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CRITICAL ANALYSIS OF THE MOTION OF RUNNING GEAR ELEMENTS OF ROLLING STOCK - STATIC AND KINEMATIC MODELLING ROLLING RESISTANCE OF WHEELSET

KRITICKÁ ANALÝZA POHYBU ČASTÍ PODVOZKU KOĽAJOVÝCH VOZIDIEL - STATICKÉ A KINEMATICKÉ MODELOVANIE VALIVÉHO ODPORU DVOJKOLIA

Petar KOLEV[1] Petar GREKOV[2] Valentin NEDEV[3]

SUMMARY:

A wagon wheelset in general position with a transverse dislocated geometric centre was considered in this study. Its scheme of forces in a state without a motion was defined. The motion of the wheelset absence of nosing, where its kinematic characteristics was defined, was considered as well.

KEYWORDS: *wheelset, kinematic characteristics, illustration of force.*

INTRODUCTION

The wagon wheelset is a basic part of the rolling stock. It directs its motion along the track and transfers all loads from the wagon to the rails and reversed. The track interaction forces and running resistance are largely dependent on the structure, material and manufacturing technology of the wheelset. Therefore, a detailed examination of this important element of the wagon is needed to increase the safety movement of trains and to improve their smoothing of operation.

1. STATIC EXAMINATION OF THE WAGON WHEELSET AND DETERMINATION OF ITS SCHEME OF FORCES AT STANDSTILL.

Let's examine a wheelset in general position with transverse dislocated geometric centre (fig. 1).

We introduce coordinate system Oxyz with beginning начало $O \equiv C$ (geometric center of the wheelset) when two wagon wheels roll along the circumferences of their rim profile with identical radii $(r_Л = r_Д = r)$.

The distance between A and B contact points of the wheels with the rails is 2L and the distance between the faces of the rims – 2l.

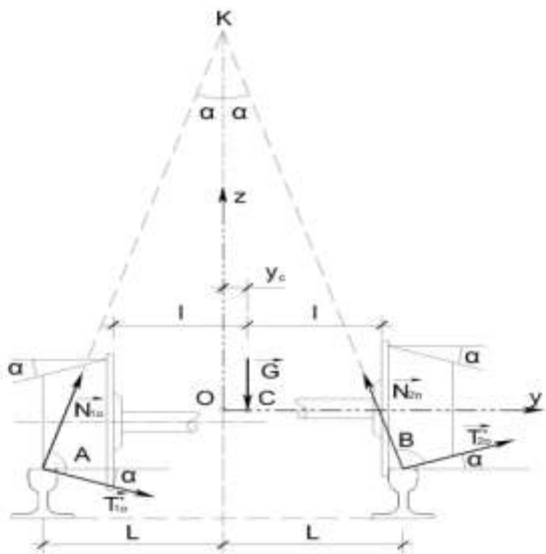

Fig.1

When the geometric centre C has been shifted along y-axis with distance y_c and it's

[1] Petar Kolev, DSc, Eng. Math., TK UT, Bulgaria, Sofia, 158 Geo Milev Str., tel: +359 2 9709-240,petarkolev@abv.bg.
[2] Petar Grekov, Eng, VSU LK, Bulgaria, Sofia 1373, Suchodolska str. 175, tel: +359 2 80 29 100, petar_grekov@abv.bg.
[3] Valentin Nedev, Assoc. Prof. Eng. Math, PhD., TK UT, Bulgaria, Sofia, 158 Geo Milev Str., tel.: +359 2 9709-484, valnedev@vtu.bg.

coordinate on x-axis is zero x е нула $(x_c = 0)$ the structure of the wheelset shows that $z_c = 0$. Under axial displacement according y-axis the “right” wagon wheel is lifted so as to the “left” is lowered.
In this position, the forces, acting on the wheelset (fig.1) are:

- $\vec{G}$ - Gravity Force;
- $\vec{N}_{1,o}$ and $\vec{N}_{2,o}$ - Normal Pressure Forces, applied in contact points A and B between the wheels and rails, perpendicular to the surfaces of the rims;
- $\vec{T}^{`}_{1o}$ and $\vec{T}^{`}_{2o}$ - Friction Forces

From the condition of equilibrium of the wheelset

$$\sum_i M_{K,i} = 0: -Gy_C + (T'_{10} + T'_{20}) \frac{L}{\sin\alpha} = 0 \quad (1)$$

it follows that:

$$T'_{10} + T'_{20} = \frac{Gy_C \sin\alpha}{L}. \quad (2)$$

From the instantaneous equilibrium conditions:

$$\begin{cases} \sum_i M_{A,i} = 0: -G(L + y_C) + 2L(N_{20}\cos\alpha + T'_{20}\sin\alpha) = 0; \\ \sum_i M_{B,i} = 0: G(L - y_C) - 2L(N_{10}\cos\alpha - T'_{10}\sin\alpha) = 0. \end{cases} \quad (3)$$

it follows that:

$$\begin{cases} N_{10} = \dfrac{G(L - y_C) + 2LT'_{10}\sin\alpha}{2L\cos\alpha}; \\ N_{20} = \dfrac{G(L + y_C) - 2LT'_{20}\sin\alpha}{2L\cos\alpha}. \end{cases} \quad (4)$$

If the wheelset is examined in starting position, when $y_c = 0$, from (2) is obtained:

$$T'_{10} + T'_{20} = 0 \quad (5).$$

Since the two Friction Forces are unidirectional, the condition (5) is fulfilled when $T^{`}_{10} = T^{`}_{20} = 0$.

From (4) follows that Normal Pressure Forces are equal:

$$N_{10} = N_{20} = \frac{G}{2\cos\alpha} \quad (6)$$

2. KINEMATIC EXAMINATION OF WAGON WHEELSET

Wagon wheelset (fig. 2) in general position with transverse dislocated geometric centre is examined. We assume absence of nosing, when the wheelset moves.

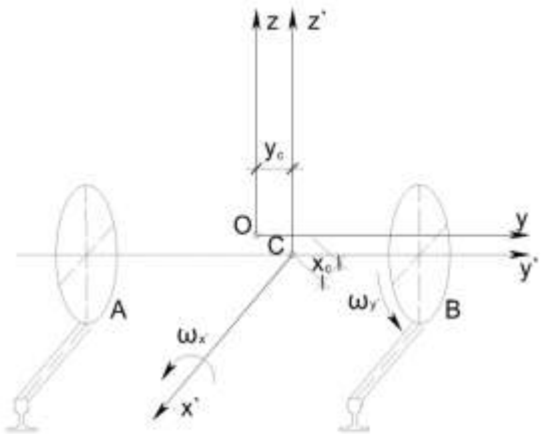

Fig. 2

A coordinate system O`x`y`z` with a beginning that coincides with the shifted along y-axis geometric center C is introduced.

Fig. 3 shows the rotation of the wheelset relative to x` at its transversal displacement along y-axis.

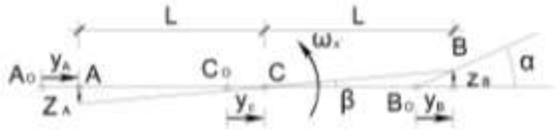

Fig.3

For the kinematic characteristics of the motion, we have:

$$\begin{cases} y_A = y_B = y_C; \\ z_B = y_B tg\alpha \Rightarrow \dot{z}_B = \dot{y}_B tg\alpha; \\ \omega_{x'} = \dfrac{\dot{z}_B}{L} = \dfrac{\dot{y}_C tg\alpha}{L}; \\ tg\beta = \dfrac{z_B}{L}, \ z_B << L \ \Rightarrow \\ \quad \beta \approx tg\beta = \dfrac{y_B}{L} tg\alpha = \dfrac{y_C}{L} tg\alpha. \end{cases} \quad (7)$$

Along the x-axis, assuming absence of nosing, the wheelset performs translation (fig. 4), wherein the velocities of the points of the axis are equal.

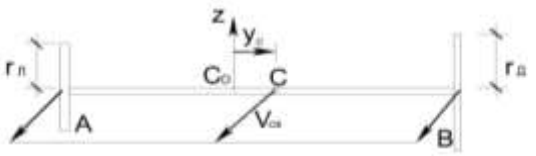

Fig.4

The two admissible states of the Instanteneous Centre of Velocity along y`- axis are shown in fig. 5.

Besides the Forces of Normal Pressure $\vec{N}_{1,o}$ и $\vec{N}_{2,o}$, the Longitudinal Friction Forces $\vec{T}''_{10}$ и $\vec{T}''_{20}$, applied in points A and B are introduces in the figure.

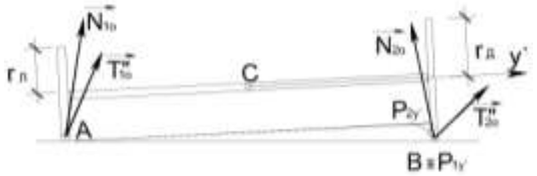

Fig.5

Since when $y_c > 0$: $(N_{1_0} > N_{2_0})$, it can be assumed that $T''_{20} > T''_{10}$. Moreover, $(r_Д > r_Л)$. Its obvious that the right wheel is in more favourable situation of the forces. Thefore two states can be assumed:

a) Instantaneous Cenre of Rotation $P_{1_{y'}} \equiv B$;

b) Instantaneous Cenre of Rotation $P_{2_{y'}}$ is outside the wheels, closer to the right wheel.

The first state (fig. 6) is possible for the case of mobile wheelset. It si obvious that, when we have motion in a straight section and occurred deviation $y_c > 0$ the right wheel performs pure rolling and the left – rolling with slip.

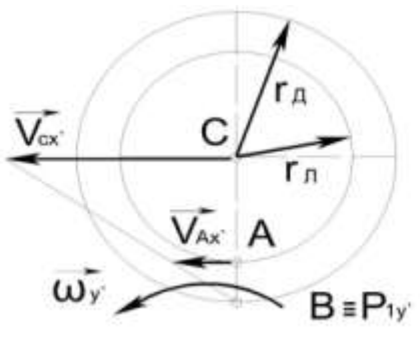

Fig.6

It is obvious from fig. 6:

$$\omega_{y'} = \frac{v_{Cx}}{r_Д} = \frac{\dot{x}_C}{r + z_B} = \frac{\dot{x}_C}{r + y_B tg\alpha} = \frac{\dot{x}_C}{r + y_C tg\alpha} \qquad (8)$$

and

$$v_{Ax'} = \omega_{y'}(r_Д - r_Л) = \frac{\dot{x}_C}{r + y_C tg\alpha}\left[r + y_B tg\alpha - r + y_B tg\alpha\right] = \qquad (9)$$

$$= \frac{2\dot{x}_C y_C tg\alpha}{r + y_C tg\alpha}$$

If we examine the wheelset in a starting position when $y_c = 0$, from (9) we obtain $V_{Ax'} = 0$, i.e. the left wheel will perform pure rolling. This analysis shows that for the Friction Forces that cause motion is valid:

$$T''_{i0} \le \mu N_{i0} \quad (i = 1, 2); \; T''_{10} = \mu_0 N_{10}; \qquad (10)$$

$$T''_{20} = \mu_0 N_{20}$$

The second state (fig.7) is possible when the wheelset is driven.

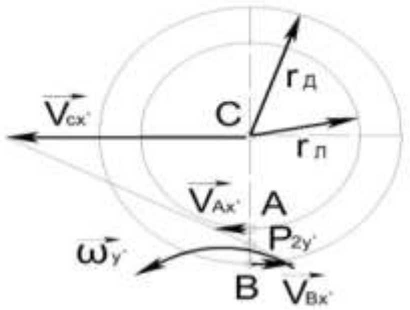

Fig.7

Under the action of the Driving Momentum $M_{y'}$ and absence of mounting – the track, the driving wagon wheelset will rotate with angular velocity $\omega_{y'}$.

Under a motion in straight section and occurred deviation $y_c > 0$, the velocity of point B from the right wheel will be bigger than those of point A from the left wheel $(r_Д > r_Л)$.

The rail as a partial reversible connection will impede the motion of point B and point A with Friction Forces, directed in opposite direction of their relative velocities. If these Friction Forces are large enough, then point B will become immovable and will coincide with Instantaneous Centre of Velocity, along which we will have instantaneous rotation (first state).

Assuming $(T''_{10} \cdot r_л < T''_{20} \cdot r_д)$, the conditions for the first and second state of the driven wheelset are obtained by the relation between the Friction Forces and Driving Momentum.

For the second state (fig. 7) is required:

$$T''_{10} r_Л + T''_{20} r_Д < M_{y'} \qquad (11)$$

For the first state (fig.6), when $P_{1_{y'}} \equiv B$

it should:

$$T''_{10} r_Л + T''_{20} r_Д > M_{y'} \qquad (12)$$

The shifting of the wheelset from the first to the second state and reverse happens with a collision in the flange of the wagon wheels. Under motion, the wheelset passes from extreme “left” to extreme “right” position. Considering the action of the Friction Forces, this process becomes weaker with time. We will do a research in this field in our next work..

LITERATURE

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