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STUDY CONCERNING THE BEHAVIOUR FROM THE SAFETY VIEWPOINT AGAINST THE DERAILMENT DEPENDING ON THE CENTRE CASTING TORQUE OF THE RAILWAY VEHICLES (LUBRICATED PLANE CENTRE CASTING, RESPECTIVELY NON LUBRICATED)

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Abstract: *The paper examines the differences between the torque in the centre casting of the railway vehicles in the curve running. The purpose of this study is to establish the influence of a lubricated plane centre casting, respectively non lubricated, on the report Y/Q (the safety value against the derailment).*

Key words: *railway vehicle, torque, Y/Q relation, derailment.*

SECTION 1 (INTRODUCTION)

Because of the differences between the torque in the centre casting of the railway vehicles in the curve running , appeared at the lubricated or non lubricated plane centre casting, there is a consequence on the guiding force Y and implicitly on the report Y/Q. The purpose of this study is to establish the influence of a lubricated plane centre casting, respectively non lubricated, on the report Y/Q (the safety value against the derailment).

SECTION 2

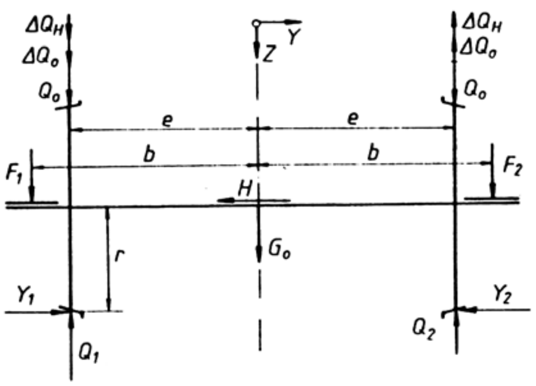

Figure 1. Load transfers on the vehicle axle

Calculation hypothesis:

- one takes the wear profile case "S78", pointed, for witch the radius values depending on the movement against the medium axle of the track y_c are obtained through the Lagrange interpolation with three points (that has the same error as the square interpolation)
- one does not take into account the vertical elements of the friction forces at the wheel - rail contact,
- one takes into account the load transfer from one wheel on another.

Over-widening

R[m]	100-150	151-250	251-350
S[mm]	25	20	10

Over – raising

-for R < 350 m , $h[mm] = \frac{R[m]-50}{2}$;

-for R ≥ 350 m, $h = 150mm$;

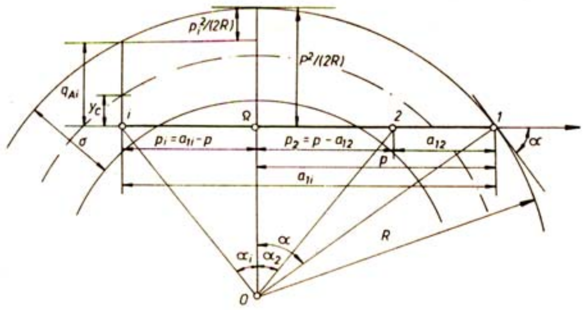

Figure 2. Impact of the clearance on the geometrical placing of the vehicle

The Ω base of the perpendicular line drawn from the curve centre of the track on the longitudinal axle of the vehicle is named pole, and the perpendicular line on this - polar centre

The distance from the first axle to the pole Ω is named polar distance

For the study of vehicle placing in curves one determines first the distance y between the pole Ω and the exterior stretches of rails of radius R

$$y = \frac{p^2}{(2R)};$$

q_{Ai} – the axle distance against its exterior stretch of rails, that establi its position in track ($q_{Amax}=\sigma$), that is the distance between the point A_{10} of the exterior wheel lip and the interior flank of the rail from the exterior stretch of rails.

One takes a vehicle with n axles, a wheel base, placed in the curve with radius R, in free position.

Approaching to the exterior stretch of rails of an intermediary axle (figure 2) will be:

$$q_{Ai} = \left(p^2 - p_i^2\right)/(2R) = \left[p^2 - (a_{1i} - p)^2\right]/(2R) = (a_{1i}/R)\cdot(p - a_{1i}/2);$$

yci – transversal displacement against the medium centre of the track at the axle I, with positive sign at the movement to the curve exterior;

From here results the polar distance depending on the q_{AI}:

$$p = \frac{a_{1i}}{2} + \frac{R \cdot q_{Ai}}{a_{1i}};$$

The insufficient maximum over-raising accepted I=90 mm in our country.

σ - gauge clearance;

$\sigma = 10 + S$;

a_{1i} - distance between the axle 1 and the axle i;

a = a_{1n} - wheel flange;

p_i - polar distance of the axle I, that is the distance from the axle I to the pole Ω. The Sigh is positive if the pole is after the axle in the direction of traffic and negative if it is in front of the axle;

p = p_1 - polar distance of the axle 1, that is just the polar distance of the bogie;

$p_i = p_1 - a_{1i}$;

$p_c = \frac{a_{1n}}{2}$ - polar distance in the case of cord position;

$p_s = \frac{a_{1n}}{2} + \frac{R \cdot \sigma}{a_{1n}}$ - polar distance in the case of secant position;

<u>Sliding speeds between the wheels and the rails</u>

$\Delta r_{e,i}$ - radius difference because of the movement with y_c on the exterior stretch of rails , respectively interior.

The signs convention is the next:

- on the exterior stretch of rails, at a positive movement of y_c (to the exterior of the curves) is obtained a positive movement Δr_e (to the wheel flange);

- on the interior , at a positive movement of y_c (to te exterior of the curve) is obtained a negative movement Δr_i (contrary to the wheel flange).At the movement y_c on the interior stretch of rails is also added the over – widening S.

$\Delta r_{e,i}$ is obtained through the interpolation with the polynominal Lagrange.

$$w_{e_x} = V\left[(1-K) + \left(\frac{e}{r} - K\frac{\Delta r_e}{r}\right)\right];$$

$$w_{i_x} = V\left[(1-K) + \left(\frac{e}{r} - K\frac{\Delta r_i}{r}\right)\right];$$

K – regime value;

$\omega_y = \frac{V}{r}$ - for free axle case;

$\omega_y = K\frac{V}{r}$ - for free axle in hauled or braking condition.

K = 1 - for the free axle case;
0 < K < 1 - for the axle in braking conditions;
1 < K < ∞ - for axle in braking conditions;

η - transversal distance against the transversal centre of the axle, where the running cone meets the rotation cone in hauling or braking conditions and of the taking into account of the load transfer between the two wheels of the same axle (there is a offset).

s - the height of the running cone;

$$s = \frac{2(e + \sup ral \arg irea)}{\Delta r_e - \Delta r_i}$$

This formula is valid for the wear profile and results from the similitude of the triangles formed by the running cone . The sign from the denominator is due to the signs convention adopted for $\Delta r_{e,j}$

$$\eta = \frac{\Delta Q_0}{Q_0} e \quad ; \qquad K = \frac{s}{R}\frac{R+\eta}{s+\eta} \quad ;$$

$$w_{e_y} = w_{i_y} = -(p_1 - a_{1i})\frac{V}{R} \quad ;$$

Sliding values

$\gamma_{e,i_x} = \frac{w_{e,i_x}}{V}$ - sliding values on the in the direction x, on the exterior stretch of rails , respectively interior;

$\gamma_{e,i_y} = \frac{w_{e,i_y}}{V}$ - sliding values in the direction y, on the exterior stretch of rails, respectively interior;

$\gamma_{e,i} = \sqrt{\gamma_{e,i_x}^2 + \gamma_{e,i_y}^2}$ - resulted sliding values;

Hertz values

$$(A+B)_{e,i} = \frac{r_{e,i} + \rho_s}{r_{e,i} - \rho_s};$$

$$(A-B)_{e,i} = \frac{\rho_s - r_{e,i}}{r_{e,i} - \rho_s};$$

$$\cos\beta_{e,i} = \frac{|(A-B)_{e,i}|}{(A+B)_{e,i}};$$

where:
r - the radius of the nominal running tread;
ρ_s - the radius of the rail running surface;
ρ_s=0,3 m.

$\beta[^o]$	90	80	70	60	50	40	30	20	10	0
m	1	1,128	1,284	1,486	1,754	2,136	2,731	3,778	6,612	∞
n	1	0,893	0,802	0,717	0,641	0,567	0,493	0,408	0,319	0

One does the interpolation with the polynominal Lagrange through three points, having the β angle value and will obtain the values m and n (on the exterior and interior stretch of rails)

$$g_{e,i} = \frac{a_{e,i}}{b_{e,i}} = \frac{n_{e,i}}{m_{e,i}} \quad ;$$

$a_{e,i}, b_{e,i}$ - semiaxis of contact ellipses on the exterior stretch of rails, respectively interior

g	1	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1
c_{11}	4,3	4,4	4,54	4,72	4,96	5,27	5,74	6,52	7,97	11,92
c_{22}	3,72	3,87	4,06	4,29	4,6	5,02	5,63	6,59	8,43	13,35

Also, through the interpolation with the polynominal Lagrange through 3 points are obtained c_{11} and c_{22}.

Interpolation with the polynominal Lagrange

Generally there is:

$$y = \sum_{i=1}^{n}\prod_{j=1}^{n}\frac{(x - x_j)}{(x_i - x_j)} y_i \quad ;$$

For the Lagrange interpolation through 3 points there is:

$$y = \frac{(x-x_2)(x-x_3)}{(x_1-x_2)(x_1-x_3)}y_1 + \frac{(x-x_1)(x-x_3)}{(x_2-x_1)(x_2-x_3)}y_2 + \frac{(x-x_1)(x-x_2)}{(x_3-x_1)(x_3-x_2)}y_3;$$

Pofile constant value

$$K_{e,i} = m_{e,i} \cdot n_{e,i} \left[\frac{3\sqrt{G}(1-\sigma)}{2(A+B)_{e,i}} \right]^{2/3} \quad ;$$

Where:

$\sigma = 0{,}3$ - Poisson value;

G = 840 tf/cm^2 - transversal flexibility mode;

$G \cdot (a \cdot b)_{e,i} = KN_{e,i}^{2/3}$;

$N_{e,i} \cong Q_{0_{e,i}}$ - wheel load;

Decreased coefficient of pseudo-sliding χ

$$\chi_{e,i} = \frac{G \cdot (a \cdot b)_{e,i}}{N} \cdot \frac{c_{11} + c_{22}}{2} \quad ;$$

Friction coefficient μ

$$\mu_{e,i} = 0{,}35 - 0{,}02425 Q_{0_{e,i}} + 0{,}001 Q_{0_{e,i}}^2 \quad ;$$

Friction coefficients with pseudo-sliding

$$\tau_{e,i_x} = \frac{\chi_{e,i} \gamma_{e,i_x}}{\sqrt{1 + \left(\frac{\chi_{e,i} \gamma_{e,i}}{\mu_{e,i}} \right)^2}}$$ - on the exterior stretch of rails;

$$\tau_{e,i_y} = \frac{\chi_{e,i} \gamma_{e,i_y}}{\sqrt{1 + \left(\frac{\chi_{e,i} \gamma_{e,i}}{\mu_{e,i}} \right)^2}}$$ - on the interior stretch of rails;

$$\tau_{e,i} = \sqrt{\tau_{e,i_x}^2 + \tau_{e,i_y}^2}$$ - resultant.

Friction forces at the wheel-rail contact

$T_{e,i_x} = -\tau_{e,i_x} \cdot N_{e,i}$;

$T_{e,i_y} = -\tau_{e,i_y} \cdot N_{e,i}$;

Friction moment in the plane centre casting

$$M_{FC} = D_{mediu} \cdot F_{FCrapodină} = \frac{D_{EC} - D_{IC}}{2} \cdot \mu \cdot \frac{M_{vagon} - 2 \cdot M_{boghiu}}{2}$$

The calculation will be done in 2 cases:

1) without taking into account the friction moment in the centre casting (lubricated centre casting);

2) μ=0.5 - non lubricated centre casting, so with a friction moment M_{FC} applied in the centre casting (actually one considers an increase of the friction coefficient with 0,5 in each case).

Equilibrium equations (of forces and moments) on the bogie generally

One writes the forces and moments equations, taking into account the load transfer, so the differences between the interior and exterior stretch of rails, for these 3 possible cases of placing the bogie in curve: free, secant and chord.

The signs convention is this classic: axis x has the direction of the track centre and the positive sign in the vehicle direction of traffic, axis y has the transversal direction of the track and the positive sign to the exterior of the curve, and the axis z has vertical direction and positive sign down.

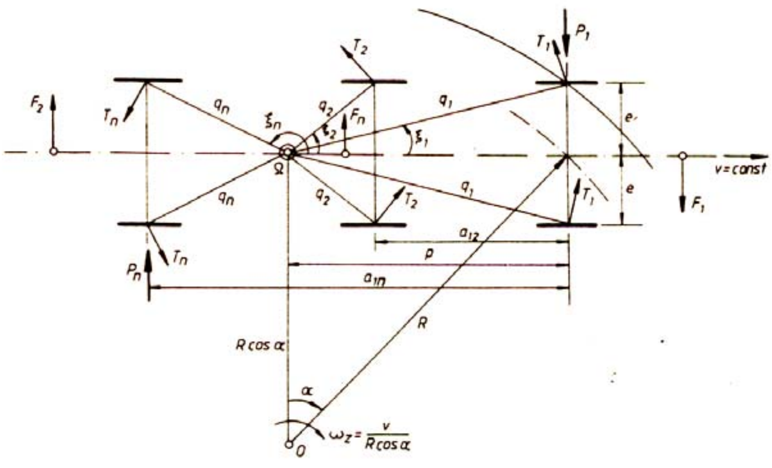

Figure 3. Model for the curve negotiation study of the of the bogie

Free position

$$-P_1+\sum_{i=1}^{n}T_{ey_i}+\sum_{i=1}^{n}T_{iy_i}+F_{cn}+F_v=0 \;;$$

$$M_{FC}-P_1p_1-\sum_{i=1}^{n}T_{ey_i}p_i-\sum_{i=1}^{n}T_{iy_i}p_i+(e-\eta)\sum_{i=1}^{n}T_{ex_i}p_i+(e+\eta)\sum_{i=1}^{n}T_{ix_i}p_i+(F_{cn}+F_v)\left(p_1-\frac{a_{1n}}{2}\right)=0$$

Secant position

$$-P_1+\sum_{i=1}^{n}T_{ey_i}+\sum_{i=1}^{n}T_{iy_i}+F_{cn}+F_v+P_n=0$$

$$M_{FC}-P_1p_1+\sum_{i=1}^{n}T_{ey_i}p_i+\sum_{i=1}^{n}T_{iy_i}p_i+(e-\eta)\sum_{i=1}^{n}T_{ex_i}p_i+(e+\eta)\sum_{i=1}^{n}T_{ix_i}p_i+(F_{cn}+F_v)\left(p_1-\frac{a_{1n}}{2}\right)-P_n(a_{1n}-p_1)=0$$

Chord position

$$-P_1+\sum_{i=1}^{n}T_{ey_i}+\sum_{i=1}^{n}T_{iy_i}+F_{cn}+F_v-P_n=0 \;;$$

$$M_{FC}-P_1p_1+\sum_{i=1}^{n}T_{ey_i}p_i+\sum_{i=1}^{n}T_{iy_i}p_i+(e-\eta)\sum_{i=1}^{n}T_{ex_i}p_i+(e+\eta)\sum_{i=1}^{n}T_{ix_i}p_i+(F_{cn}+F_v)\left(p_1-\frac{a_{1n}}{2}\right)+P_n(a_{1n}-p_1)=0$$

The unknowns are the polar distance p_1 and the guiding forces P_1, respectively P_n for the secant and chord positions. One has only two equations, so the system can not be directly solved in the cases of secant and chord positions. But in the free position one has no guiding force at the last axle, so the system can be solved in this case. This system has the particularity that although the friction forces are known for each position occupied by the bogie through the polar distance that comes into the calculation formula, has no linear variation, being used the interpolation during the calculation of the Hertz coefficients. That means that only one approximate solved method can be found. A solved way is this graphic graphic, with the curves M D Z. Another way is given by the numerical methods for calculation, approximate way at witch is established the desired precision , and then, through successive iterations is determined the solution. In this application was used the bisection method or the interval reducing to one half method.

So, solving the system of free position one obtains the value of the polar distance.

After that, one will discuss:

- if $p_c<p<p_s$ results that the bogie in free position, so one can establish directly P_1 and p_1.
- if $p<p_c$, results that the bogie is in chord position and replacing in the system of the chord position the value of the polar distance $p=p_c$, result the guiding forces P_1 and P_n.
- if $p>p_s$, results that the bogie is in secant position and replacing in the system of the secant position the value of the polar distance $p=p_s$, result the guiding forces P_1 and P_n

Guiding force: $Y=P_1-T_{ey_1}-T_{iy_1}$;

Maximum running speed in curve:

$$V_{\max}=\sqrt{\frac{R}{11{,}8}(h+I)} \;;$$

Total uncompensated Centrifugal force distributed on the bogie will be

$$F_{cn}=F_{cn_{boghiu}}+F_{cn_{cutie}}=\left(\frac{V^2}{3{,}6^2\cdot R}-g\frac{h}{2e}\right)\left[G_{s_{boghiu}}+\frac{G_{cs}}{2}(1+S)\right]$$

S – vehicle flexibility coefficient. One considers S=0,3

The force given by the pressure of the wind, distributed on the bogie:

$$F_v = \frac{F_{cv}}{2} + F_{bv} = \frac{S_c}{2}W + S_b W \quad ;$$

W - specific pressure of the wind ;

Load transfer: $\Delta Q = \dfrac{F_{cn}h_c + F_v h_v}{2e}$;

In this study one considers the tank wagon on the bogies type Diamond CSI, no. 82535765377-6, involved in the investigated derailment , occurred on the 22nd of February 2007 on the switch 47A in the railway station Dej Triaj, with the next characteristics:

- bogies type Diamond CSI with the pitch of 1,80 m;
- the exterior diameter of the centre casting D_{EC}=0,308 m
- the interior diameter of the centre casting DI_C=0,073 m
- the medium diameter of the centre casting D_{medium}=0,1905 m
- the radius of the nominal running tread r=0,6 m
- wagon tare =34,1 t
- load limit of the wagon=48,9 t
- total weight of the wagon M_{wagon}=83t
- load on wheel Q_0=10,375 t
- bogie weight M_{bogie}= 4,6 t
- axle weight M_{axle}= 1,1 t
- weight of the bogie lateral frame m $_{lateral\ frame}$ =0,7 t
- sprung weight of the wagon M_{body} = M_{wago} - 2xM_{bogie} = 83 – 2x4,6=73,8 t
- lateral surface of the (tank wagon) body=30m^2;

The data resulted from the commission measurements at the switch 47 A in the railway station Dej Triaj

- gauge on curve (measured in point. 2) 1435+25=1460mm
- R=190m

The calculation was done in these 2 cases:

1) **without taking into account the friction moment in the centre casting (lubricated centre casting).**

The following values resulted:

- maximum running speed in a curve with a radius of 190m=50,76 km/h; the calculation speed (according to the regulations for the running on switches) = 30km/h
- centrifugal force on the bogie = 3,85 kN
- force given by the wind pressure =7,90 kN
- guiding force at the axle 1 = P_1 = -45,58 kN
- guidance force of the axle 1:
- load on the wheel from the exterior of the curve at the axle 1
- safety coefficient against the derailment

2) **μ=0,5 – non lubricated centre casting, so with friction moment M_{FC} applied to the centre casting (actually is considered an increase of the friction value with 0,5 in this case**).

The following values resulted:

- maximum running speed in a curve with the radius of 190m=50,76 km/h; the calculation speed (according to the regulations for the running on switches) = 30km/h
- centrifugal force on the bogie = 3,85 kN
- force given by the wind pressure = 7,90 kN
- guiding force at the axle 1 = P_1 = -48,33 kN
- guiding force of the axle 1:
- load on the wheel from the exterior of the curve at the axle 1;
- safety coefficient against the derailment

The conclusion is that between the lubricated centre casting case and this of non lubricated one, the leading force increases with 6,03 % and the safety coefficient against the derailment (report Y/Q) increases with 0,02, that allows to consider that the non lubrication of the centre casting is a favoring factor and not a direct cause of the wagon derailment.

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ИЗСЛЕДВАНЕ НА ПОВЕДЕНИЕТО ОТ ГЛЕДНА ТОЧКА НА БЕЗОПАСНОСТТА СРЕЩУ ДЕРАЙЛИРАНЕТО В ЗАВИСИМОСТ ОТ УСУКВАНЕТО НА ЦЕНТЪРА НА ОТЛИВКАТА ПРИ ЖЕЛЕЗОПЪТНИ ВОЗИЛА (ОТЛИВКА СЪС СМАЗАНА РАВНИНА НА ЦЕНТЪРА И СЪОТВЕТНО НЕСМАЗАНА)

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РУМЪНИЯ

Резюме: *Докладът разглежда различията в момента на усукване в центъра на отливката на железопътните возила при движение в крива. Целта на изследването е да се установи влиянието на смазаната и съответно несмазана повърхност на центъра на отливката върху отчетеното съотношение Y/Q (стойността на безопасност срещу дерайлиране).*

Ключови думи: *железопътно возило, момент на усукване, съотношение Y/Q, дерайлиране.*