THE INFLUENCE OF THE WHEEL CONICITY ON THE HUNTING MOTION CRITICAL SPEED OF THE HIGH SPEED RAILWAY WHEELSET WITH ELASTIC JOINTS

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Abstract. The axle hunting is a coupled lateral and yaw self oscillatory motion which is largely determined by wheel–rail contact geometry. The stability of this motion is an important dynamic problem that determines the maximum operating speed of railway vehicle. The progressive depreciation in the working time of the railway vehicles components can lead to the intensifying of the vibration level. In this paper is studied the influence of the variation of the wheel conicity on the hunting motion stability of the high speed railway vehicles wheelset with elastic joints and passive linear elasticity and dissipation forces in horizontal plane.

Key words: hunting, stabilization, pseudosliding, damping, conicity.

1. INTRODUCTION

The profile irregularity of the railway line is one of the essential vibration sources to vehicle and track. In time, fatigue and damage of components of the dynamic system vehicle-track will emerge. The deterioration of railway structure components intensifies the vibration in the railway vehicles system. Some structural parameters have variation in a large domain and their influences on the one or more dynamic phenomena are important. One of the structural parameters with an important influence of the lateral stability of railway vehicles is wheel conicity. The parameter has a variation between 0.05 (a new wheel tread) and 0.2 (a worn wheel tread) with an important influence on the hunting motion stability of railway vehicles.

The hunting motion, occurring in case of the railway vehicles, is a consequence of the reversed conic shape of the wheel rolling surfaces [1, 2]. This produces a difference in the rolling radii of the two wheels when the wheelset is displaced to one side. Since the wheels are rigidly connected together through the axle, they must spin at the same rate. Therefore, the forward velocity of one wheel is larger than the forward velocity of the other one. This causes a rotation of the axle toward the center of the track, with the yaw angle continuing to increase until the axle center moves back to the middle of the track. This motion continues, with

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the axle oscillating from side to side in coupled lateral and yaw motion referred to as axle hunting. Below a certain vehicle riding speed, called the critical speed, the hunting motion appears as a damped sinusoidal oscillation along the track centerline. Above this critical speed, the motion becomes unstable and the displacement increases until the play between the wheel flanges and track is consumed. As the speed increases, the wheel – track contact force becomes large enough to cause rail damage, discomfort and eventually can lead to derailment. Particularly, for the high-speed passenger trains, the problem of achieving high-speed operation without the hunting instability has always been of interest to vehicle designers [3]. The effect of primary suspension and the effect of lateral linear stiffness on the hunting stability of a rail wheelset have been investigated in [4, 5]. Passive stabilization of the amplitude of self-oscillations or elimination of self-oscillations by appropriately selecting the parameters of the tread contour has been studied in [6, 7]. The influence of passive linear and non-linear dissipative horizontal forces on the hunting motion stability of a wheelset with elastic joints was analysed in [8–10].

In this paper is analyzed the effect of wheel conicity to the hunting motion stability of a wheelset with elastic joints.

2. ANALYTICAL MODEL OF WHEELSET HUNTING MOTION

The wheelset is modeled by an oscillating system with two degrees of freedom. The hunting motion is studied with respect to an inertial system of reference which moves with a constant velocity along the track centerline. In Fig. 1 is shown the physical model of the wheelset with elastic joints and dampers in parallel connections.

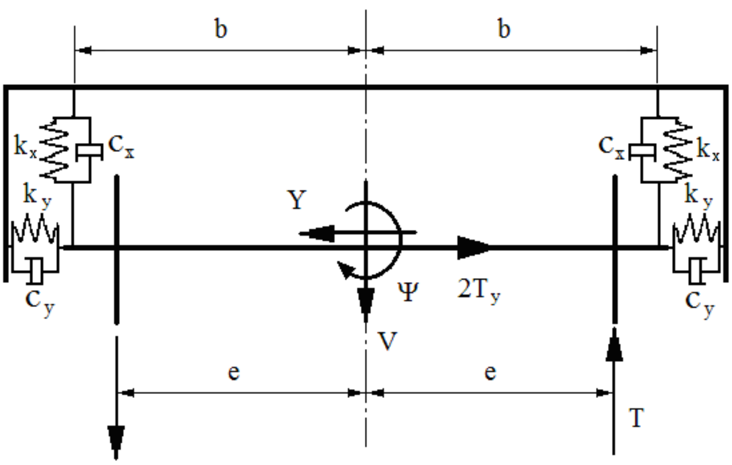


Fig. 1 – Mechanical model of an wheelset with elastic joints and linear viscous damping.

In this case, as is shown in Fig. 1, the movement equations are given by:

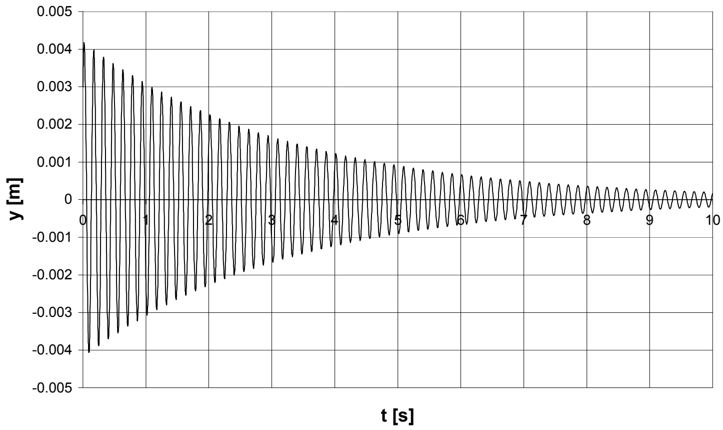
$$\begin{aligned} & m_0\ddot{y} + \left(2c_y + \frac{2\chi Q}{v}\right)\dot{y} + 2k_y y - 2\chi Q\Psi = 0, \\ & I_{0z}\ddot{\Psi} + \left(2c_x + 2\chi Q\frac{e^2}{v}\right)\dot{\Psi} + 2bk_x\Psi + 2e\chi Q\frac{\gamma}{r}y = 0. \end{aligned} \tag{1}$$

3. THE SIMULATION RESULTS

The simulation program is in Matlab-Simulink with the following input parameters:

$m_0 = 1,200$ kg	wheelset mass
$\chi_x = \chi_y = [50...400]$, $\chi_x = \chi_y = 300$	quasi-slipping coefficients
Q=75 kN	static load to the wheelset
$k_x = 9\cdot 10^5$ N/m, $k_x = 5.43\cdot 10^5$ N/m	elasticity coefficients
$c_x = [0...60]$ kNs/m, $c_y = [0...60]$ kNs/m	damping coefficients
$b = 1$m, $e = 0.75$m	geometric parameters of the wheelset
$y_1 = 3$ mm, $\varphi_1 = 0.5$	initial conditions in simulations
$\gamma = 0.05 - 0.22$	wheel conicity

In Fig. 2 are shown the displacement of hunting motion of the axle versus time and phase trajectory for v = 68 m/s. This situation corresponds to a situation before the critical speed of the hunting motion of the railway axle.



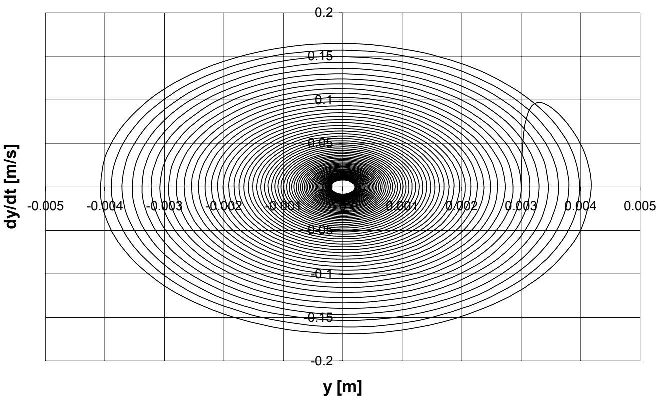


Fig. 2 – The hunting motion displacement before critical speed.

In Fig. 3 are shown the displacement of hunting motion of the axle versus time and phase trajectory for $v = 76$ m/s, corresponding to a situation after the critical speed of the hunting motion of the railway axle [1, 2].

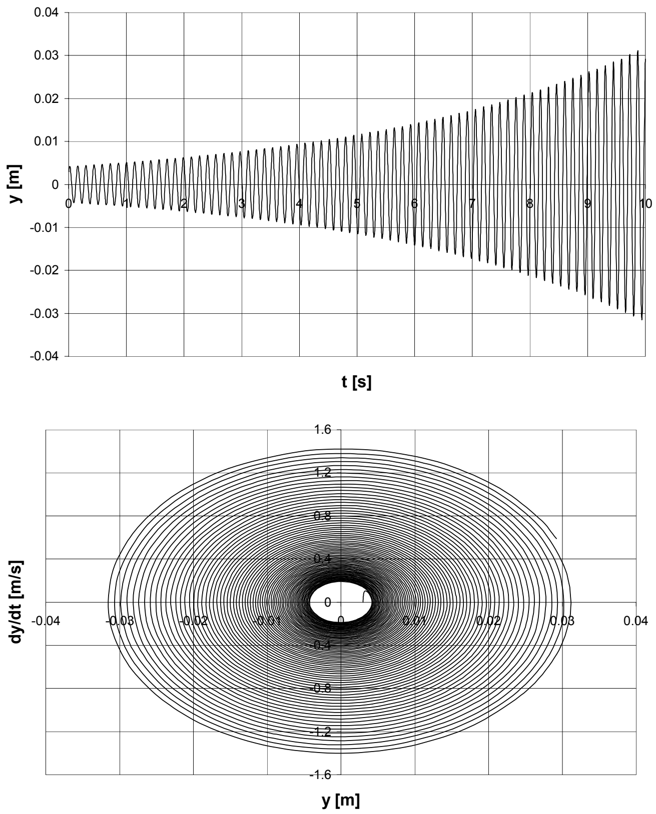


Fig. 3 – The hunting motion displacement after critical speed.

In Fig. 4 are shown the displacement of hunting motion of the axle versus time and phase trajectory for $v = 72$ m/s, corresponding to the critical speed of the hunting motion of the railway axle.

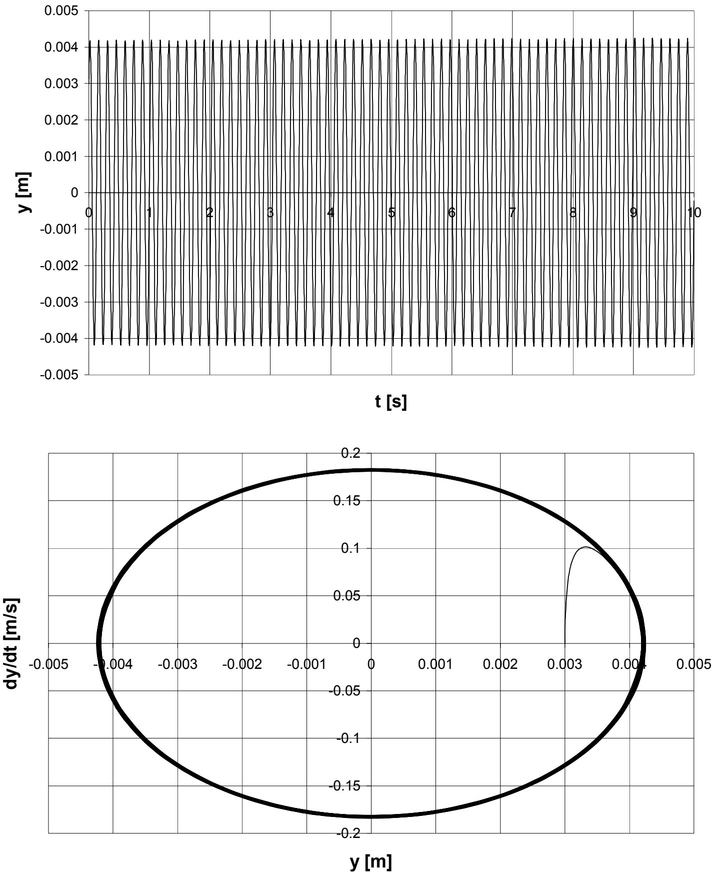


Fig. 4 – The hunting motion displacement at critical speed.

In Fig. 5 is shown the critical speed variation of the hunting motion of a wheelset versus wheel conicity for some values of the longitudinal and transversal dissipation coefficients c_x and c_y.

In Fig. 6 is shown the variation of the amplitude of elastic forces T_x and T_y in horizontal plane versus wheel conicity for some values of longitudinal dissipation coefficient c_x.

The amplitudes of elastic and damping forces were determined at critical speed for each case considered in numerical simulation.

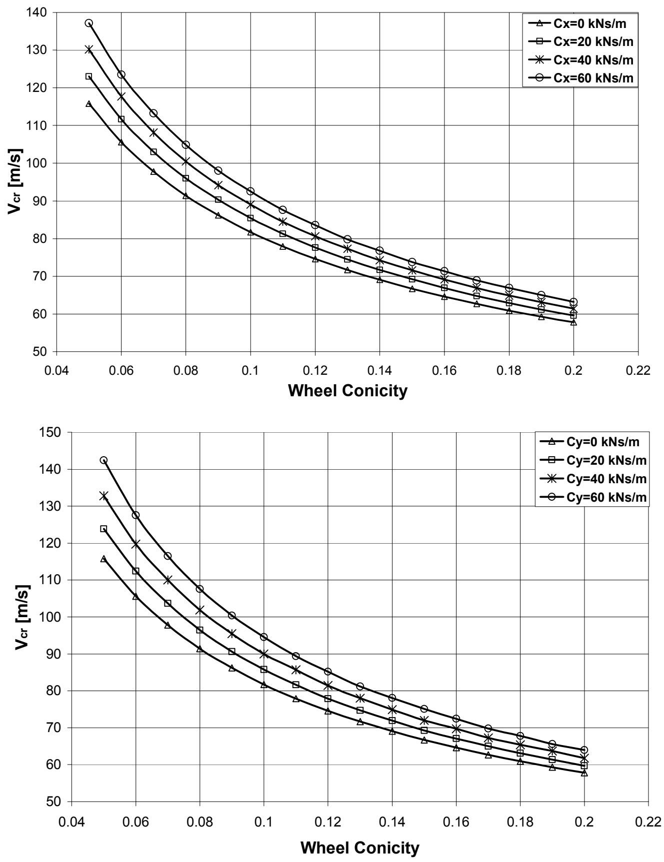
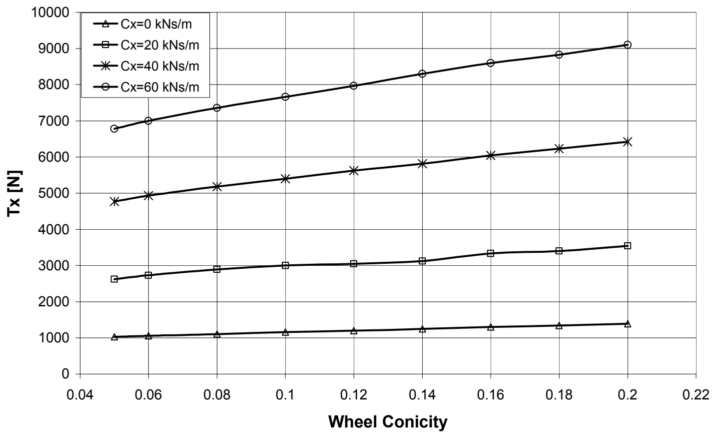


Fig. 5 – Variation of critical speed with the wheel conicity for some values of the longitudinal and transversal dissipation coefficients c_x and c_y.



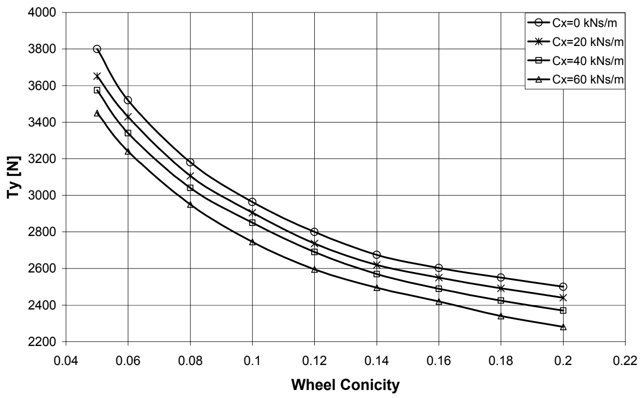
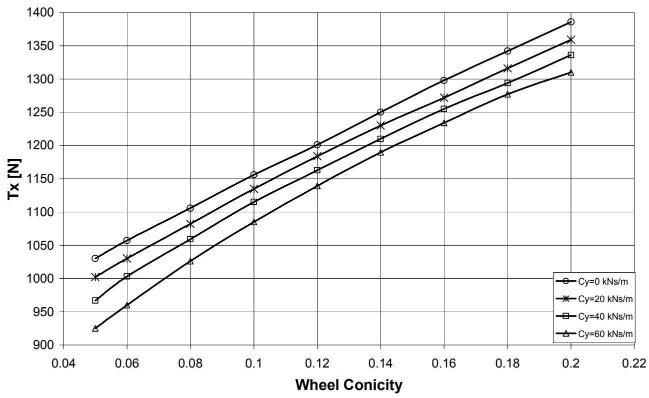


Fig. 6 – Variation of the elastic forces T_x and T_y with the wheel conicity for some values of longitudinal dissipation coefficient c_x.

In Fig. 7 is shown the variation of the elastic forces T_x and T_y versus the wheel conicity for some values of transversal dissipation coefficient c_y.



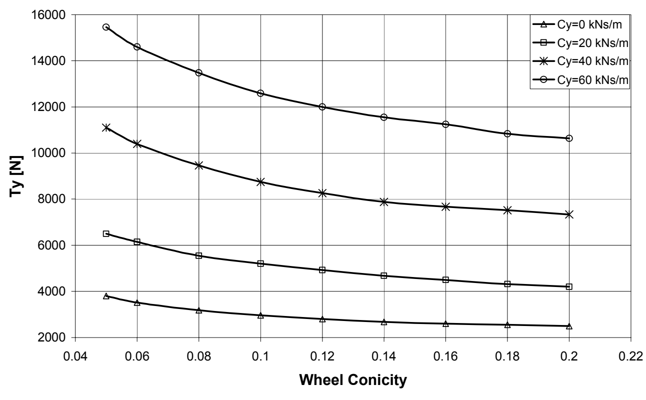


Fig. 7 – Variation of the elastic forces T_x and T_y with the wheel conicity for some values of transversal dissipation coefficient c_y.

In Fig. 8 is shown the variation of the elastic forces T_{cx} and T_{cy} versus the wheel conicity for some values of the longitudinal and transversal dissipation coefficients c_x and c_y.

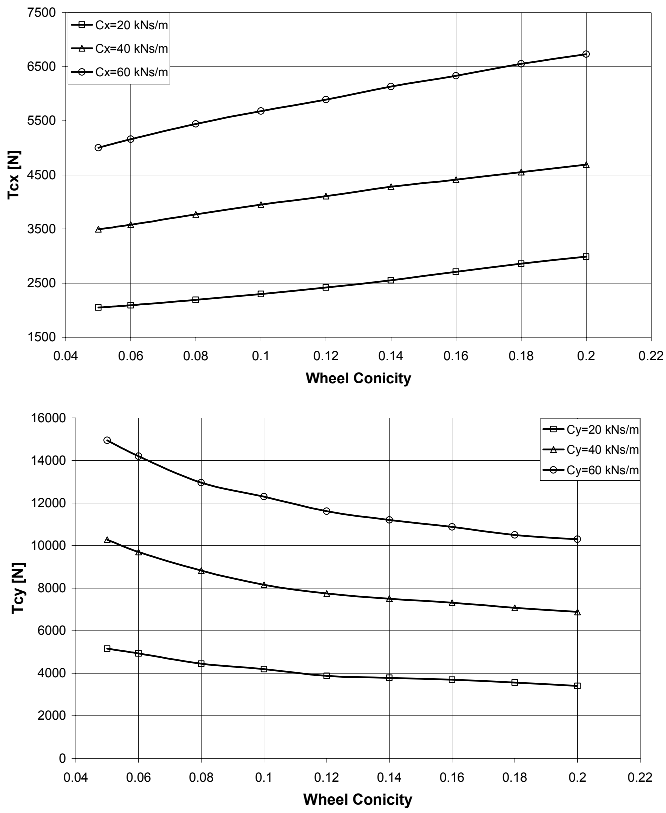


Fig. 8 – Variation of the elastic forces T_{cx} and T_{cy} with the wheel conicity for some values of the longitudinal and transversal dissipation coefficients c_x and c_y.

4. CONCLUSIONS

1. The hunting motion of the vehicle axle has a strong dynamic instability for higher speed than critical speed and that fact leads to the decrease of the maximum train speed.
2. The hunting motion critical speed decreases with the wheel conicity increase, which means that the vehicles with new wheel have better stability performances.
3. The longitudinal forces T_x and T_{cx} increase when the longitudinal or transversal dissipation force increase.
4. The transversal forces T_y and T_{cy} decrease when the longitudinal or transversal dissipation force increase.

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