Numerical and Experimental Study on Contact Force Fluctuation between Wheel and Rail Considering Rail Flexibility and Track Condition

Saki IENAGA[*], Yoshiaki TERUMICHI[#], Kazuhiko NISHIMURA[†], Minoru NISHINA[†]

[*] Department of Science and Technology, Graduate School of Sophia University
7-1 Kioi-cho, Chiyoda-ku, 102-8554 Tokyo, Japan
saki.ienaga@sophia.ac.jp

[*] Department of Engineering and Applied Science, Sophia University
7-1 Kioi-cho, Chiyoda-ku, 102-8554 Tokyo, Japan
y-terumi@sophia.ac.jp

[†] Technology Research and Development Department (KOMAKI), Central Japan Railway Company
1545-33 Ohyama, Komaki-shi, 485-0801 Aichi, Japan
[kazuhiko.nishimura, minoru.nishina]@jr-central.co.jp

Abstract

Suppressing fluctuations in the contact force between train wheels and the rail is desirable from the viewpoints of ensuring riding comfort and running safety, reducing the need for track maintenance, and preventing undue environmental disturbances such as noise. The contact force is affected by the interaction between the vehicle and the track motion. Therefore, efforts are being made to determine an optimum combination of factors such as the vehicle weight and track structure, including the use of ballasted or slab track.

The present study investigates the mechanism that gives rise to fluctuations in the contact force between the wheels and the track. Numerical simulations and experiments are carried out for a railway vehicle motion considering a wide range of rigidity of the ballasted track. It is expected that by comparing the results, the accuracy of the numerical analysis can be improved.

The magnitude of the contact force fluctuates depending on the contact position, the vehicle speed and the coupled vibrations between the vehicle and the track. In order to analyze the contact force precisely, a numerical simulation is conducted that considers the three-dimensional geometry of the contact, in addition to the flexibility of the track. The contact geometry is modeled using four surface parameters that describe the location of the contact point, and define the wheel and rail profiles (Figure 1) [1]. The track flexibility determines the coupled vibrations that occur between the vehicle and the track.

The analytical model is a three-dimensional vehicle/track system based on multibody dynamics. The vehicle model consists of a car body, two bogie frames and four wheelsets, all of which are regarded as rigid bodies, connected to each other by nonlinear springs and dampers. The track model consists of rails, sleepers and ballasts connected to each other by springs and dampers (Figure 2). The sleepers and ballasts are regarded as rigid bodies. The rails are treated as flexible beams by applying an absolute nodal coordinate formulation, which is a kind of nonlinear finite element method used for flexible multibody systems with large amounts of deformation and rotation. The wheel/rail contact model is based on Hertzian nonlinear elastic contact theory. The normal contact force is determined by the elastic deformation of the wheel and the rail at the contact point, and the tangential contact force is determined by creepage. The position of the contact between the wheel and the rail is calculated using an on-line contact algorithm based on the Newton-Raphson method.

The experiments are performed on a test track under various track-support conditions. The test vehicle runs on the track, and the contact force and rail displacement are measured. When a track with unsupported sleepers is used, the contact force between the wheels and the rail fluctuates significantly [2][3]. Fluctuations in the contact force and rail displacement are investigated while varying the vehicle speed and track-support rigidity. Similar conditions are used in both the numerical and experimental studies so that the results can be directly compared.

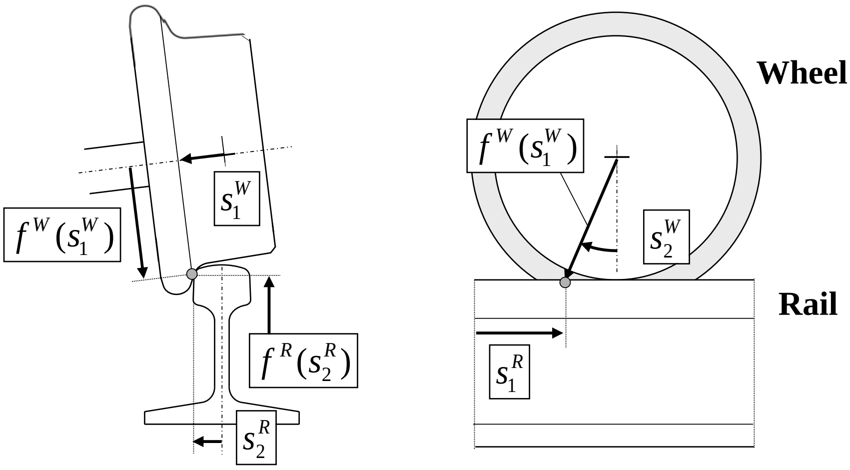

Figure 1: Surface parameters for wheel and rail.

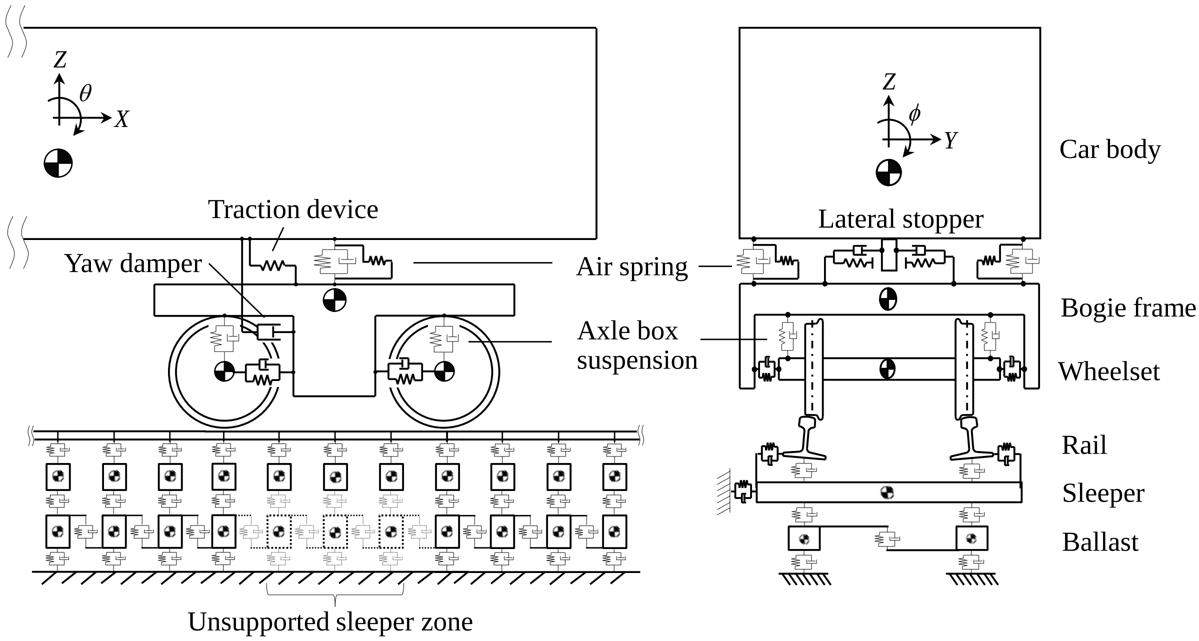

Figure 2: Analytical model for vehicle and track.

References

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