Bifurcation Analysis of a Railway Wheelset With Nonlinear Wheel-rail Contact

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Research Article

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Abstract

Stability is a key factor for the operation safety of railway vehicles, while current work employs linearized and simplified wheel/rail contact to study the bifurcation mechanism and assess the stability. To study the stability and bifurcation characters under real nonlinear wheel/rail contact, a fully parameterized nonlinear railway vehicle wheelset model is built. In modeling, the geometry nonlinearities of wheel and rail profiles come from field measurements, including the rolling radius, contact angle, and curvatures, etc. Firstly, four flange force models and their effects on the stability bifurcations are compared. It shows that an exponent fitting is more proper than a quintic polynomial one to simulate the flange, and works well without changing the Hopf bifurcation type. Then the effects of each term of the nonlinear geometry of wheel/rail contact on the Hopf bifurcation and Limit Circle bifurcation are discussed. Both the linear term and nonlinear term of rolling radius have a significant influence on Hopf bifurcation and Limit Point of Circle (LPC) bifurcation. The linear critical speed (Hopf bifurcation point) and the nonlinear critical speed (LPC bifurcation point) changes times while within the calculated range of the linear term of the rolling radius. Its nonlinear term changes the bifurcation type and the nonlinear critical speed almost by half. The linear term of contact angle, the radius of curvature of wheel, and rail profile should be taken into consideration since they can change both the bifurcation point and type, while the cubic term can be ignored. Furtherly, the field measured wheel profiles for several running mileages are employed to examine the real geometry nonlinearities and the according Hopf bifurcation behavior. The result shows that a larger suspension stiffness would increase the running stability under wheel wear.

Full Text

This preprint is available for download as a PDF.

Figures

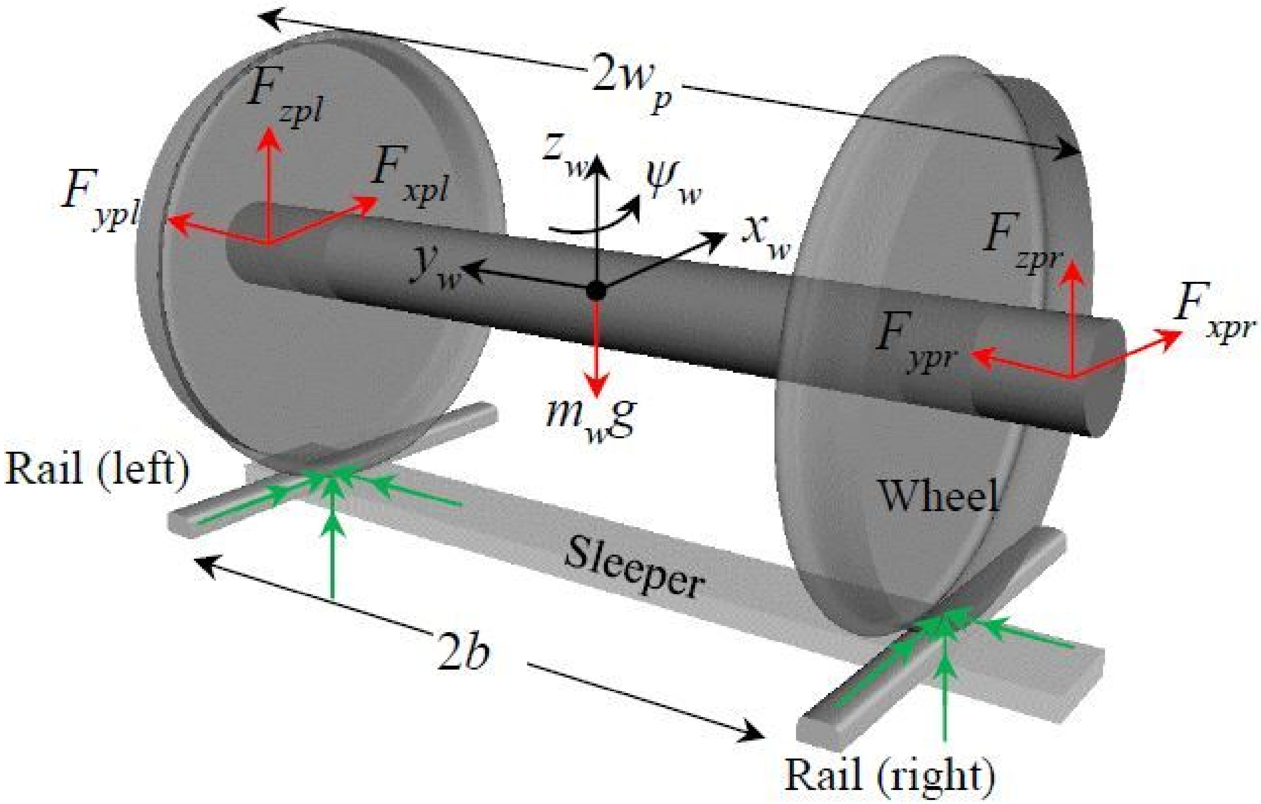

Figure 1

wheelset and primary suspension forces and wheel/rail forces.

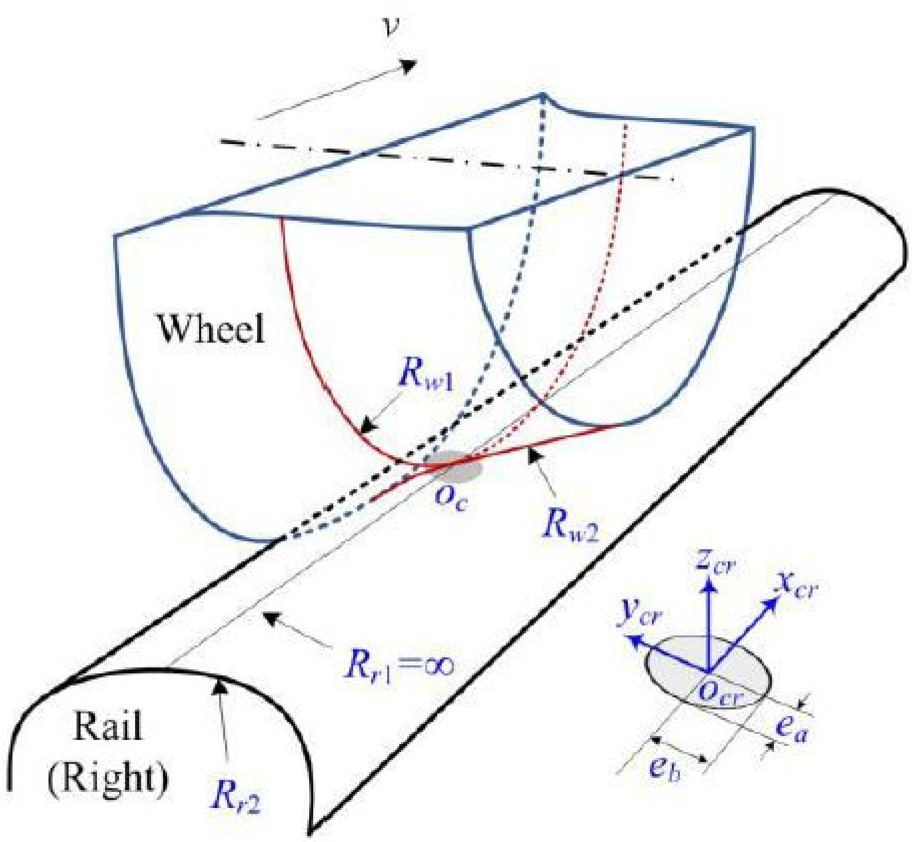

Figure 2

Curvatures nonlinearities at the wheel/rail contact point.

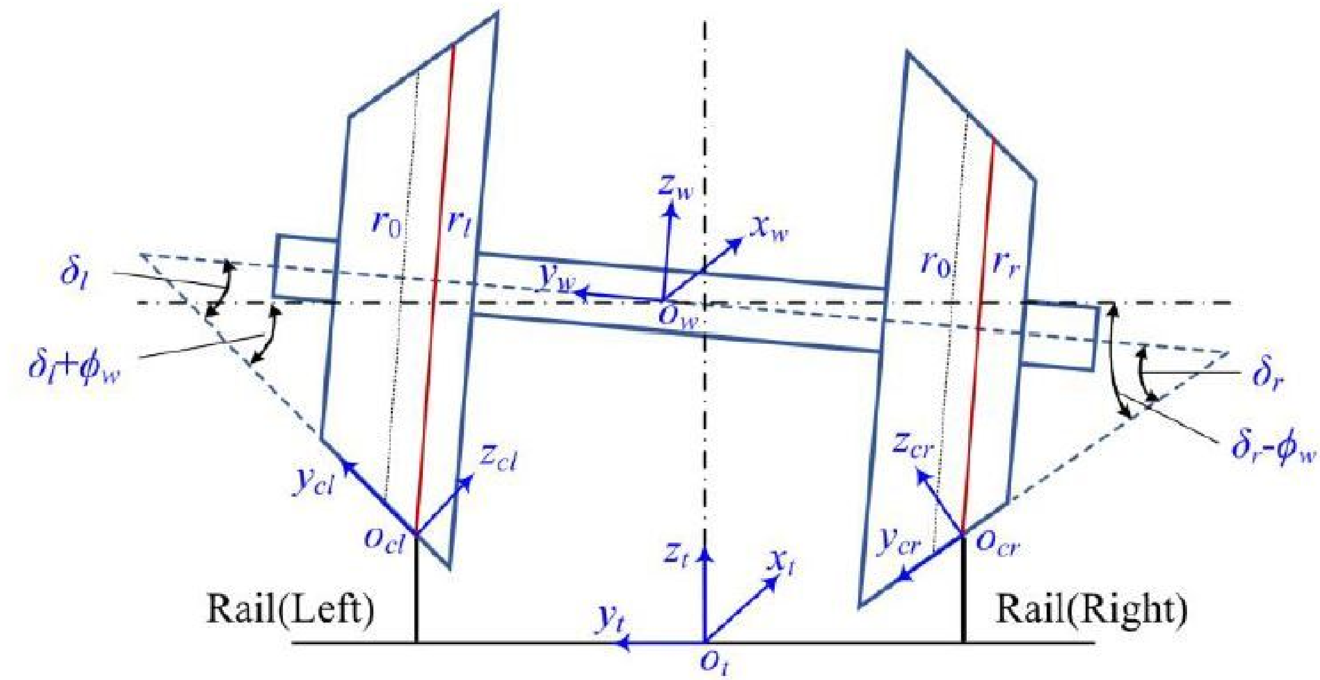

Figure 3

Wheel-rail contact geometry demonstration.

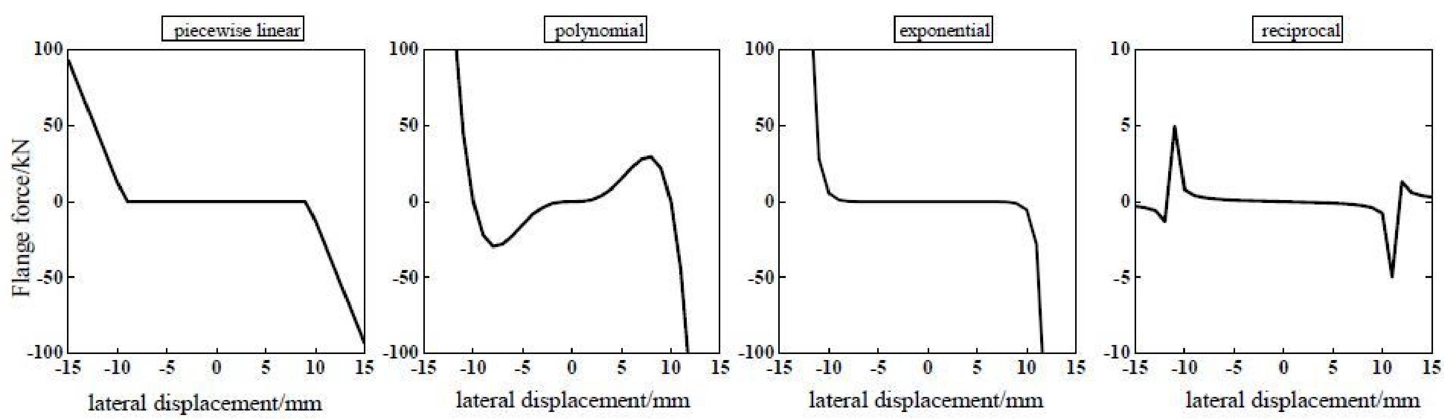

Figure 4

Comparison between flange force models.

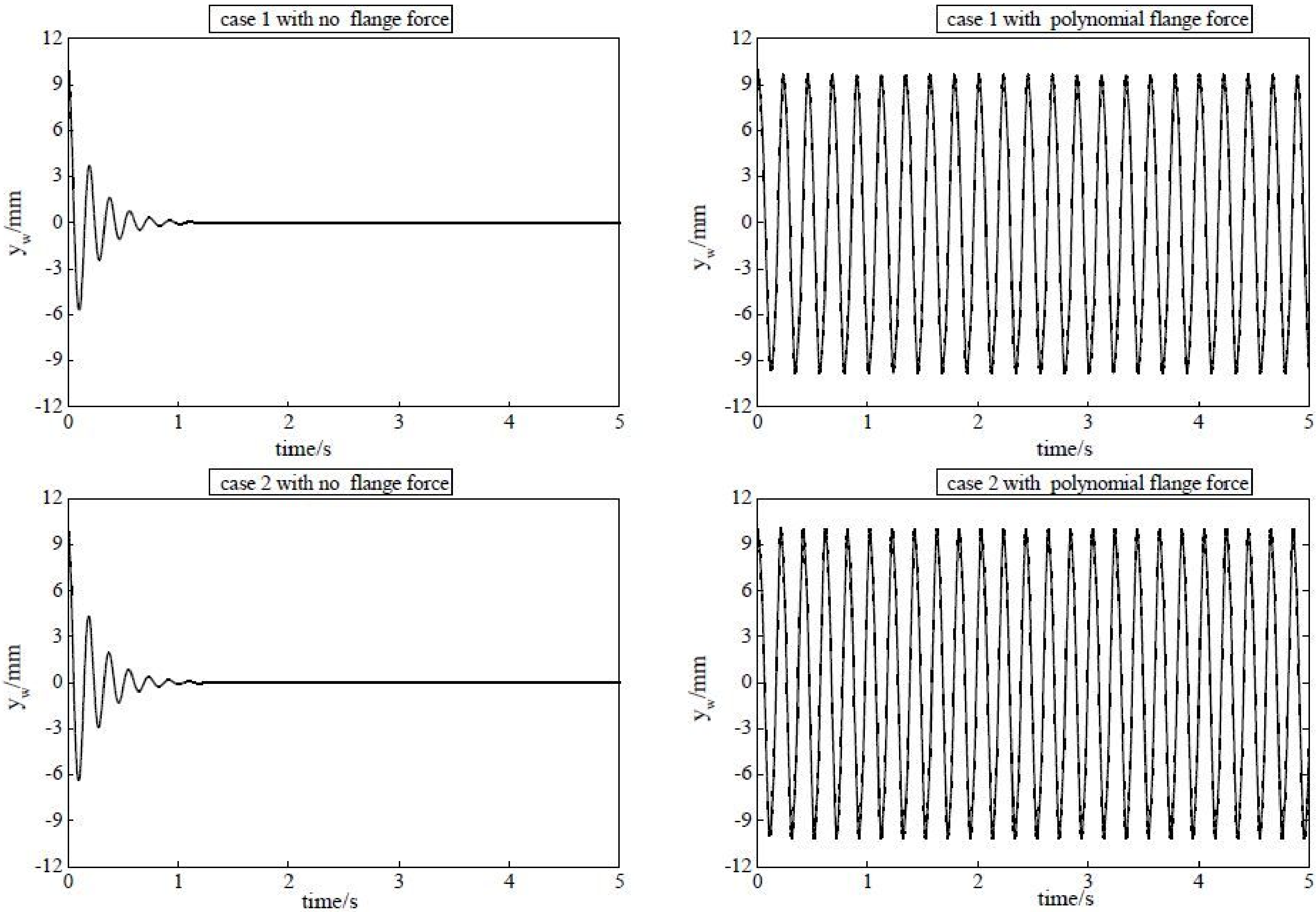

Figure 5

ODE integral with a running speed of 40 m/s and an initial disturbance of 10 mm

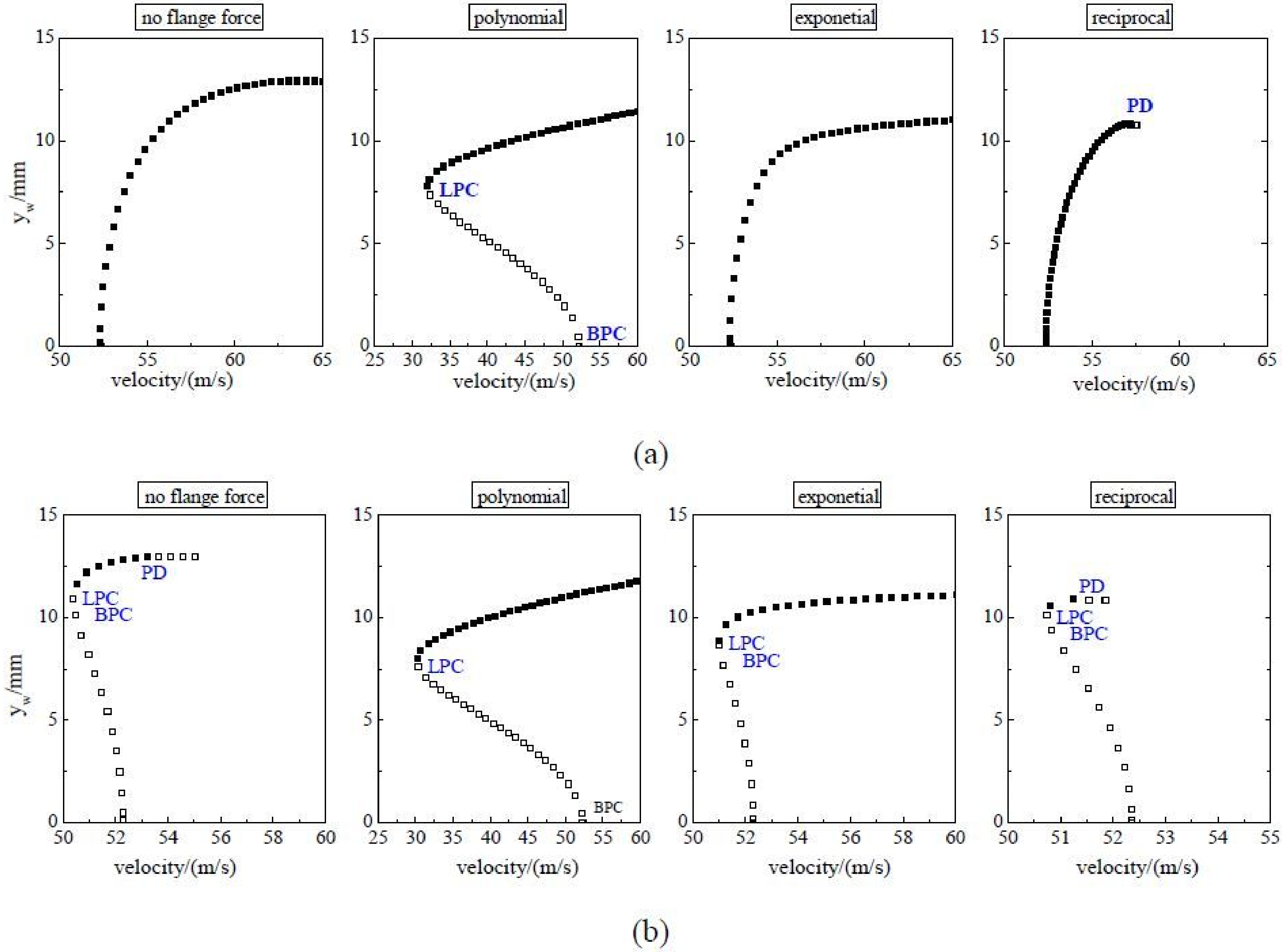

Figure 6

Bifurcation map (a) case1 (b) case2. (open symbols stand for unstable limit circle, while solid ones for stable limit circle)

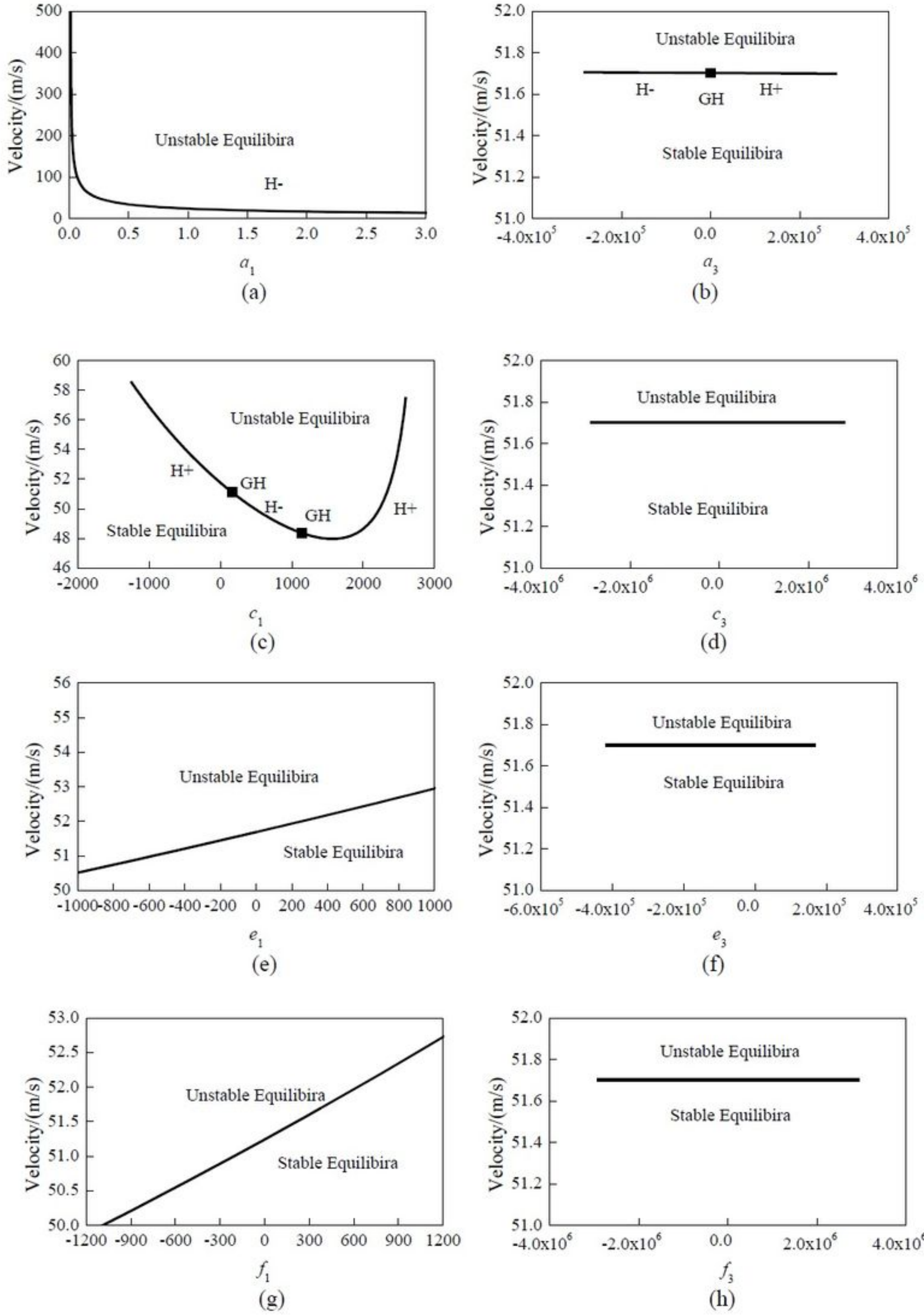

Figure 7

Hopf bifurcation curve between velocity and (a) a1, (b) a3, (c) c1, (d) c3, (e) e1, (f) e3, (g) f1, and (h) f3.

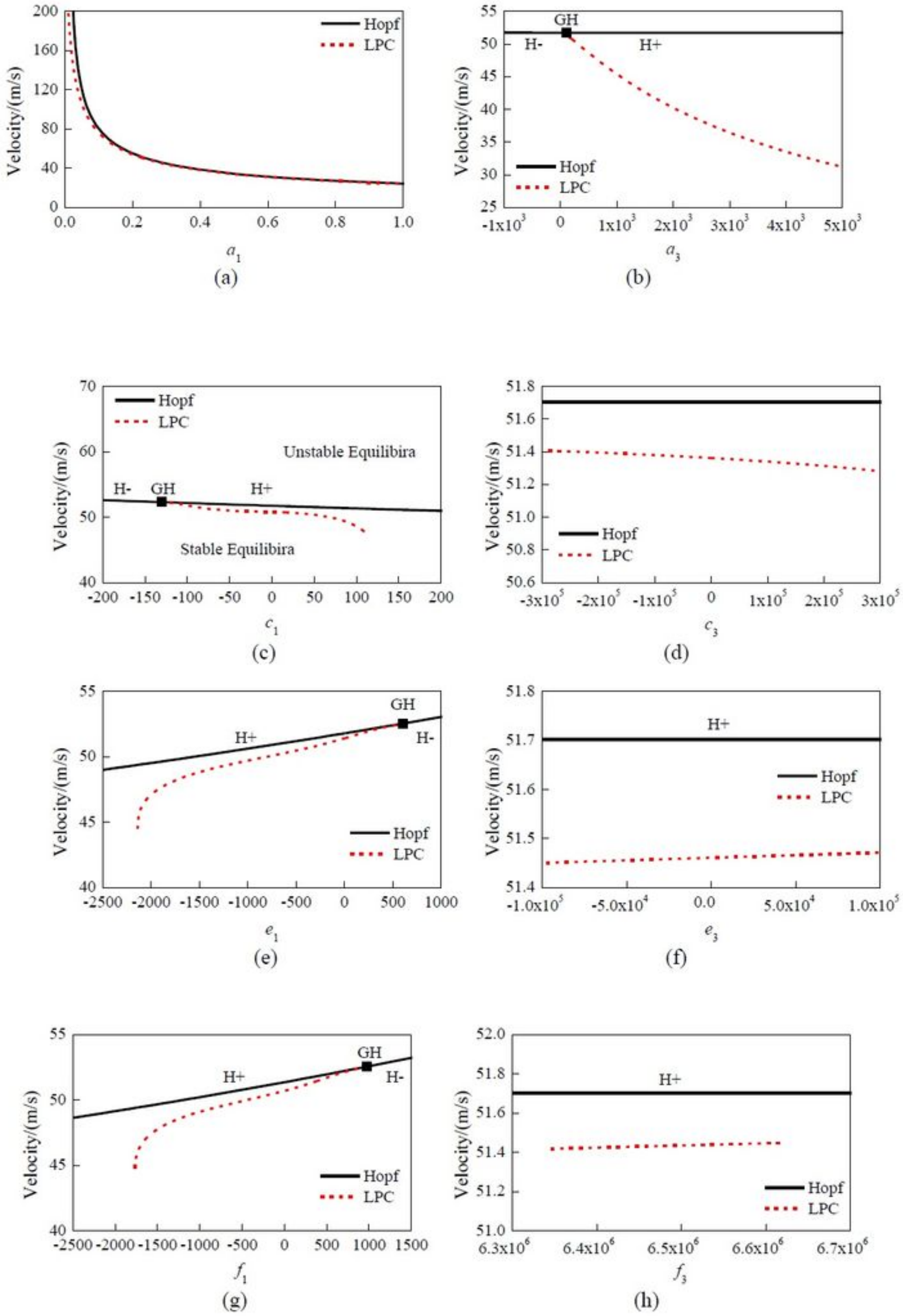

Figure 8

Hopf bifurcation curve and LPC bifurcation curve between velocity and (a) a1, (b) a3, (c) c1, (d) c3, (e) e1, (f) e3, (g) f1, and (h) f3.

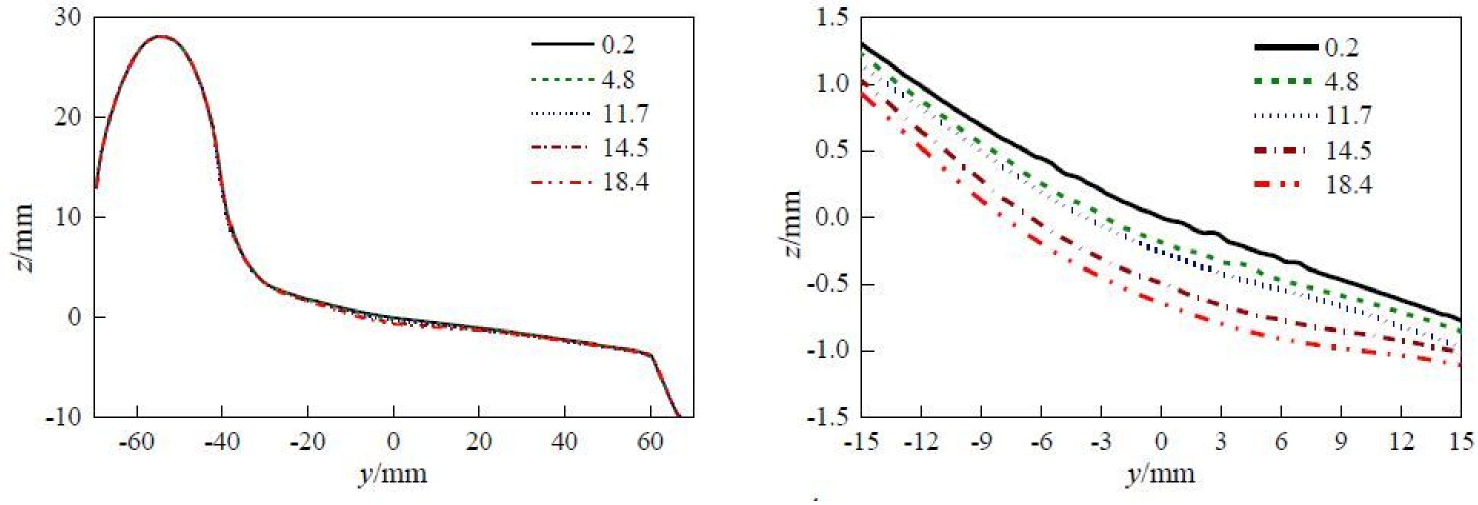

Figure 9

Profile with different running mileage (×104 km). (a) whole view (b) enlarged view

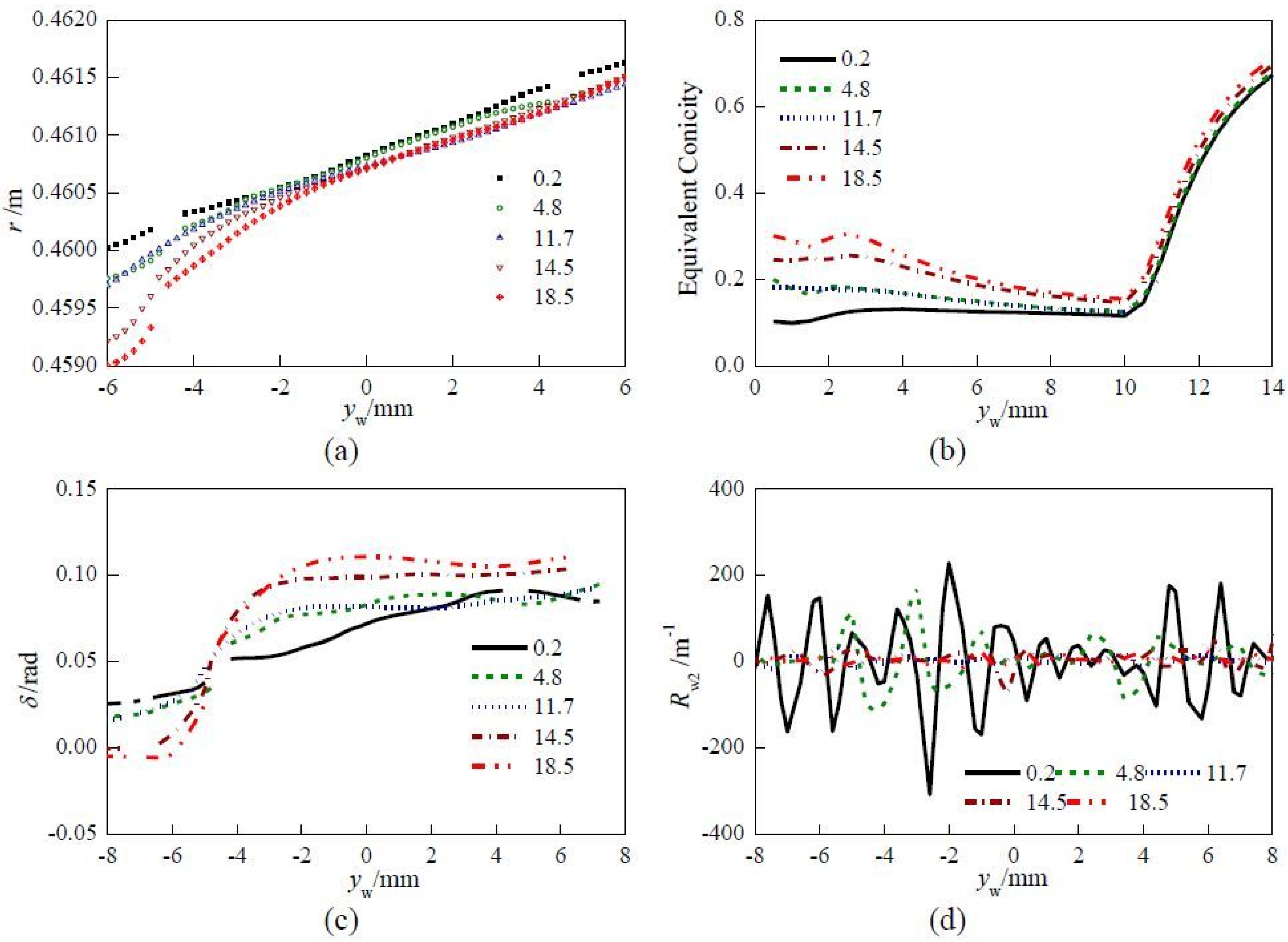

Figure 10

Contact geometry between new and worn profiles with a mileage of 0.2, 4.8, 11.7, 14.5 and 18.5×104 km (a) rolling radius, (b) equivalent conicity, (c) contact angle, (d) radius of curvature of wheel.

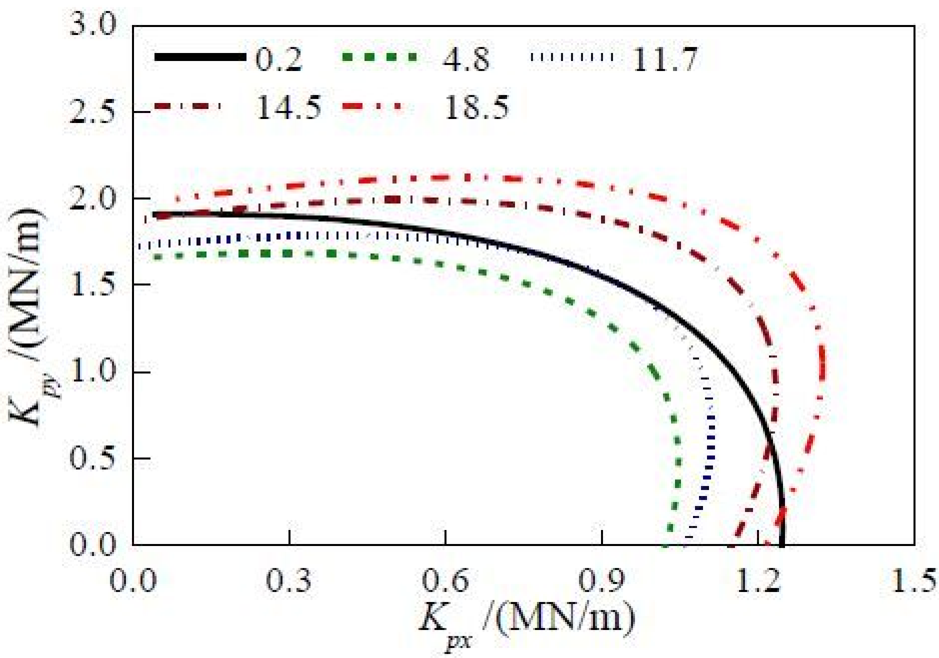

Figure 11

Required suspension stiffness for a Hopf bifurcation of 70 m/s with worn wheel profiles.