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ANALITICAL STUDY ON THE DERAILMENT OF HIGH SPEED RAIL VEHICLE BY TRACK EXCITATIONS ON EARTHQUAKES

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ABSTRACT

1.Introduction

Considerable numbers of earthquake disasters have been experienced in Japan. Thus the study and research of earthquake disaster prevention are highly aware in Japan. In a railway industry, for instance, infrastructures have been reinforced and a new alert system has been employed to regulate the operating system to stop trains immediately if a great earthquake occurs. A railway is organized by a variety of individual technologies, and functions safely and properly as a system, therefore it is beneficial for the system safety to study and examine the individual potential cases of disasters caused by earthquakes from various different viewpoints. In our research, we focus on the study to examine the derailing vehicle behaviors and assess the safety of the vehicle on excited tracks operated at high speeds up to 300km/h with our vehicle dynamics simulation[1]. In 1970s, to assess the vehicle safety on a long bridge connecting Japan's islands, a simplified 3 DoF vehicle model was developed and the safety limits for track excitations were discussed[2]. In 1995, South Hyogo Prefecture Earthquake brought numbers of derailment of trains under operation[3], and since then many studies has even started to examine the case that rail vehicles derail solely by the track excitations on great earthquakes[4].

2.Developed Simulation

In this paper, our original vehicle dynamics simulation[1] is employed to analyze the vehicle motions on excited tracks, specifically focusing on the effect of vehicle speed. We suggest a 14 DoF vehicle dynamics model, shown in Fig.1, to represent the entire dynamic response of a vehicle and rails underneath. To precisely capture the fundamental vehicle motions, nonlinear behaviors of suspension springs and bump stops, and slide forces acting at contact areas between the vehicle body and the bogie are modeled. In addition, to assess the effect of vehicle speed including the case of a vehicle stationed, both of coulomb friction and creep forces at wheel/rail contact are modeled selectable in the simulation. We use sine wave inputs for the time histories of track excitations rather than practical seismic waves to simplify our discussion, and use the frequency range of 0.5 to 2.0Hz as is practically most interested.

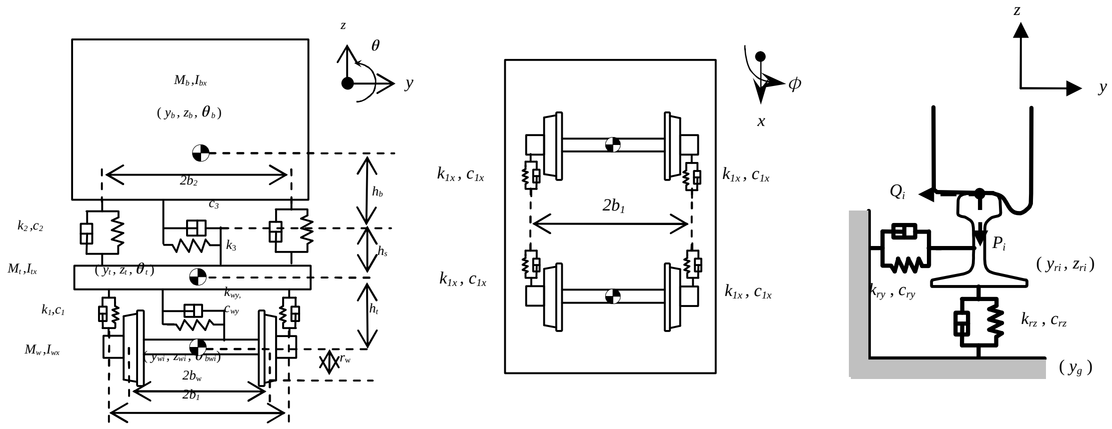


Fig.1 14 DoF vehicle dynamics model

3. Numerical Results

We employ the simulation for the analyses and obtain the major outcomes as follows:

(1) Most of derailments are brought as the result of the rocking motion of a vehicle. As shwon in Fig.2, a vehicle starts to lift up the wheel, then involves more than 30mm vertical wheel lift and lateral wheel/rail relative slide simultaneously, and finally the lifting wheel goes beyond the top of rail resulting in derailment. By contrast, in higher input frequencies, some of derailments are caused by the slide up of wheel on rail with severe wheel/rail impact. In general, interestingly, the derailing behaviors are observed similarly regardless of the vehicle speed.

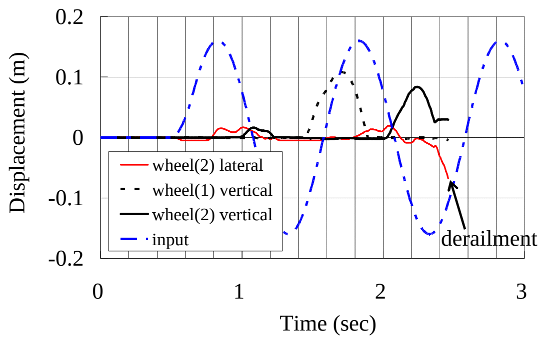
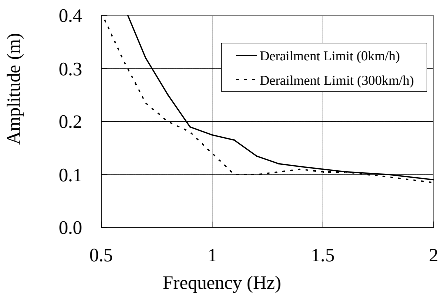


Fig.2 Time histories of vehicle rocking motion (input: sine wave of 1Hz ±0.16m)

(2) On the other hand, as shown in Fig.3, the excitation amplitudes for derailment are influenced by the vehicle speed particularly in lower input frequencies. The derailment

limit decreases according to the increase of the vehicle speed. This trend can be explained by the sensitivity of the relative slide between wheel and rail due to creepage and coulomb friction. A wheel tends to slide more on a rail even by small lateral acceleration in lower frequency excitations if the rolling speed of a wheel goes higher.

(3) As shown in Fig.4, the excitation amplitudes for 30mm of wheel lift are relatively independent of vehicle speed, which implies that the vehicle vertical and roll motions, highly related this wheel-lift, are not strongly coupled to the wheel/rail slide motion due to the creepage.



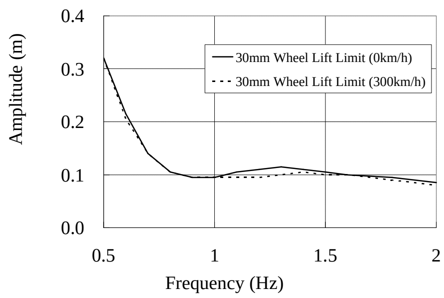


Fig.3 Excitation amplitudes for derailment   Fig.4 Excitation amplitudes for 30mm wheel lift

4. Conclusions

We obtain the following outcomes throguh the analyses base on the simulation. (1) Most of derailments are brought as the result of the rocking motion of a vehicle. Generally, the derailing behaviors are observed similarly regardless of the vehicle speed. (2) The excitation amplitudes for derailment decrease according to the increase of the vehicle speed particularly in lower frequencies of excitations. This trend can be explained by the sensitivity of wheel/rail slide due to the creepage. (3) The excitation amplitudes for 30mm of wheel lift are relatively independent of vehicle speed, which implies that the vehicle vertical and roll motions are not strongly coupled to the wheel/rail slide due to the creepage.

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