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ANALYSIS OF CARRYING STRUCTURE INFLUENTIAL PARAMETERS ON BOND FUNCTION OF REVOLVING AND NON - REVOLVING PARTS

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Summary: *By choosing the geometric values of radial-axial bearing support structure, we can influence not only on defining the necessary stiffness of carrying structure of construction and transport mechanization, but also on functionality and reliability of radial-axial bearing. Long life and functionality of these bearings greatly depends on carrying structure stiffness and bearing support surface. The paper shows the analysis of carrying structure shape and geometry influence on proper functioning of revolving and non-revolving machine parts bond. This has been done through systematization of theoretical and experimental research results of realized solutions in order to eliminate the influence of terrain unevenness on radial-axial bearing support surface deplanation.*

Keywords: *radial-axial bearing, carrying frame, mechanization, deplanation, structure.*

1. INTRODUCTION

During the excavators' operation, due to terrain unevenness, it is not possible to make full contact between caterpillar running gear and support surface, so the carrying structure torsion can occur. The excavator carrying structure torsion causes the structure support surface deplanation for radial-axial bearing bond. Research results of load transfer from revolving to bond with non-revolving part should define the influential parameters whose values influence the proper function of the mentioned bond.
Structures diversity of portal cranes on the one hand, as well as construction machines with revolving parts on the other, is conditioned firstly by various demands and needs that are required from construction and transport mechanization, then by experimental researches results and also by effort to achieve optimal solutions. Considering the demands and needs, there are two solutions of carrying structure: type "H" and type "X" (Fig. 1).

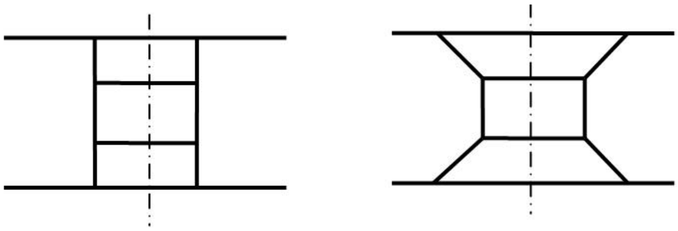

Figure 1: Structure solutions types

The aim of analyses of construction and transport mechanization carrying structures is to achieve better adjustability of machine to the terrain, that is, to make contact of all wheels with the terrain, while keeping the torsion of radial-axial bearing support surface within the boundaries that anable normal function of revolving and non-revolving parts connection. In case the terrain deviates from ideal straight line (Fig. 2), and if it occurred through manufacturing h_k, the machine is supported in 3 points and there exists a gap between the fourth support and the terrain $\Delta = h_0 + h_k$. If the machine is exposed to increasing vertical load, the gap would decrease due to structure and ground deformation, so that after certain weight is achieved, the machine would have four support points again.

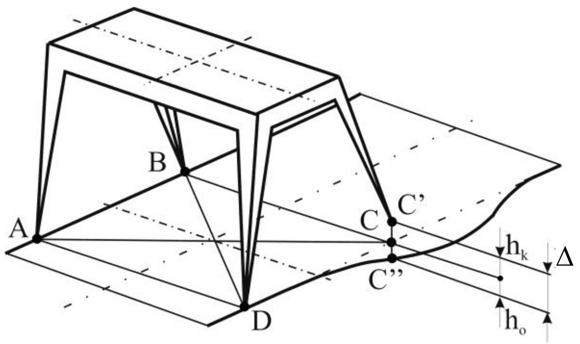

Figure 2: Terrain deviation

Occurance of structure and terrain deviations can be precisely evaluated if the support force is expressed as follows:

$$R = R_k \pm C\Delta \tag{1}$$

R_k - support reactions previously determined
C - Machine and terrain equivalent stiffness
$\Delta = h_k + h_0$ – gap between support and terrain
Sign (-) is taken for supports that lie on diagonal with the gap while sign (+) is taken for the other two supports.

2. MODEL DEFINITION

Analytical determination of dependence between stiffness and support structure geometric parameters relations would ensure finding the values of the structure geometric parameters that would provide good adjusting to the terrain and proper radial-axial bearing bond function. Assuming that one of the support points (support C, Fig. 2) lowers for value Δ, the basic system is formed by putting in the unknown force X_1 in support C, and instead of removed restraints the unknown forces X_i *(i=2,3,...,7)*.
Carrying structure types "H" and "X" are presented as frames (Fig. 3). As a general method for solving the static undefined systems, the force method is used.

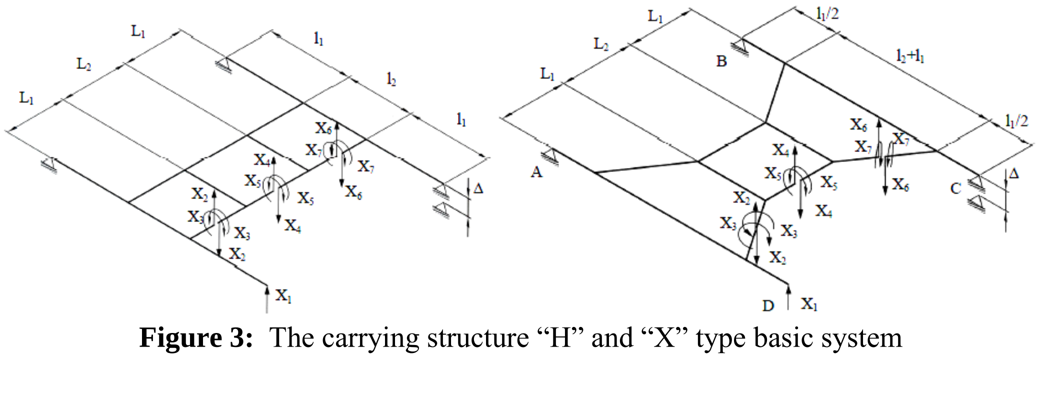

Figure 3: The carrying structure "H" and "X" type basic system

2.1. Solving the given problem

By solving the canonic equation system, along with previous determination of influential coefficients, the unknown force X_1 is obtained, that is, additional force in support as a result of elastic structure deformation. So, knowing the support deformation value Δ, we can determine the structure stiffness for both types (“H” and “X” types).
Canonic equations for obtaining the unknown parameters values have the general form as follows:

$$\sum_{j=1}^{10} \delta_{ij} \cdot X_j + \Delta_i = 0 \quad ; \quad i = 1,...,7 \qquad \textbf{(2)}$$

where:

δ_{ij} - deformation at point i due to unit load $\overline{X}_j = 1$ acting;

X_j - real value of the unknown parameter;

Δ_i - deformation at point i due to external load acting.

Matrix form of canonic equations is:

$$\begin{bmatrix} \delta_{11} & \delta_{12} & \delta_{13} & \delta_{14} & \delta_{15} & \delta_{16} & \delta_{17} \\ \delta_{21} & \delta_{22} & \delta_{23} & \delta_{24} & \delta_{25} & \delta_{26} & \delta_{27} \\ \delta_{31} & \delta_{32} & \delta_{33} & \delta_{34} & \delta_{35} & \delta_{36} & \delta_{37} \\ \delta_{41} & \delta_{42} & \delta_{43} & \delta_{44} & \delta_{45} & \delta_{46} & \delta_{47} \\ \delta_{51} & \delta_{52} & \delta_{53} & \delta_{54} & \delta_{55} & \delta_{56} & \delta_{57} \\ \delta_{61} & \delta_{62} & \delta_{63} & \delta_{64} & \delta_{65} & \delta_{66} & \delta_{67} \\ \delta_{71} & \delta_{72} & \delta_{73} & \delta_{74} & \delta_{75} & \delta_{76} & \delta_{77} \end{bmatrix} \cdot \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \end{Bmatrix} = \begin{Bmatrix} -\Delta_1 \\ -\Delta_2 \\ -\Delta_3 \\ -\Delta_4 \\ -\Delta_5 \\ -\Delta_6 \\ -\Delta_7 \end{Bmatrix} \qquad \textbf{(3)}$$

Vereschagin method was used for solving the problem, where the influence of shear and tension is neglected. The calculation of the influential coefficients for both types of carrying structures is done by forming the diagrams of bending and torsion moments for external load and unit load. Some of diagrams for unit loads $\overline{X}_j = 1$, where j=1,...,7, for both structure types are shown in Fig. 4.

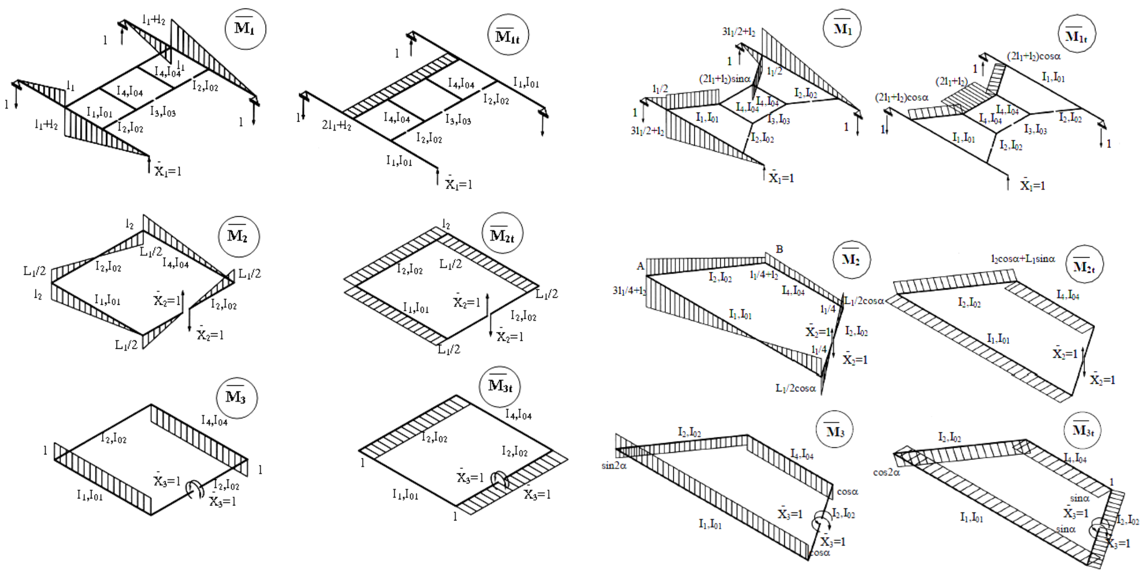

Figure 4: Some of diagrams for unit loads: a) “H” type and b) “X” type

For easier comparative analysis of these two types, i.e., generalization of expression for influential coefficients, it is necessary to establish the relation between bending and torsion stiffness of boxlike cross section. The method of determining the relation between bending and torsion stiffness of boxlike cross sections is shown in details in papers [1-3]. For boxlike cross section made of constant thickness plates and with height/width relation *k=h/b*, the bending and torsion stiffness relation is defined with following expression [1]:

$$\frac{EI}{GI_0} = 1,73 \cdot k \qquad \textbf{(4)}$$

From the point of application, this expression is justified for usage, because having in mind the limitations on which it was established, it gives small relative errors. For adopted dependences, as well as for the characteristics of realized solutions of both types carrying structures (Table 1), with relation $I_2 = I_3 = I_4$, where:
I_2 – moment of inertia of transversal boxlike girder,
I_3 – moment of inertia of transversal boxlike girder at the bearing support point,
I_4 – moment of inertia of longitudinal boxlike girder at the bearing support point,
it is possible to obtain the influential coefficients of such shape, where the unknown value X_1 will depend on coefficient k and support deformation Δ.

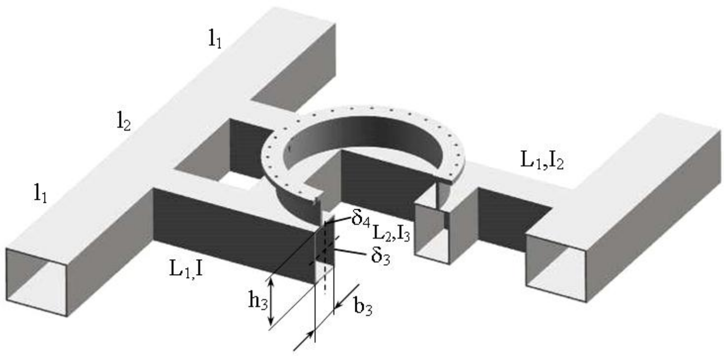

Figure 5: Realized solution of radial-axial bearing carrying frame

Table 1: Basic dimensions of realized solution

Dimension	"H"	"X"
L_1 [mm]	725	725
L_2 [mm]	800	800
l_1 [mm]	1000	1000
l_2 [mm]	800	800
$l_k = \frac{L_1}{\cos\alpha}$ [mm]	-	880
α [^{0}]		34.59
I_2 [cm^4]	16126	16126
I_1 [cm^4]	20270	20270

Simplified expressions for some influential coefficients obtained in this way are shown in Table 2.
Final solutions of canonic equations system, i.e., determination of the unknown value X1, are done with the software package MATLAB in accordance with block diagram (Fig. 6). Table 3 and diagrams in Figure 7 show unknown parameter X_1 for various values of boxlike cross section height/width relation k and deformation Δ, in order to make comparative analysis of named carrying structure types towards better adjustment of the machine to the terrain.
On the base of this results, the conclusion is that the carrying structure "H" type is "more elastic" than "X" type, that is, "H" type structure adjusts better to the terrain for about 15%. However, in real life, this percentage is even higher, which means that at "H" portal the unevenness and deviations of crane track from horizontality that are higher in relation to "X" type portal structure, can be overcome.
The aim of such problem generalization is pointing out the influence of shape and geometry of carrying structure on proper function of revolving and non-revolving machine parts bond.

Table 2: Simplified expressions for some influential coefficients

δ_{ij}	"H" type - x[10^{-3}]	"X" type - x [10^{-3}]
δ_{11}	0.10699994+0,90290574k	0.323831439+0.799686064k
δ_{12}	0.0115269296+0.083124655k	0.080384968+0.111060863k
δ_{13}	-0.026311461-0.103905819k	-0.087331765-0.036892869k
δ_{14}	0.091723757k	0.091723757
δ_{15}	-0.114654697	-0.114654697k
δ_{16}	δ_{12}	δ_{12}
δ_{17}	δ_{13}	δ_{13}
δ_{21}	20270	0.323831439+0.799686064k
δ_{22}	0.010924278+0.033391729k	0.05804144+0.06656184329 k
δ_{23}	-0.016967122-0.029687376k	-0.053185873-0.02375809k
δ_{24}	-0.00503976+0.005937475k	-0.007402157+0.005937475k
...	...	...
δ_{67}	-0.016967122-0.029687376k	-0.053185873-0.02375809k
δ_{71}	δ_{17}	δ_{17}
δ_{72}	δ_{27}	δ_{27}
δ_{73}	δ_{37}	δ_{37}
δ_{74}	δ_{47}	δ_{47}
δ_{75}	δ_{57}	δ_{57}

Table 3: X_1 for various values of boxlike cross section height/width relation k and deformation Δ

	"H"- type			"X"- type		
k	Δ=5 mm	Δ=10 mm	Δ=15 mm	Δ=5 mm	Δ=10 mm	Δ=15 mm
1	16.0063	32.0126	48.0189	17.9924	35.9848	53.9772
1.5	11.1896	22.3792	33.5688	12.5146	25.0292	37.5438
2	8.6044	17.2088	25.8132	9.6083	19.2166	28.8249
2.5	6.9905	13.981	20.9715	7.8023	15.6046	23.4069
3	5.8868	11.7736	17.6604	6.5698	13.1396	19.7094

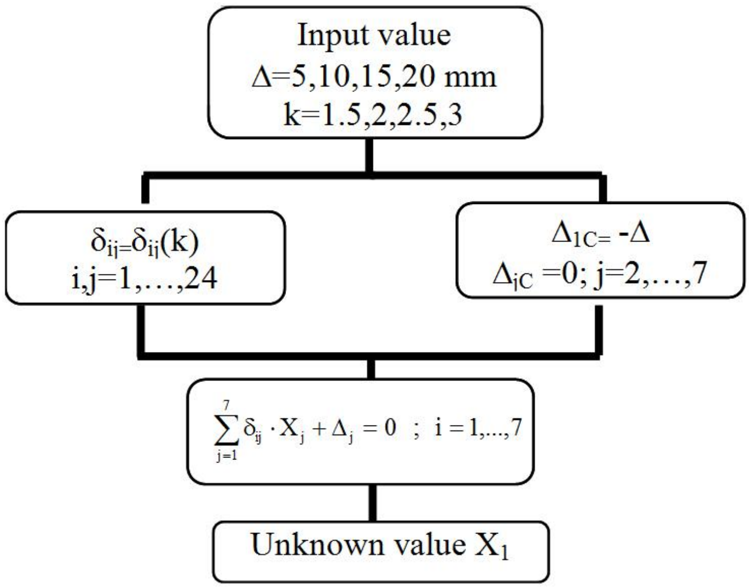

Figure 6: MATLAB block diagram

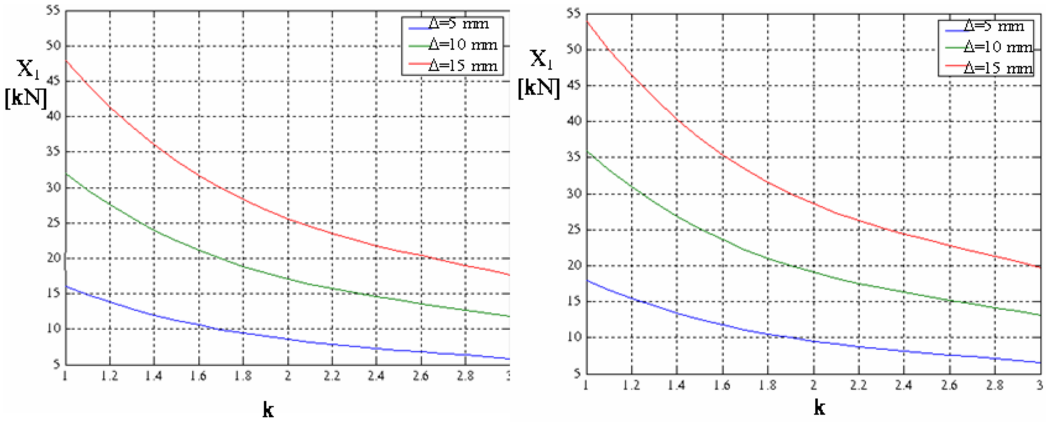

Figure 7: Comparative diagrams of relations X_1 from coefficient k for "H" and "X" type

Adequate stiffness of the whole structure, and even the support surface for the axial-radial bearing bond, can be achieved by suitable choice of geometric values and by the carrying structure shape, as well as by installation of intermediate elements (cylindrical girder).

3. CONCLUSION

Special attention in this paper was directed toward further development and improvement of revolving and non-revolving bonds in machines of construction and transport mechanization, to be specific, towards proper functioning of revolving and non-revolving parts bond through radial-axial bearings of great diameters. Studying the influential parameters on the bond is of complex nature, so it is necessary decrease the number of influential parameters without violating the generality of the considered problem.

Increased structure stability with own boundary parameters, provides advantage in comparison with other ways of support, and by itself it provides the justifiable analysis and research of influential parameters on the revolving and non-revolving parts bond.

On the ground of the analyses, we come to a conclusion that it is possible, by relation choice of carrying structure geometric values, to increase the stiffness of carrying structure and to adjust machine to the terrain, which leads to proper function of revolving and non-revolving parts bond.

However, even with so defined relation, it is not possible to provide such stiffness where the support surface deplanation is less than allowed. By comparative analysis of support surfaces deformation at characteristic points for various support variants, it is possible to determine the influence of intermediate elements installation, e.g. cylindrical girder on deplanation decrease and support surface deformation within radial-axial bearing bond. By cylindrical girder installation, it is not always possible to achieve deformations that are less than allowed, while the machine stability in operation is partly decreased.

That is the reason why we should research the carrying structure shape without cylindrical girder and direct our attention towards development of carrying structure with swivel joint, which will greatly eliminate terrain unevenness influences on bearing support surface deplanation.

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