uses finite element method. In this method, it is meshed with shell element. Its left end is constrained and right end is loaded by force F or moment M . So translation displacement s or rotation displacement ϕ is obtained. According to Hook law:

$$F(M) = K \cdot s(\phi) \quad (1)$$

Here, K represents translation stiffness and rotation stiffness.

The FE-model of spring plank is shown in figure 3.



Figure 3. The FE-model of spring plank

3.2. Stiff Body with Spring Stiffness Equivalent of Spring plank

Stiffness equivalent of spring plank is same with above. But in dynamics model spring plank is also considered as stiff body having mass and moment of inertia. Its left end is connected with left swing bolster by a joint and its right end is connected with right swing by a spring.

3.3. flexible body equivalent of spring plank

Flexible body equivalent of spring plank uses modal superposition method [4]. This method uses no-damp modal shapes of spring plank as basis. Dynamics differential equations of spring plank is decoupled and solved with transformation of coordinate. Then dynamics response is obtained by superposing each modal. According to Ritz method, elastic deformation u of body equals to product of modal vector Φ and modal coordinate a :

$$u = \sum_i \Phi_i a_i \quad (2)$$

Modal response is obtained by introducing (2) into dynamics differential equations of spring plank. By combining with dynamics differential equations of vehicle system [5], dynamics responses of whole system are obtained.

4. Result of Vehicle System Dynamics Simulation

There are many vehicle dynamics performance index. Because lateral acceleration and perpendicular acceleration of car-body have influence on integrity of freight, their root-mean-square (RMS) values are used to compare and analyze. Their sensor points are located in car-body floor far 1000 meter apart from center plate. American five-level spectrum is regarded as railway excitation. The calculation of the creep forces is based on Hertzian contact properties. The calculation of wheel-rail contact uses Kalkers simplified theory of rolling contact. RMS values of lateral car-body acceleration at various running velocities in riding straight track are shown in figure 4. RMS values of perpendicular car-body acceleration are shown in figure 5.

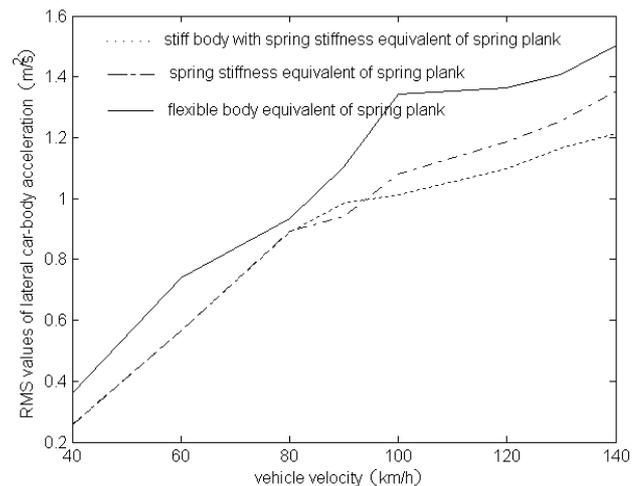


Figure 4. RMS values of lateral car-body acceleration

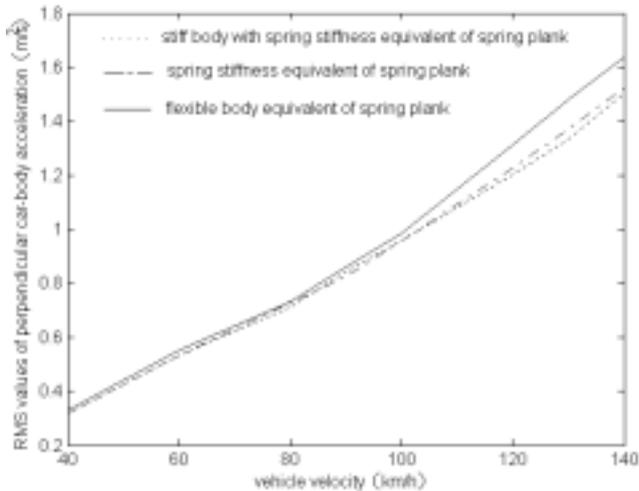


Figure 5. RMS values of perpendicular car-body acceleration

Contact info:

Yang Guangwu

Assistant

National Key Laboratory of Traction Power

Southwest Jiaotong University

Chengdu, Sichuan, 610031 China

Phone:86-28-87600660 Fax:86-28-87600660

Email:yangguangwu@163.com

Website:http://jls.swjtu.edu.cn

5. Conclusions

According to simulation results, RMS values of lateral acceleration and perpendicular acceleration of car-body increase along with increment of running velocity. Among the three equivalent methods of spring plank, when using flexible body equivalent method the RMS values of lateral acceleration and perpendicular acceleration of car-body are greater than other two methods. Especially it has strongly influence on lateral car-body acceleration because contribution of elastic vibration of spring plank to dynamics response is considered and lateral car-body acceleration is keen to elastic vibration of spring plank especially. At low velocities, because mass and moment inertia of spring plank are small and its dynamics responses are not evident, spring stiffness equivalent of spring plank and stiff body with spring stiffness equivalent of spring plank have slightly influence on lateral acceleration and perpendicular acceleration of car-body.

In conclusion, if there are thin plate components in vehicle system, their flexible deformations can't be neglected. Otherwise, this will make non-conservational dynamics responses and mislead design of vehicle.

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