A Study of the Dynamic Behavior of Railway Vehicles During Seismic Activity

Takefumi MIYAMOTO
Senior Researcher, Vehicle Machanics, Railway Dynamics Division

A railway vehicle derails as a result of seismic activity either because of deformation of a railway structure or the track, or because of track vibration caused by the earthquake itself. Since the Hyogo Prefecture Nambu Earthquake of 1995, railway structures in Japan are being made more earthquake resistant through the gradual improvement of design standards that adopted the latest techniques.

With regard to the derailment of railway vehicles as a result of seismic vibrations themselves, the Railway Technical Research Institute (RTRI) has performed numerical simulations, and conducted advanced experimental research using a vibration test rig to examine the behavior of an actual Shinkansen bogie. The results have been reflected in new design standards for railway structures, and are being used to improve the seismic safety of railway systems.

(1) Running safety limits in the presence of sinusoidal waves

We developed our own simulation program to analyze the behavior of railway vehicles during an earthquake. The program uses a conventional vehicle running simulation model with added features to permit the accurate analysis of such factors as oscillatory input under the rails, wheel jump on rails, and the large roll displacement of vehicles.

Using this simulation model, we determined a running safety limits during the presence of sinusoidal waves (see Fig. 1). Figure 1 indicates sinusoidal wave vibration frequency (lateral axis) and maximum amplitude (longitudinal axis) limits required to avoid a derailment when vibrations are input from directly under a running vehicle. From this it can be determined that if the relative wheel/rail lateral displacement is more than 70 mm, a derailment is almost sure to occur.

(2) Experiments using a Shinkansen bogie on a vibration test rig

To determine the validity of our simulation analyses, we performed experiments using a vibration test rig.

The test objects used in the experiment are shown in Fig. 2. We installed a straight 5-m length of track on the large vibration rig, placed an actual Shinkansen bogie on the track, then mounted a load equivalent to half the weight of a Shinkansen car on the bogie.

The total weight of these test objects was 35 tons. Vibrations were input in mainly a lateral direction. During the experiment, vibration frequency amplitude was gradually increased until the wheels jumped 3 mm or more above the rails.

Fig. 3 compares results obtained from this experiment with the simulation results. The figure's lateral axis indicates vibration frequencies, while the longitudinal axis indicates input amplitudes when a wheel jumped 3 mm or more. These results validated results obtained through simulations.

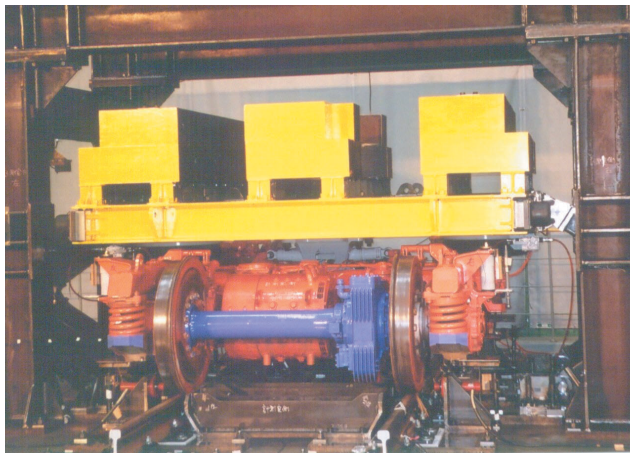

Fig. 2 Photograph of testing plant

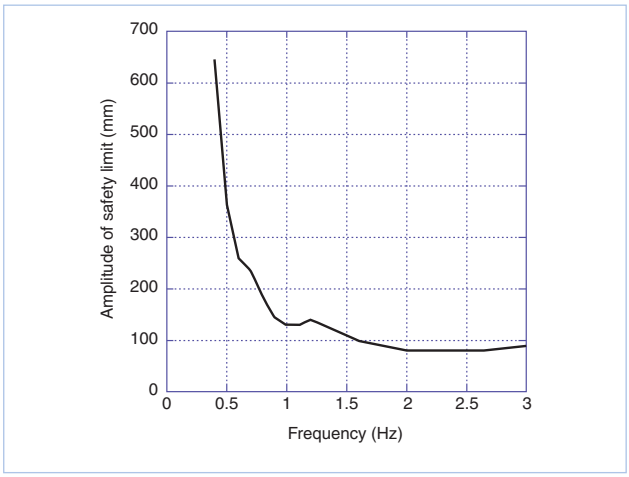

Fig. 1 Running safety limits by relative displacement between wheel and rail 70mm
- Five lateral sinusoidal waves, simulated run of Shinkansen vehicle at 350 km/h on straight track.

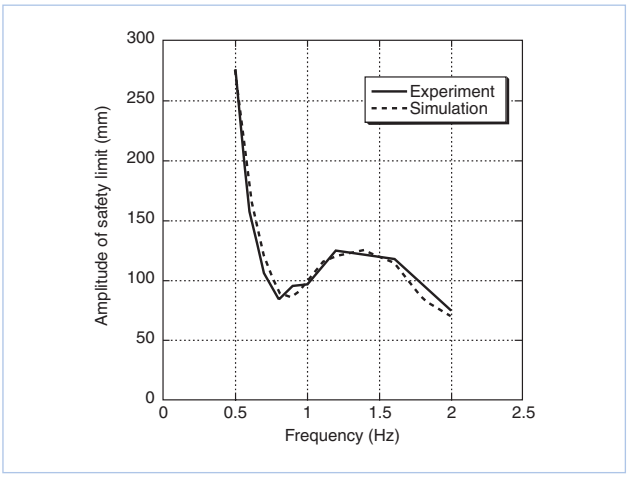

Fig. 3 Comparison between experiment and simulation results for safety limits when a wheel jumped 3 mm or more
- Five lateral sinusoidal waves, load equivalent to half the weight of a Shinkansen carbody, stopped on straight track.