HUNTING MOTION OF THE HIGH SPEED RAILWAY BOGIES WITH INTERCONNECTION AXLES

DANIEL BALDOVIN[1], SIMONA BALDOVIN[2]

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 as wheel wear, can lead to the intensifying of the vibration level. The weather can influence the lateral creep force coefficient and the hunting motion critical speed can decrease several times. In this paper is studied the influence of the wheel conicity and the lateral creep force coefficient to the hunting movement of a bogie with interconnection.

Key words: hunting motion, stabilization, creep coefficient, wheel conicity.

1. INTRODUCTION

The hunting motion occurring in case of the railway vehicles is a consequence of the reversed conic shape of the wheel rolling surfaces [1, 4]. This produces a difference in the rolling radii of the two wheels when the wheelset is displaced to one side. Therefore, the forward velocity of the first wheel is larger than the forward velocity of the second wheel. 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 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.

The influence of the wheel conicity and the lateral creep force coefficient to the hunting movement of a wheelset is studied in [1, 2]. Particularly, for the high-speed passenger trains, the problem of achieving high-speed operation without the

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hunting instability has always been of interest to vehicle designers [5]. The effect of primary suspension and the effect of lateral linear stiffness on the hunting stability of a rail wheelset have been investigated in [6, 7].

The hunting phenomenon often occurs when railway vehicles are run at high speeds, and represents a coupled oscillation of the wheelset in its lateral displacement and yaw angle. Many investigations concerning the hunting stability of trucks running on tangent tracks are to be found in the published literature. The stability of a track with interconnection axles, in alignment and curved was studied in [8, 9].

In this paper is analyzed the effect of wheel conicity and the lateral creep force coefficient to the hunting motion stability of a track with interconnection axles in alignment.

2. ANALYTICAL MODEL OF BOGIE WITH INTERCONNECTION AXLES

A bogie with interconnection axles is modeled by an oscillating system with four 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, it is shown the physical model of the bogies with interconnection axles.

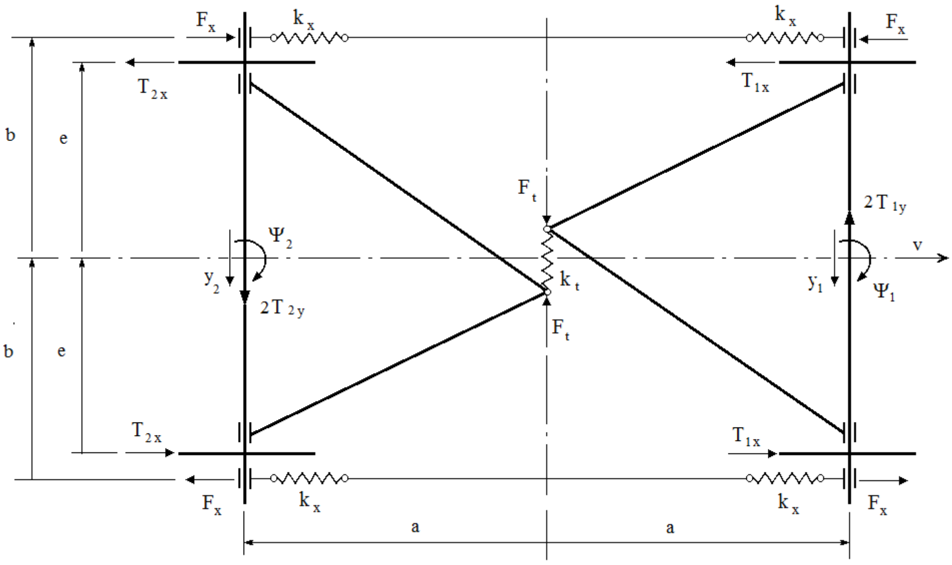


Fig. 1 – Mechanical model of a bogie with interconnection axles.

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

$$
\begin{aligned}
&m_0\ddot{y}_1 - k_t\left[y_1 - y_2 - a(\Psi_1+\Psi_2)\right] + 2xQ\left(\frac{\dot{y}_1}{v} - \Psi_1\right) = 0,\\
&I_{oz}\ddot{\Psi}_1 + 2b\frac{kx}{2}(\Psi_1-\Psi_2)b + ak_t\left[y_1 - y_2 - a(\Psi_1+\Psi_2)\right] + 2exQ\left(\frac{\gamma}{r}y_1 - \frac{e}{v}\dot{\Psi}_1\right) = 0,\\
&m_0\ddot{y}_2 + k_t\left[y_1 - y_2 - a(\Psi_1+\Psi_2)\right] + 2xQ\left(\frac{\dot{y}_2}{v} - \Psi_2\right) = 0,\\
&I_{oz}\ddot{\Psi}_2 - 2b\frac{kx}{2}(\Psi_1-\Psi_2)b + ak_t\left[y_1 - y_2 - a(\Psi_1+\Psi_2)\right] + 2exQ\left(\frac{\gamma}{r}y_2 + \frac{e}{v}\dot{\Psi}_2\right) = 0.
\end{aligned}
\tag{1}
$$

3. THE SIMULATION RESULTS

The simulation program is in Matlab/Simulink with the following enter parameters:

Table 1

Wheelset mass	$m_0 = 1\,500$ kg
Lateral creep force coefficients	$\chi_x = \chi_y = [50...400]$
Static load to the wheelset	$Q = 75$ kN
Elasticity coefficients	$k_t = 5\cdot10^6,\ k_x = 10^6$ N/m
Wheel conicity	$\gamma = [0.1...0.26]$
Geometric parameters of the wheelset	$b = 1$ m, $e = 0.75$ m
Bogie wheelbase	$a = 1.28$ m
Initial conditions in simulations	$y_1 = 2$ mm, $\psi_1 = 0.1$ $y_2 = 1$ mm, $\psi_2 = 0.8$

In Figs. 2, it is shown the displacement of hunting motion of the first axle in time and in phases plane for $V = 80$ m/s.

This situation is corresponding to a situation before the critical speed of the hunting movement of the railway axle.

In Figs. 3, it is shown the displacement of hunting motion of the axle in time and in phases plane for $V= 84$ m/s; this is corresponding to a situation after the critical speed of the hunting movement of the railway axle.

In Figs. 4, it is shown the displacement of hunting motion of the axle in time and in phases plane for $V = 81$ m/s; this is corresponding to critical speed of the hunting movement of the railway axle.

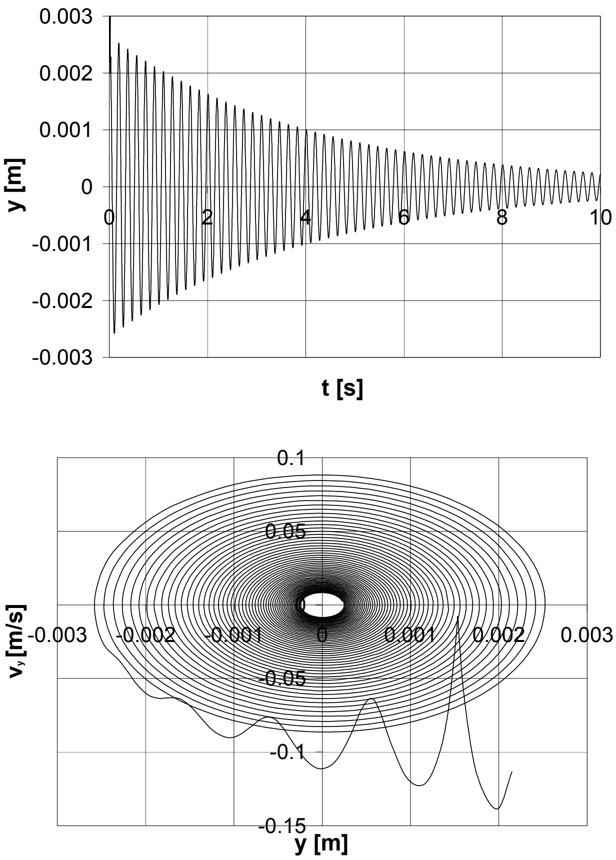
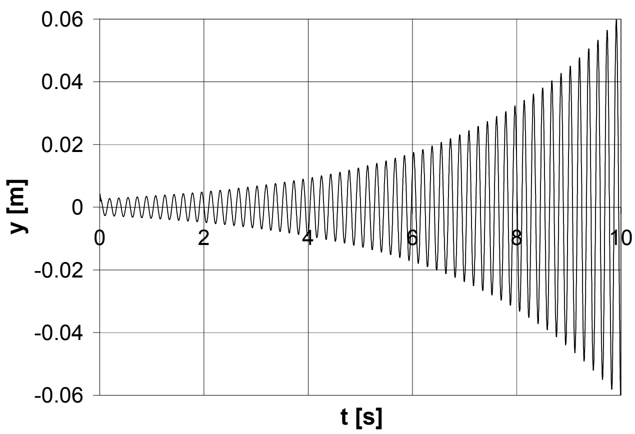


Fig. 2 – The hunting motion displacement before critical speed.



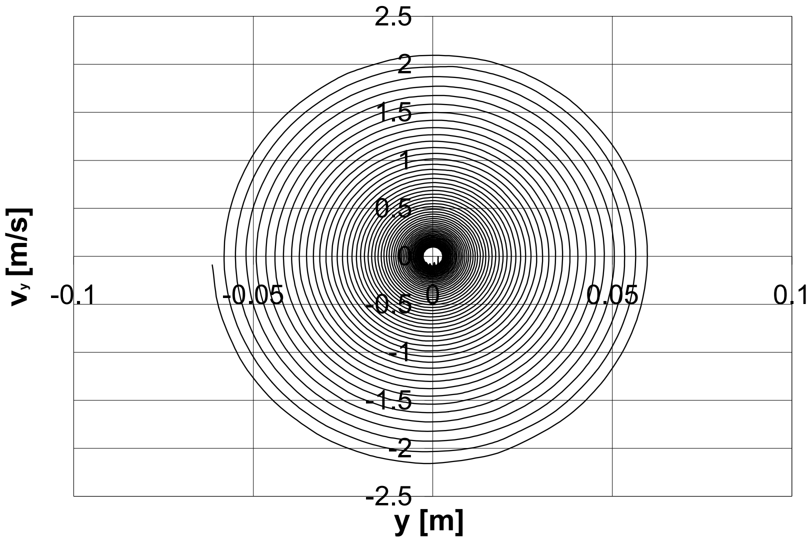
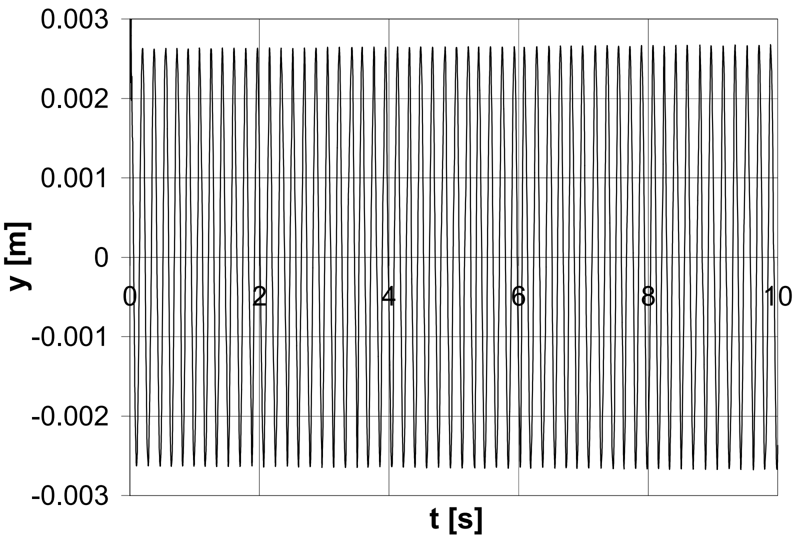


Fig. 3 – The hunting motion displacement after critical speed.

In Fig. 5, it is shown the critical speed of hunting motion *versus* wheel conicity for some values of the lateral creep force coefficient.



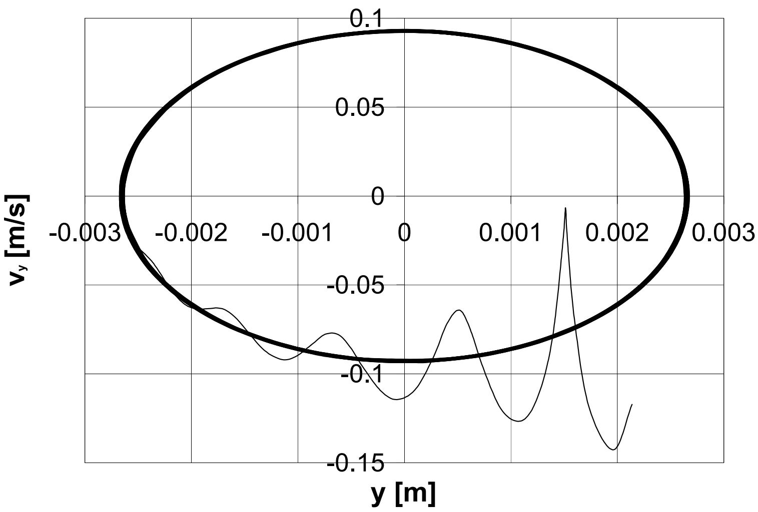


Fig. 4 – The hunting motion displacement at critical speed.

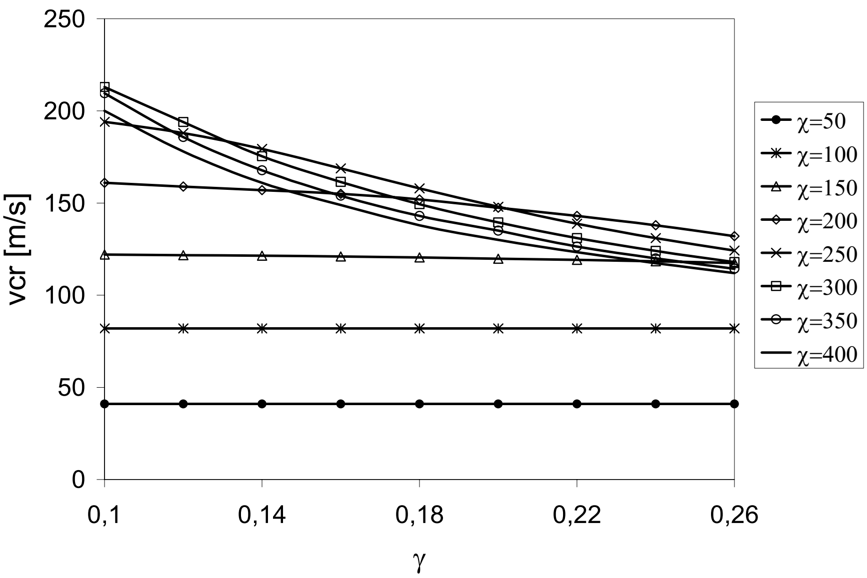


Fig. 5 – The critical speed of hunting motion *versus* wheel conicity.

In Fig. 6, it is shown the critical speed of hunting motion *versus* the lateral creep force coefficient for some values of the wheel conicity.

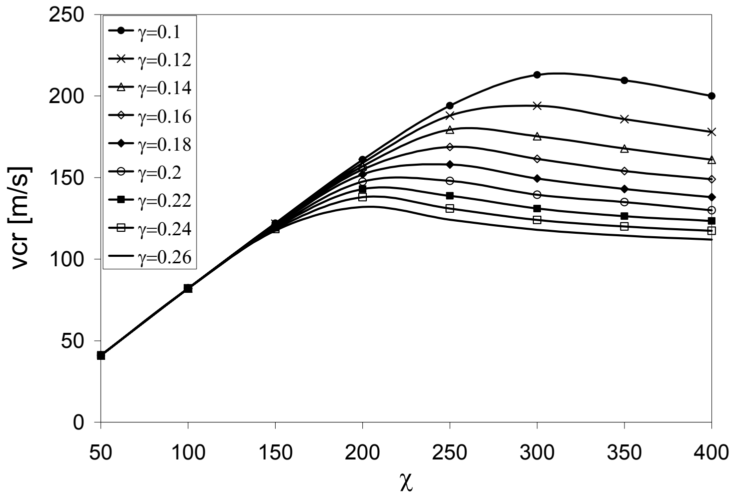


Fig. 6 – The critical speed of hunting motion *versus* lateral creep force coefficient.

4. CONCLUSIONS

1. The hunting movement of the bogies with interconnection axles has a strong dynamic instability for higher speed than critical speed of the hunting motion and that fact coerce the maximum train speed.

2. The bogies with interconnection axles increase the hunting motion critical speed compared with conventional bogies.

3. The hunting motion critical speed is decreasing with the wheel conicity increase, which means that the vehicles with new wheels are increasing the stability performances of the hunting motion.

4. The hunting motion critical speed of the bogies with interconnection axles has a maximum value according to the lateral creep force coefficient, situated between 200 and 300 as is shown in Fig. 6.

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