INFLUENCE OF ANTICLIMBING DEVICE ON THE VARIATION OF LOADS ON WHEELS IN DIESEL ELECTRIC 4000 HP

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Dispozitivul anticabraj introduce sarcini suplimentare pe roțile osiilor locomotivelor. In lucrare se prezinta variatia acestor sarcini, funcție de datele constructive ale locomotivei Diesel electrice de 4000 CP.

The anticlimbing device inserts additional tasks over axles' wheels of locomotives. In this study, the variation of these tasks depending on the construction data of Diesel-electric locomotive of 4000 HP is presented.

Keywords : the anticlimbing device

1. Introduction

Axles' individual action system introduces in mounted axle – suspense - bogie frame ensemble, forces and moments that determine a redistribution of tasks between the axles of the bogie.

2. Forces introduced by the anticlimbing device

At the box the reactions from the anticlimbing device act (fig. 1.a). From the equations of equilibrium of the box one can calculate the reactions $\Delta C_1$and ΔC_2 from vertical fulcrum points of the drop box on bogies:

$$\Delta C_1 = N_1 * \frac{a_1 + a_L}{a_L} + N_2 * \frac{a_2}{a_L} \tag{1}$$

$$\Delta C_2 = N_2 * \frac{a_L - a_2}{a_L} - N_1 * \frac{a_1}{a_L} \tag{2}$$

where : N_1 – force on the first bogie to pivot distance p_1; N_2 - force on the second bogie to pivot distance p_2

The forces ΔC_1 and ΔC_2 load bogies through their components $\frac{\Delta C_1}{2}$ and

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$\frac{\Delta C_2}{2}$ from points 7, 8 and 10, 11 of vertical fulcrum of the box on bogies.

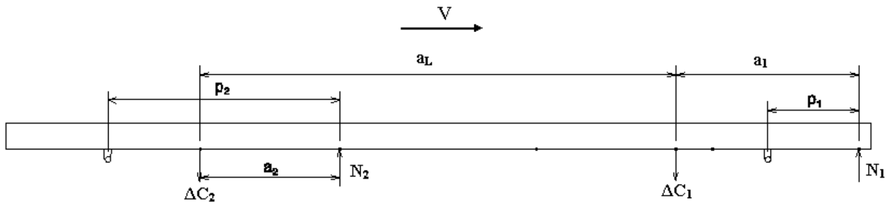

Fig. 1.a

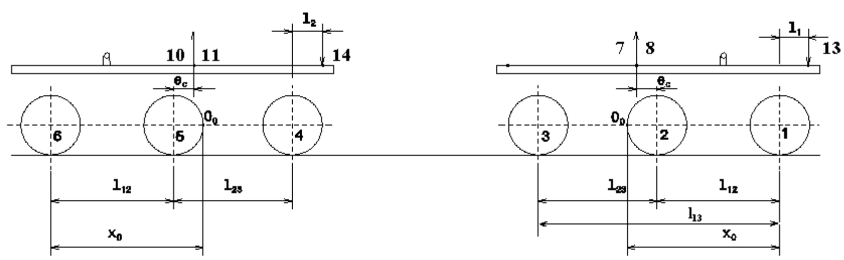

Fig. 1.b

2. The reduction torsion of loads introduced by device

Coordinates of the points of application of loads introduced by the anticlimbing device (Fig. 1.b) are given in Table 1.

Bringing back matrices $[r_0]$ of loads in the oscillation center, with specifications from Table 1 are:

Table 1

Bringing back matrices $[r_0]$ of loads in the oscillation center

Point no:	Coordinates of point where load is applied			Components of loads		
	x	y	z	P_x	P_z	C_y
7	x_o-l_{12}-e_c	b_0	h_7	0	$\frac{\Delta C_1}{2}$	0
8	x_o-l_{12}-e_c	$-b_0$	h_8	0	$\frac{\Delta C_1}{2}$	0
10	-(x_o-l_{12}-e_c)	b_0	h_{10}	0	$\frac{\Delta C_2}{2}$	0

11	$-(x_o-1_{12}-e_c)$	$-b_0$	h_{11}	0	$\frac{\Delta C_2}{2}$	0
13	x_o+1_1	0	h_{13}	0	$-N_1$	0
14	$-(x_o-1_{13}-1_2)$	0	h_{14}	0	$-N_2$	0

$$[r_0]_7 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & b_0 & 0 \\ h_7 & -(x_0 - 1_{12} - e_c) & 1 \end{bmatrix} \qquad [r_0]_8 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -b_0 & 0 \\ h_8 & -(x_0 - 1_{12} - e_c) & 1 \end{bmatrix}$$

$$[r_0]_{10} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & b_0 & 0 \\ h_{10} & -(x_0 - 1_{12} - e_c) & 1 \end{bmatrix} \qquad [r_0]_{11} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & b_0 & 0 \\ h_{11} & (x_0 - 1_{12} - e_c) & 1 \end{bmatrix}$$

$$[r_0]_{13} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ h_{13} & -(x_0 - 1_1) & 1 \end{bmatrix} \quad [r_0]_{14} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ h_{14} & (x_0 - 1_{13} - 1_2) & 1 \end{bmatrix}$$

The values of loads introduced on the bogies by the anticlimbing device are composed of:

$$\{P_7\}_N = \begin{bmatrix} 0 \\ \frac{\Delta C_1}{2} \\ 0 \end{bmatrix} ; \qquad \{P_8\}_N = \begin{bmatrix} 0 \\ \frac{\Delta C_1}{2} \\ 0 \end{bmatrix} ; \qquad \{P_{10}\}_N = \begin{bmatrix} 0 \\ \frac{\Delta C_2}{2} \\ 0 \end{bmatrix}$$

$$\{P_{11}\}_N = \begin{bmatrix} 0 \\ \frac{\Delta C_2}{2} \\ 0 \end{bmatrix} ; \qquad \{P_{13}\}_N = \begin{bmatrix} 0 \\ -N_1 \\ 0 \end{bmatrix} ; \qquad \{P_{14}\}_N = \begin{bmatrix} 0 \\ -N_2 \\ 0 \end{bmatrix}$$

Bringing back torsion in O_0 of these loads are:

For bogie I

$$\{T_{0I}\}_N = [r_0]_7 * \{P_7\}_N + [r_0]_8 * \{P_8\}_N + [r_0]_{13} * \{P_{13}\}_N$$

$$\{T_{0I}\}_N = \begin{bmatrix} 0 & 1 & 0 \\ 0 & b_0 & 0 \\ h_7 & -(x_0 - 1_{12} - e_c) & 1 \end{bmatrix} \begin{bmatrix} 0 \\ \frac{\Delta C_1}{2} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 & 1 & 0 \\ 0 & -b_0 & 0 \\ h_8 & -(x_0 - 1_{12} - e_c) & 1 \end{bmatrix} \begin{bmatrix} 0 \\ \frac{\Delta C_1}{2} \\ 0 \end{bmatrix} +$$

$$+ \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ h_{13} & -(x_0 + l_1) & 1 \end{bmatrix} \begin{bmatrix} 0 \\ -N_1 \\ 0 \end{bmatrix}$$

$$\{T_{0I}\}_N = \begin{bmatrix} -N_1 + \Delta C_1 \\ 0 \\ (x_0 + 1_1)N_1 - (x_0 - 1_{12} - e_c)\Delta C_1 \end{bmatrix} \tag{3}$$

For bogie II

$$\{T_{0II}\}_N = [r_0]_{10} * \{P_{10}\}_N + [r_0]_{11} * \{P_{11}\}_N + [r_0]_{14} * \{P_{14}\}_N$$

$$\{T_{0II}\}_N = \begin{bmatrix} 0 & 1 & 0 \\ 0 & b_0 & 0 \\ h_{10} & (x_0 - 1_{12} - e_c) & 1 \end{bmatrix} \begin{bmatrix} 0 \\ \dfrac{\Delta C_2}{2} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 & 1 & 0 \\ 0 & -b_0 & 0 \\ h_{11} & (x_0 - 1_{12} - e_c) & 1 \end{bmatrix} \begin{bmatrix} 0 \\ \dfrac{\Delta C_2}{2} \\ 0 \end{bmatrix}$$

$$+ \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ h_{14} & (x_0 - 1_{13} - 1_2) & 1 \end{bmatrix} \begin{bmatrix} 0 \\ -N_2 \\ 0 \end{bmatrix}$$

$$\{T_{0II}\}_N = \begin{bmatrix} -N_2 + \Delta C_2 \\ 0 \\ -(x_0 + 1_{13} - 1_2)N_2 + (x_0 - 1_{12} - e_c)\Delta C_2 \end{bmatrix} \tag{4}$$

Considering expression of x_0 given by relation (5).

$$x_o = \frac{1_{12} + 1_{13}}{3}$$

$$x_o = \frac{1950 + 4100}{3} = 2016{,}66mm \tag{5}$$

also by relations (1) and (2), result: for bogie I:

$$\{T_{0I}\}_N = \begin{bmatrix} \dfrac{a_1}{a_L}N_1 + \dfrac{a_2}{a_L}N_2 \\ 0 \\ N_1(1_{12} + 1_1 + e_c) - \left(\dfrac{1_{23} - 1_{12}}{3} - e_c\right)\left(\dfrac{a_1}{a_L} * N_1 + \dfrac{a_2}{a_L} * N_2\right) \end{bmatrix} \tag{6}$$

for bogie II:

$$\{T_{0II}\}_N = \begin{bmatrix} -\left(\dfrac{a_1}{a_L} * N_1 + \dfrac{a_2}{a_L} * N_2\right) \\ 0 \\ N_2(1_{23} + 1_2 - e_c) - \left(\dfrac{1_{23} - 1_{12}}{3} - e_c\right)\left(\dfrac{a_1}{a_L} * N_1 + \dfrac{a_2}{a_L} * N_2\right) \end{bmatrix} \tag{7}$$

3.-Variation of loads on wheels determined by anticlimbing device

Loads introduced in ellipses by anticlimbing device are:
For bogie I:

$$\{P_s^{'}\}_I = [A]_I * \quad \{T_{0I}\}_N = \begin{bmatrix} \frac{1}{3} & -\frac{1}{3b_0} & -\frac{1}{l_{13}+l_{23}} \\ \frac{1}{3} & \frac{1}{3b_0} & -\frac{1}{l_{13}+l_{23}} \\ \frac{1}{6} & -\frac{1}{6b_0} & +\frac{1}{l_{13}+l_{23}} \\ \frac{1}{6} & \frac{1}{6b_0} & +\frac{1}{l_{13}+l_{23}} \end{bmatrix} \begin{bmatrix} P_{zoI} \\ M_{xoI} \\ M_{yoI} \end{bmatrix}_N = \begin{bmatrix} P_{a1}^{'} \\ P_{a2}^{'} \\ P_{31s}^{'} \\ P_{32s}^{'} \end{bmatrix}_N \qquad (8)$$

Performing calculations and taking into account the relation (6) results:

$$P_{a1}^{'} = \frac{l_{23}-e_c}{l_{13}+l_{23}}\left(\frac{a_1}{a_L} * N_1 + \frac{a_2}{a_L} * N_2\right) - \frac{l_{12}+l_1+e_c}{l_{13}+l_{23}} * N_1$$

$$P_{a2}^{'} = P_{a1}^{'}$$

$$P_{31s}^{'} = \frac{1}{2} * \frac{l_{12}+2e_c}{l_{13}+l_{23}}\left(\frac{a_1}{a_L} * N_1 + \frac{a_2}{a_L} * N_2\right) + \frac{l_{12}+l_1+e_c}{l_{13}+l_{23}} * N_1$$

$$P_{32s}^{'} = P_{31s}^{'}$$

For bogie II:

$$\{P_s^{'}\}_{II} = [A]_{II} * \{T_{0II}\} = \begin{bmatrix} \frac{1}{6} & -\frac{1}{6b_0} & -\frac{1}{l_{13}+l_{23}} \\ \frac{1}{6} & \frac{1}{6b_0} & -\frac{1}{l_{13}+l_{23}} \\ \frac{1}{3} & -\frac{1}{3b_0} & +\frac{1}{l_{13}+l_{23}} \\ \frac{1}{3} & \frac{1}{3b_0} & +\frac{1}{l_{13}+l_{23}} \end{bmatrix} \begin{bmatrix} P_{zoII} \\ M_{xoII} \\ M_{yoII} \end{bmatrix}_N = \begin{bmatrix} P_{41s}^{'} \\ P_{42s}^{'} \\ P_{f1}^{'} \\ P_{f2}^{'} \end{bmatrix}_N \qquad (9)$$

$$P_{41s}^{'} = -\frac{1}{2} * \frac{l_{12}+2e_c}{l_{13}+l_{23}}\left(\frac{a_1}{a_L} * N_1 + \frac{a_2}{a_L} * N_2\right) - \frac{l_{12}+l_2-e_c}{l_{13}+l_{23}} * N_2$$

$$P_{42s}^{'} = P_{41s}^{'}$$

$$P_{f1}^{'} = \frac{l_{23}-e_c}{l_{13}+l_{23}}\left(\frac{a_1}{a_L} * N_1 + \frac{a_2}{a_L} * N_2\right) + \frac{l_{23}+l_2-e_c}{l_{13}+l_{23}} * N_2$$

From the distribution of these forces on the axles' spindles results additional loads on axles' wheels given by anticlimbing device:

For bogie I:

$$\left\{P'_{ij}\right\}_I=\begin{bmatrix}P'_{11}\\P'_{12}\\P'_{21}\\P'_{22}\\P'_{31}\\P'_{32}\end{bmatrix}=\begin{bmatrix}\frac{P'_{a1}}{2}\\\frac{P'_{a2}}{2}\\\frac{P'_{a1}}{2}\\\frac{P'_{a2}}{2}\\P'_{31s}\\P'_{32s}\end{bmatrix}\tag{10}$$

For bogie II:

$$\left\{P'_{ij}\right\}_{II}=\begin{bmatrix}P'_{41}\\P'_{42}\\P'_{51}\\P'_{52}\\P'_{61}\\P'_{62}\end{bmatrix}=\begin{bmatrix}P'_{41s}\\P'_{42s}\\\frac{P'_{f1}}{2}\\\frac{P'_{f2}}{2}\\\frac{P'_{f1}}{2}\\\frac{P'_{f2}}{2}\end{bmatrix}\tag{11}$$

The constructive data of the analyzed locomotive are presented below:

$a_1=2725\quad mm$; $a_2=2915\quad mm$; $l_1=720\quad mm$

$l_2=820\quad mm$; $N_1=5740\quad daN$; $N_2=5410\quad daN$

The vector of additional loads wich are introduced on the wheels by the anticlimbing device is :

For bogie I:

$$\left\{P'_{ij}\right\}_I=\begin{bmatrix}-785 & daN\\-785 & daN\\-785 & daN\\-785 & daN\\2961 & daN\\2961 & daN\end{bmatrix}\tag{12}$$

For bogie II:

$$\left\{P'_{ij}\right\}_{II} = \begin{bmatrix} -2981{,}7 & daN \\ -2981{,}7 & daN \\ +795{,}3 & daN \\ +795{,}3 & daN \\ +795{,}3 & daN \\ +795{,}3 & daN \end{bmatrix} \tag{13}$$

4. Variation of loads on wheels at anticlimbing device locomotive

Variation of loads on wheels at anticlimbing device locomotive results from the relations:

$$\left\{P_{ij}\right\}_{I} = \begin{bmatrix} P_{11} \\ P_{12} \\ P_{21} \\ P_{22} \\ P_{31} \\ P_{32} \end{bmatrix} = \begin{bmatrix} \frac{P_{a1}+P_0}{2} \\ \frac{P_{a2}+P_0}{2} \\ \frac{P_{a1}+P_0}{2} \\ \frac{P_{a2}+P_0}{2} \\ P_{31s}-\frac{P_v}{2} \\ P_{32s}-\frac{P_v}{2} \end{bmatrix} = \begin{bmatrix} c_{11}*F_0 \\ c_{12}*F_0 \\ c_{21}*F_0 \\ c_{22}*F_0 \\ c_{31}*F_0 \\ c_{32}*F_0 \end{bmatrix} \quad \text{and} \quad \left\{P'_{ij}\right\}_{I} = \begin{bmatrix} P'_{11} \\ P'_{12} \\ P'_{21} \\ P'_{22} \\ P'_{31} \\ P'_{32} \end{bmatrix} = \begin{bmatrix} \frac{P'_{a1}}{2} \\ \frac{P'_{a2}}{2} \\ \frac{P'_{a1}}{2} \\ \frac{P'_{a2}}{2} \\ P'_{31s} \\ P'_{32s} \end{bmatrix} \quad \text{and}$$

respectively

$$\left\{P_{ij}\right\}_{II} = \begin{bmatrix} P_{41} \\ P_{42} \\ P_{51} \\ P_{52} \\ P_{61} \\ P_{62} \end{bmatrix} = \begin{bmatrix} P_{41s}+\frac{P_v}{2} \\ P_{42s}+\frac{P_v}{2} \\ \frac{P_{f1}}{2}-\frac{P_v}{2} \\ \frac{P_{f2}}{2}-\frac{P_v}{2} \\ \frac{P_{f1}}{2}-\frac{P_v}{2} \\ \frac{P_{f2}}{2}-\frac{P_v}{2} \end{bmatrix} = \begin{bmatrix} c_{41}*F_0 \\ c_{42}*F_0 \\ c_{51}*F_0 \\ c_{52}*F_0 \\ c_{61}*F_0 \\ c_{62}*F_0 \end{bmatrix} \text{ and } \left\{P'_{ij}\right\}_{II} = \begin{bmatrix} P'_{41} \\ P'_{42} \\ P'_{51} \\ P'_{52} \\ P'_{61} \\ P'_{62} \end{bmatrix} = \begin{bmatrix} P'_{41s} \\ P'_{42s} \\ \frac{P'_{f1}}{2} \\ \frac{P'_{f2}}{2} \\ \frac{P'_{f1}}{2} \\ \frac{P'_{f2}}{2} \end{bmatrix}$$

In this way:
For bogie I:
$$\{\Delta Q_{ij}\}_I = \{P_{ij}\}_I + \{P_{ij}^{'}\}_I$$

$$\{\Delta Q_{ii}\}_I = \begin{bmatrix} \Delta Q_{11} \\ \Delta Q_{12} \\ \Delta Q_{21} \\ \Delta Q_{22} \\ \Delta Q_{31} \\ \Delta Q_{32} \end{bmatrix} = \begin{bmatrix} P_{11} + P_{11}^{'} \\ P_{12} + P_{12}^{'} \\ P_{21} + P_{21}^{'} \\ P_{22} + P_{22}^{'} \\ P_{31} + P_{31}^{'} \\ P_{32} + P_{32}^{'} \end{bmatrix} = \begin{bmatrix} c_{11} * F_0 & + \dfrac{P_{a1}^{'}}{2} \\ c_{12} * F_0 & + \dfrac{P_{a2}^{'}}{2} \\ c_{21} * F_0 & + \dfrac{P_{a1}^{'}}{2} \\ c_{22} * F_0 & + \dfrac{P_{a2}^{'}}{2} \\ c_{31} * F_0 & + P_{31s}^{'} \\ c_{32} * F_0 & + P_{32s}^{'} \end{bmatrix}$$

Replacing the constructive data of the locomotive, it results:

$$\{\Delta Q_{ii}\}_I = \begin{bmatrix} +0,235398 * F_0 & -785 & daN \\ +0,235398 * F_0 & -785 & daN \\ +0,235398 * F_0 & -785 & daN \\ +0,235398 * F_0 & -785 & daN \\ -0,441567 * F_0 & +2961 & daN \\ -0,441567 * F_0 & +2961 & daN \end{bmatrix} \tag{14}$$

For bogie II:

$$\{\Delta Q_{ii}\}_{II} = \begin{bmatrix} \Delta Q_{41} \\ \Delta Q_{42} \\ \Delta Q_{51} \\ \Delta Q_{52} \\ \Delta Q_{61} \\ \Delta Q_{62} \end{bmatrix} = \begin{bmatrix} P_{41} + P_{41}^{'} \\ P_{42} + P_{42}^{'} \\ P_{51} + P_{51}^{'} \\ P_{52} + P_{52}^{'} \\ P_{61} + P_{61}^{'} \\ P_{62} + P_{62}^{'} \end{bmatrix} = \begin{bmatrix} c_{41} * F_0 & + P_{41}^{'} \\ c_{42} * F_0 & + P_{42}^{'} \\ c_{51} * F_0 & + \dfrac{P_{f1}^{'}}{2} \\ c_{52} * F_0 & + \dfrac{P_{f2}^{'}}{2} \\ c_{61} * F_0 & + \dfrac{P_{f1}^{'}}{2} \\ c_{62} * F_0 & + \dfrac{P_{f2}^{'}}{2} \end{bmatrix}$$

$$\left\{\Delta Q_{ii}\right\}_{II} = \begin{bmatrix} +0{,}441567 * F_0 & -2981{,}7 & daN \\ +0{,}441567 * F_0 & -2981{,}7 & daN \\ -0{,}235398 * F_0 & +795{,}3 & daN \\ -0{,}235398 * F_0 & +795{,}3 & daN \\ -0{,}235398 * F_0 & +795{,}3 & daN \\ -0{,}235398 * F_0 & +795{,}3 & daN \end{bmatrix} \tag{15}$$

Variation of loads on wheels is given in the diagram from Fig. 2.

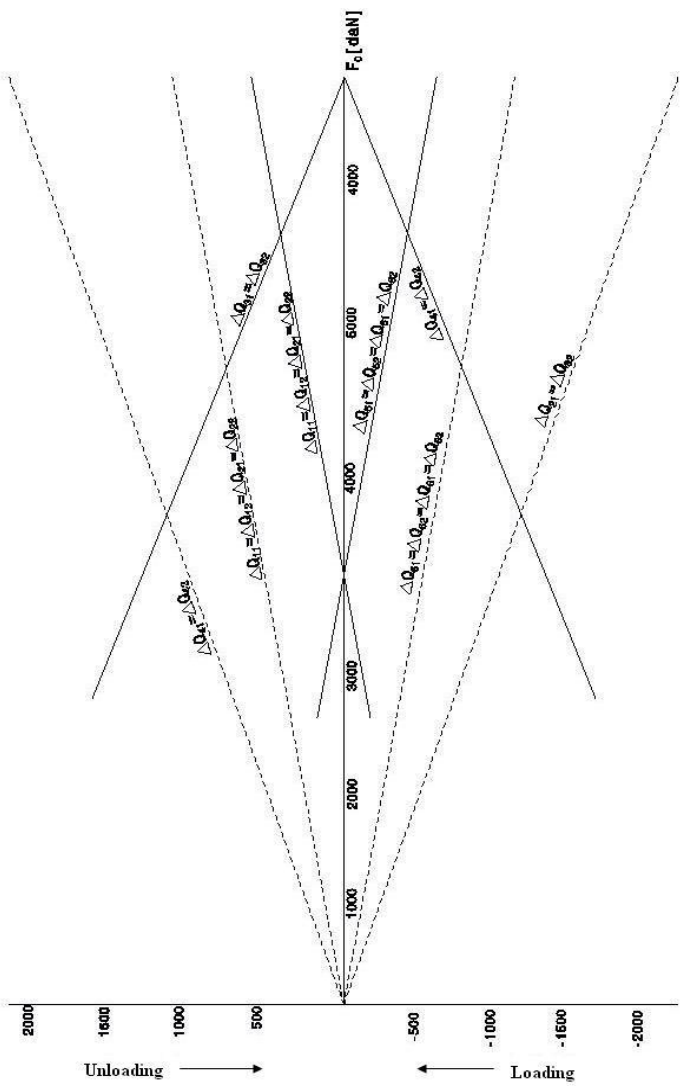

Fig. 2 Variation of loads on wheels

Variation of loads on wheels at anticlimbing device locomotive is represented with continous line and variation of loads on wheels at locomotive without anticlimbing device is represented with dashed line.

5. Conclusions

The anticlimbing device loads bogies in order to produce a decrease of discharge axles 1 and 2 of first bogie, so that the first bogie's II axle (axle number 4 of locomotive).

Consequently, towards the direction of movement in Fig. 1.a, the anticlimbing device introduces a force N_1 on the first bogie at distance p_1 towards the pivotal, distance l_1 towards the first axle and N_2 on II bogie at distance p_2 towards the pivotal, distance l_2 towards axle number 4.

REFERENCES

[1] *I .Sebeşan, B.Ţăruş, C.Crăciun, S. Arsene,* Studiul variaţilor sarcinii pe osiile locomotivei 060 EA (Study the multiple pregnancy locomotive axles 060 AE*),* volumul „Simpozionul Naţional de Material Rulant de Cale Ferată (The National Symposium of Railway Rolling Stock), 2006", Editura MatrixRom, Bucureşti, 2007.

[2] *I. Sebeşan, C.Tudorache,M.Dumitriu, M.Sebeşan,* On some evaluation problems of the dynamic performances of locomotives referring to LDH 1250 CP, Academic Journal Mechanics, Transport, Communications, issue 1, 2008, Bulgaria .

[3] *I.Sebeşan, B.Ţăruş, C.Crăciun, S. Arsene,* Studiul variaţilor sarcinii pe osiile locomotivei 060 EA, (Study the multiple pregnancy locomotive axles 060 AE) volumul „Simpozionul Naţional de Material Rulant de Cale Ferată (The National Symposium of Railway Rolling Stock), 2006", Editura MatrixRom, Bucureşti, 2007.

[4]"Dimensioning the rubber suspension elements for an electric traction motor", The First International Railway Vehicles Symposium, U.P.B., Chair of Railway Vehicles, Bucharest, 25-26 November 2005.

[5] *I. Sebeşan, G. Dumitru,* Studiul comportamentului vibratoriu al sistemelor de antrenare a osiilor motoare ale vehiculelor feroviare pentru mari viteze,(Study of vibrational behavior of the drive axle systems of rail vehicles for engine speeds) volumul „Simpozionul Naţional de Material Rulant de Cale Ferată - 2003", Editura MatrixRom, Bucureşti, 2004.

[6] *I. Sebeşan, D. Hanganu*, Proiectarea suspensiilor pentru vehicule pe şine,(Suspension design for rail vehicles) Bucureşti, Editura Tehnică, 1993.

[7] *I.Sebeşan*, Dinamica vehiculelor de cale ferata (Railway vehicles dynamics), Editia. I, Editura Tehnică, 1995, Dinamica vehiculelor de cale ferată (Railway vehicles dynamics), Editia II, Editura Tehnică, 1996 (lucrare distinsă cu Premiul Aurel Vlaicu al Academiei Române, 1997).

[8] *I. Sebeşan, I. Copaci*, Teoria sistemelor elastice la vehiculele feroviare,(Theory of elastic systems in railway vehicles), Editura MatrixRom, 2008.