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Analysis of Critical Hunting Speed and Running Safety of Conventional Railway Vehicle Truck on Curved Track

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Abstract
Critical hunting speed and running safety are important aspects of the dynamic behavior of railway vehicles. In this paper, a study of the dynamic behaviour of a single railway vehicle truck running on tangent and curved tracks is carried out using a mathematical model of the combined system. It is seen from literature that there are no reported studies using the combined truck/curved track system in which rail lateral displacement is computed considering two point wheel/rail contact for evaluation of critical hunting speed, as well as derailment due to wheel climb.
In this study, the truck (Figure 1) consists of the truck frame with suspended wheelsets (Figure 2), while the track is idealized as a laterally flexible rail modelled as a spring mass damper system (Figure 3). The combined truck/track system has 10 degrees of freedom (DOF), consisting of the lateral displacement and yaw angle of the wheelsets and truck frame, as well as the lateral displacement of the left and right rails. Equations of motion using a model with single-point and two-point wheel-rail contact as shown in Figure 4 are derived [1]. Nonlinearities in the wheelset model include the nonlinear wheel-rail profile and the friction-creep characteristics of the wheel-rail contact geometry. The longitudinal and lateral primary suspensions are assumed to have linear stiffness and damping characteristics. A combination of linear Kalker's theory [2] and non-linear Heuristic creep model [3] is adopted to calculate the creep forces. The mathematical equations of motion are solved using fourth order Runge-Kutta method [4], which requires that the second order differential equations be transformed into a set of first order differential equations. The transformed state space equations are solved in the time domain to obtain the dynamic response of a conventional truck, moving on tracks of various radii. The numerical simulation is done using MATLAB.

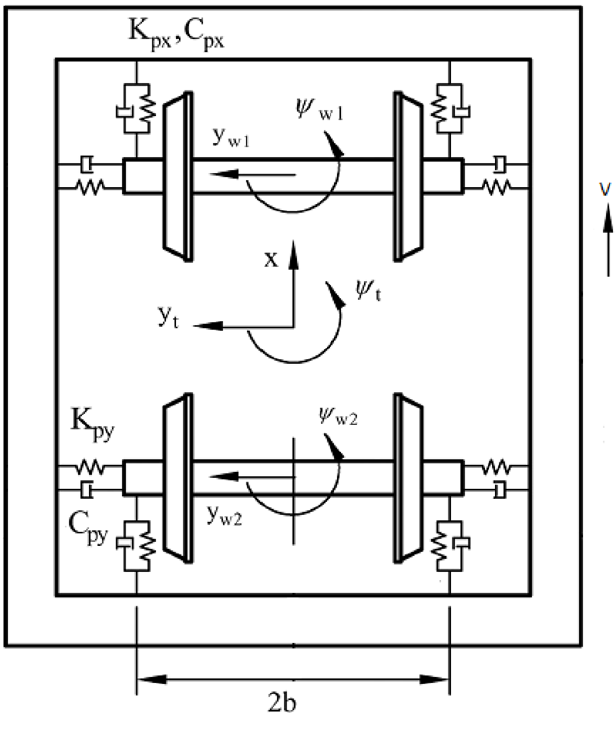


Figure 1. Truck model

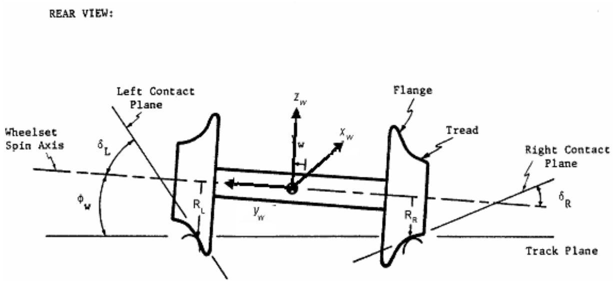


Figure 2. Typical wheelset cross section [1].

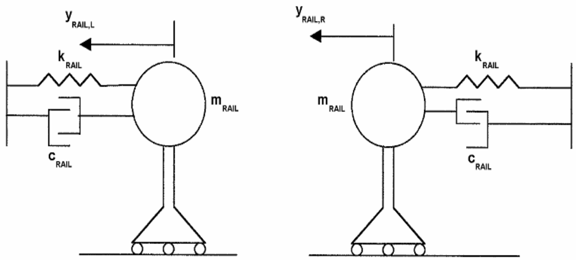
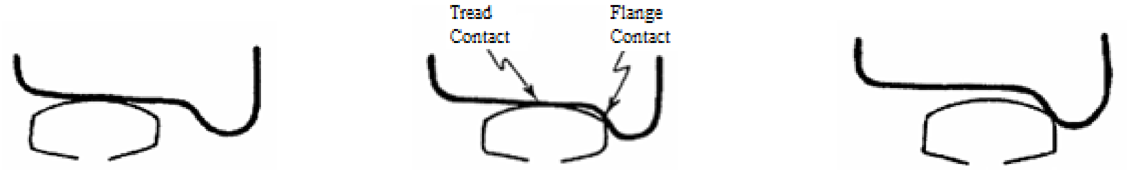


Figure 3. Flexible rail model [1].



One-Point Tread Contact $y_w - y_{rail,L} < y_{fc}$ | Two-Point Contact $y_w - y_{rail,L} = y_{fc}$ | One-Point Flange Contact $y_w - y_{rail,L} > y_{fc}$

Figure 4. Single-point and two-point left wheel-rail contact situations [1].

In the figures above, C_{rail} and K_{rail} are the damping and stiffness of the left and right rails respectively; m_{rail}, $y_{rail,L}$ and $y_{rail,R}$ represent the mass of the rail and lateral displacement of the left and right rails respectively; y_{w1}, y_{w2} and y_t denote the lateral displacements of the front and rear wheelsets and truck frame respectively; K_{px} and C_{px} denote the stiffness and damping of the primary suspension in the longitudinal direction; K_{py} and C_{py} represent the stiffness and damping of the primary suspension in the lateral direction; y_{fc} is the flange clearance i.e., distance between the flange and the rail; and Ψ_{w1}, Ψ_{w2} and Ψ_{wt} are the yaw motions of the front and rear wheelsets and truck frame respectively.

The nonlinear critical hunting speed of the vehicle on tracks of different radii is obtained from phase portrait or limit cycle [5]. The running safety of the vehicle is evaluated from the derailment quotient and the offload factor. Derailment quotient is defined as the ratio of the wheel's guiding (lateral) force to the vertical force between the wheels and rails [6]. Offload factor is defined as the ratio of the reduction in vertical force to the static wheel load [7]. Using these criteria, the effects of railway vehicle speeds on the derailment quotients and off-load factors are evaluated using both the linear and nonlinear creep models for various radii of tracks. Finally the effect of primary suspension, wheel conicity, super elevation angle and radius of curvature of the track, on the running safety, is assessed.

References

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