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Study of The Stress-Strain State of The Shaking Conveyor Mechanism

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AbstractIn this paper is studied a vibratory conveyor that is placed on an elastic base. Using the closed contours method it was determined the system that needs to be solved to obtain graphical representation for the generalized coordinates determining the position of the mechanical system elements. The shaking conveyor represents the chase hanged or supported to the fixed section. The chase commits oscillating motions hereupon the cargo which is in the chase, migrates concerning to the chase. The nature of the flow and its parameters are determined by the nature of the oscillating committed by the chase.Justifying the dynamic parameters of the shaking conveyor and a study of the stress-strain state. Installation causes fluctuations fixed tray. Uniformly distributed load on the tray acts in each element of the mechanism. On the basis of the program APM structure 3D investigated the stress-strain state and determined movement of each link mechanism with results and calculations.

Key words: *stress-strain state, vibrating conveyor, equation, APM structure 3D, differential equation.*

I. INTRODUCTION

The big application in various fields of the industry was received by the vibrating conveyors applied to transportation of hot, poisonous, chemical aggressive cargoes by the supplement of complete tightness of their relocation [4], and also for transportation of the metallic cuttings damped with emulsion and oil, hot earth which has been beaten out from casting forms, small casting, foundry fusion mixture, etc. The vibrating conveyor represents the chase hanged or supported to the fixed section. The chase commits oscillating motions hereupon the cargo which is in the chase, migrates concerning to the chase [5-8]. The nature of the flow and its parameters are determined by the nature of the oscillating committed by the chase. Vibrating conveyors on the conditions of the chase flow and nature of cargo movement are subdivided on inertial (with variable and constant stress of cargo to the chase) in which [9] cargo under the influence of inertia force glides on the chase, and on vibrating in which cargo tears off the chase and migrates along the chase. The vibrating conveyors [1-3] are widely applied owing to a number of advantages in these latter days.The questions of the kinematic and dynamic study of the vibrating feeder intended for dosing of the fusion mixture loading of the melting furnaces of foundry production are considered in the presented work[11-16]. The principle of operation of the vibrating conveyor is described, and it is devoted the kinematic analysis of the action. The differential equation of the link move of the reduction of the vibrating conveyor is considered in the difference method (the approximate method) solutions of the equation of move of the vibrating conveyor is resulted [10]. It is devoted to the analysis of the equations solutions of conveyor move. Here tables of the results and relocation drawing and velocity of the leading link depending on time are resulted.

II. MATERIALS AND METHODS

It is the action of theIII class. The crew BED basic crew from which there are three leads FE, AB, GD. The link OA is a leading link

Table 1. The action has following performances.

№	links				
	1	2	3	4	5
mass, kg	$m_1 = 30$	$m_2 = 65$	$m_3 = 1160$	$m_4 = 59$	$m_5 = 59$
length units, mm	$l_1 = 60$	$l_2 = 430$	$l_3 = 1100$	$l_4 = 440$	$l_5 = 440$

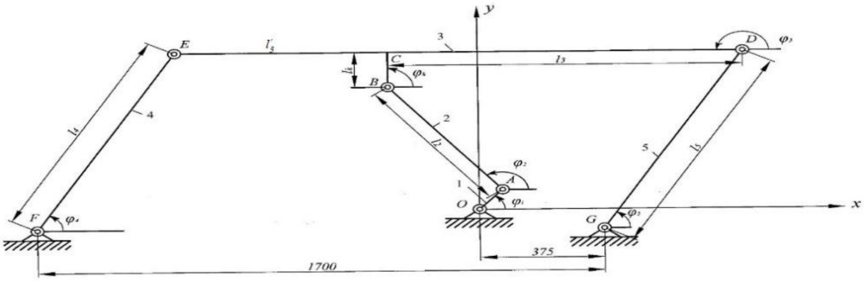


Fig. 1. Kinematic scheme of the vibrating conveyor mechanism

This action has one axis of motion, therefore relocation, velocities and speed-up of the driven link and action dots are functions of the relocation, velocities and speed-up of the leading link. Therefore we will find analytical dependences between relocations, velocities of the drivenlinks and leading link.As the leading link enters into the rotational pair with the console we set function. By the solution of theaction move problem with one degree of freedom we will use the equation of the action move of the engine aggregate. $\varphi_1 = \varphi_1(t)$

$$I_K(\varphi_1)\frac{d\omega_1}{dt} = \frac{\omega_1^2}{2}\frac{d\mathrm{I}_k(\varphi_1)}{d\varphi_1} = M_k - M_k \qquad (1)$$

It is known to us dependence $M_P(\omega)$ and $M_R(\varphi_1)$. We determine $M_R(\varphi_1)$ the resulted moment of resistance forces from power equalling of the resulted moment of force resistance and the sum of powers of the moments[5]of resistance forces of operating in links E, D, F, G.

$$M_к\omega_1 = M_E^{кед}\omega_4 + M_Д^{кед}\omega_5 + M_F^{кед}\omega_4 + M_G^{кед}\omega_5$$

$$M_к = M_E^{кед}\frac{\omega_4}{\omega_1} + M_Д^{кед}\frac{\omega_5}{\omega_1} + M_F^{кед}\frac{\omega_4}{\omega_1} + M_G^{кед}\frac{\omega_5}{\omega_1} =$$

$$= M_E^{кед}u_{41} + M_Д^{кед}u_{51} + M_F^{кед}u_{41} + M_G^{кед}u_{51} = 4\cdot u_{41}M_k$$

Let's find resulted moment of the flywheel actions $\mathrm{I}_k(\varphi_1)$ from equalling condition of kinematic energy of reduction link to the kinematic energy sum of all links of the action.

$$\mathrm{I}_k(\varphi_1) = \mathrm{I}_{S1} + m_2\vartheta_{S2\varphi_1} + \mathrm{I}_{S2}u_{22}^2 + m_3\vartheta_{S3\varphi_1}^2 + (\mathrm{I}_{4F} + \mathrm{I}_{5G})\cdot l_{41}^2 \quad (2)$$

We determine inertia moments of the first, second, fourth and fifth links.

$$\mathrm{I}_{S1} = m_1\cdot\frac{l_1^2}{2}$$

$$\mathrm{I}_{S2} = m_2\cdot\frac{l_2^2}{2}$$

$$\mathrm{I}_{4F} = \mathrm{I}_{S4} + m_4\cdot l_4' = m_4\cdot\frac{l_4^2}{2} + m_4\cdot\frac{l_4^2}{4}$$

$$\mathrm{I}_{5G} = \mathrm{I}_{S5} + m_5\cdot l_5' = m_5\cdot\frac{l_5^2}{2} + m_5\cdot\frac{l_5^2}{4}$$

We differentiate the resulted inertia moment on φ_1: For this purpose we substituted all above found values in the equation.

$$\frac{dI_k(\varphi_1)}{d\varphi_1} = 2\cdot m_2\sqrt{(l_1\sin\varphi_1 + l_2'\sin\varphi_2\cdot u_{21})^2 + (l_1\cos\varphi_1 + l_2'\cos\varphi_2\cdot u_{21})^2}\cdot\omega_1\cdot$$

$$\cdot\frac{\left\{\omega_1\left[l_1(\cos\varphi_1 - \sin\varphi_1) + l_2'\cdot u_{21}^2(\cos\varphi_2 - \sin\varphi_2)\right] + l_2'\frac{du_{21}}{d\varphi_1}(\sin\varphi_2 + \cos\varphi_2)\right\}}{\sqrt{(l_1\sin\varphi_1 + l_2'\sin\varphi_2\cdot u_{21})^2 + (l_1\cos\varphi_1 + l_2'\cos\varphi_2\cdot u_{21})^2}} + 2I_{S2}\frac{l_1}{l_2}\frac{\sin(\varphi_4-\varphi_1)}{\sin(\varphi_2-\varphi_1)}\cdot$$

$$\cdot\frac{l_1}{l_2}\left[\frac{u_{41}\cos(\varphi_4-\varphi_1) - \cos(\varphi_4-\varphi_1)}{\sin(\varphi_4-\varphi_2)} - \frac{\left[u_{21}\cos(\varphi_4-\varphi_2) - u_{41}\cos(\varphi_4-\varphi_2)\right]\cdot\sin(\varphi_4-\varphi_1)}{\sin^2(\varphi_4-\varphi_2)}\right] +$$

$$+2m_3\omega_1^2\left[-l_1(\cos\varphi_1 + \sin\varphi_1) - l_2\cdot u_{21}^2(\cos\varphi_2 - \sin\varphi_2) + l_2\frac{du_{21}}{d\varphi_1}(\cos\varphi_2 - \sin\varphi_2) + \frac{du_{51}}{d\varphi_1}(a\cdot\cos\omega_5 t - b\cdot\sin\omega_5 t)\right] +$$

$$+2(I_{4F} + I_{5G})\cdot\frac{l_1}{l_4}\left\{\frac{\cos(\varphi_1-\varphi_2)u_{21} - \cos(\varphi_1-\varphi_2)}{\sin(\varphi_2-\varphi_4)} - \frac{\left[\cos(\varphi_1-\varphi_2)u_{21} - \cos(\varphi_1-\varphi_2)\sin(\varphi_2-\varphi_1)\right]}{\sin^2(\varphi_2-\varphi_4)}\right\}\frac{l_1}{l_4}\frac{\sin(\varphi_2-\varphi_1)}{\sin(\varphi_2-\varphi_4)} =$$

$$= 2\cdot m_2\cdot\omega_1^2\left[l_1\cdot(\cos\varphi_1 - \sin\varphi_1) + l_2'\cdot u_{21}(\cos\varphi_2 - \sin\varphi_2) + l_2'\frac{du_{21}}{d\varphi_1}(\sin\varphi_2 - \cos\varphi_2)\right] +$$

$$+2\cdot I_{S2}\cdot\frac{l_1^2}{l_2^2}\frac{\sin(\varphi_4-\varphi_1)}{\sin(\varphi_2-\varphi_4)}\left\{\frac{u_{41}\cos(\varphi_1-\varphi_4) - \cos(\varphi_4-\varphi_1)}{\sin(\varphi_2-\varphi_4)} - \frac{\left[u_{21}\cos(\varphi_4-\varphi_2) - u_{41}\cos(\varphi_4-\varphi_2)\right]\sin(\varphi_4-\varphi_1)}{\sin^2(\varphi_4-\varphi_2)}\right\} -$$

$$-2m_3\omega_1^2\left[l_1(\cos\varphi_1 + \sin\varphi_1) + l_2'\cdot u_{21}^2(\cos\varphi_2 - \sin\varphi_2) - l_2\frac{du_{21}}{d\varphi_1}(\sin\varphi_2 - \cos\varphi_2) - \frac{du_{51}}{d\varphi_1}(a\cdot\cos\omega_5 t - b\cdot\sin\omega_5 t)\right] +$$

$$+2(I_{4F} + I_{5G})\cdot\frac{l_1^2}{l_4^2}\frac{\sin(\varphi_2-\varphi_1)}{\sin(\varphi_2-\varphi_4)}\cdot\left\{\frac{\cos(\varphi_1-\varphi_2)u_{21} - \cos(\varphi_1-\varphi_2)}{\sin(\varphi_2-\varphi_4)} - \frac{\left[\cos(\varphi_1-\varphi_2)u_{21} - \cos(\varphi_1-\varphi_2)\right]\cdot\sin(\varphi_2-\varphi_1)}{\sin^2(\varphi_2-\varphi_4)}\right\};$$

The move equation of the reduction link of the action looks like:

$$\mathrm{I}_{S1} + m_2\cdot\omega_1^2\left\{\left[(l_1\sin\varphi_1 + l_2'\sin\varphi_2\cdot u_{21})^2 + (l_1\cos\varphi_1 + l_2'\cos\varphi_2\cdot u_{21})^2\right] + \mathrm{I}_{S2}\frac{l_1^2}{l_2^2}\frac{\sin^2(\varphi_4-\varphi_1)}{\sin^2(\varphi_2-\varphi_4)} +\right.$$

$$+m_3\cdot\omega_1^2\left[(-l_1\sin\varphi_1 - l_2\sin\varphi_2\cdot u_{21} + a\cdot u_{51}\cdot\cos\omega_5 t)^2\right] + \left[(l_1\cos\varphi_1 + l_2\cos\varphi_2\cdot u_{21} - b\cdot u_{51}\cdot\sin\omega_5 t)^2\right] +$$

$$\left.+(\mathrm{I}_{4F} + \mathrm{I}_{5G})\frac{l_1^2}{l_4^2}\frac{\sin^2(\varphi_2-\varphi_1)}{\sin^2(\varphi_2-\varphi_4)}\right\}\cdot\frac{d\omega_1}{dt} + \frac{\omega_1^2}{2}\left\{2\cdot m_2\cdot\omega_1^2\left[(l_1\sin\varphi_1 + l_2'\sin\varphi_2\cdot u_{21})\cdot(l_1\cos\varphi_1\cdot u_{21}^2 + l_2'\sin\varphi_2\frac{du_{21}}{d\varphi_1}) +\right.\right.$$

$$\left.+(l_1\cos\varphi_1 + l_2'\cos\varphi_2\cdot u_{21})(-l_1\sin\varphi_1 - l_2'\sin\varphi_2\cdot u_{21}^2 + l_2'\cos\varphi_2\frac{du_{21}}{d\varphi_1})\right] +$$

$$+2\cdot\mathrm{I}_{S2}\frac{l_1^2}{l_2^2}\left[\frac{(\cos(\varphi_1+\varphi_4) - \cos(\varphi_1+\varphi_4))\sin(\varphi_1-\varphi_4)}{\sin^2(\varphi_2-\varphi_4)}\right] + 2m_3\omega_1^2\left[(-l_1\sin\varphi_1 - l_2\sin\varphi_2\cdot u_{21} +\right.$$

$$+a\cdot u_{51}\cos\omega_5 t)\left(-l_1\cos\varphi_1 - l_2\cos\varphi_2 u_{21}^2 - l_1\sin\varphi_2\frac{du_{21}}{d\varphi_1} + a\cos\omega_5 t\frac{du_{51}}{d\varphi_1}\right) +$$

$$\left.+(l_1\cos\varphi_1 + l_2\cos\varphi_2\cdot u_{21} - b\cdot u_{51}\sin\omega_5 t)\cdot\left(-l_1\sin\varphi_1 + l_2\sin\varphi_2\cdot u_{21}^2 + l_2\cos\varphi_2\frac{du_{21}}{d\varphi_1} - b\sin\omega_5 t\frac{du_{51}}{d\varphi_1}\right)\right] +$$

$$\left.+(\mathrm{I}_{4F} + \mathrm{I}_{5G})\left[2\frac{l_1^2}{l_2^2}\cdot\frac{\left[\cos(\varphi_1+\varphi_2) - \cos(\varphi_1-\varphi_2)\right]\sin(\varphi_2-\varphi_1)}{\sin^2(\varphi_2-\varphi_4)}\right]\right\} =$$

$$= M_{k_o} - \alpha\cdot\omega_1 - 4u_{41}(M_k' + K_0\varphi_5) \quad (3)$$

For solution of the Eq.(3) there are following initial conditions: at $t = 0,\ \omega_1 = 0,\ \varphi_1 = 60^o$

III. THE APPROXIMATE METHOD OF THE EQUATION SOLUTIONS OF THE VIBRATING CONVEYOR

For constructing on the piece $t \in [0, T]$ of the approximate solution of the move Eq.(3), we copy it in the following kind:

$$R(t)\frac{d\omega_1}{dt} + Q(t)\cdot\omega^2(t) = W(t) \quad (4)$$

where $R(t) = \mathrm{I}_{S_1} + (m_2 A(t) + m_3 H(t)\omega_1^2 + B(t) + D(t)$

$$A(t) = l_1^2 + 2l_1 l_2'(\sin\varphi_1\cdot\sin\varphi_2 + \cos\varphi_1\cdot\cos\varphi_2)\cdot u_{21} + l_2'^2\cdot u_{21}^2 .$$

$$H(t) = l_1^2 - l_2^2\cdot u_{21}^2 + (a^2\cos^2\omega_5 t + b^2\sin^2\omega_5 t)\cdot u_{51}^2 + 2l_1 l_2\cdot u_{21}(\sin\varphi_1\sin\varphi_2 +$$

$$+\cos\varphi_1\cos\varphi_2) - 2l_1\cdot u_{51}(a\cdot\sin\varphi_1\cos\omega_5 t + b\cdot\cos\varphi_2\sin\omega_5 t) - 2l_2\cdot u_{21}(a\cdot\cos\omega_5 t\sin\varphi_2 +$$

$$+ b\cdot\sin\omega_5 t\cdot\cos\varphi_2)$$

$$B(t) = \mathrm{I}_{S_2}\frac{l_1^2\sin^2(\varphi_4 - \varphi_1)}{l_2^2\sin^2(\varphi_2 - \varphi_4)}; \quad D(t) = (\mathrm{I}_{4F} + \mathrm{I}_{5G})\frac{l_1^2\sin^2(\varphi_2 - \varphi_1)}{l_4^2\sin^2(\varphi_2 - \varphi_4)}$$

$$Q(t) = (m_2 E(t) + m_3 F(t))\cdot 2\omega_1^2 + 2\mathrm{I}_{S_2}\frac{l_1^2}{l_2^2}N(t) + M(t)$$

$$E(t) = (l_1\sin\varphi_1 + l_2^1\sin\varphi_2\cdot u_{21})\cdot\left(l_1\cos\varphi_1 + l_2^1\cos\varphi_2\cdot u_{21}^2 + l_2^1\sin\varphi_2\frac{du_{21}}{d\varphi_1}\right) +$$

$$+ (l_1\cos\varphi_1 + l_2^1\cos\varphi_2\cdot u_{21})\cdot\left(-l_1\sin\varphi_1 - l_2^1\sin\varphi_2\cdot u_{21}^2 + l_2^1\cos\varphi_2\frac{du_{21}}{d\varphi_1}\right);$$

$$F(t) = (-l_1\sin\varphi_1 - l_2\sin\varphi_2\cdot u_{21} + a\cdot u_{51}\cos\omega_5 t)\cdot\left(-l_1\cos\varphi_1 - l_2\cos\varphi_2\cdot u_{21}^2 - l_1\sin\varphi_1\frac{du_{21}}{d\varphi_1} + a\cdot\cos\omega_5 t\frac{du_{51}}{d\varphi_1}\right) +$$

$$+ (l_1\cos\varphi_1 + l_2\cos\varphi_2\cdot u_{21} - b\cdot u_{51}\sin\omega_5 t)\cdot\left(-l_1\sin\varphi_1 - l_2\sin\varphi_2\cdot u_{21}^2 + l_2\cos\varphi_2\frac{du_{21}}{d\varphi_1} - b\cdot\sin\omega_5 t\frac{du_{51}}{d\varphi_1}\right)$$

$$N(t) = \frac{(\cos(\varphi_1 + \varphi_4) - \cos(\varphi_1 - \varphi_1))\sin(\varphi_1 - \varphi_4)}{\sin^2(\varphi_2 - \varphi_4)}$$

$$M(t) = (\mathrm{I}_{4F} + \mathrm{I}_{5G})\left[2\frac{l_1^2}{l_2^2}\frac{(\cos(\varphi_1 + \varphi_2) - \cos(\varphi_1 - \varphi_2))\sin(\varphi_2 - \varphi_1)}{\sin^2(\varphi_2 - \varphi_4)}\right]$$

$$W(t) = M_{Д_o} - \alpha\cdot\omega_1 - 4\cdot u_{41}(M'_{K_o} + K_o\varphi_5)$$

IV. RESULTS AND DISCUSSION

The system of differential equations modeling the movement of the material particle on the vibrating plate belonging to the conveyor was solved using Zinovyeva method. Our goal was to find the optimal values of some parameters that allow the obtaining of maximum speed of a vibratory movement on the plate.The basis of the program APM structure 3D investigated the stress-strain state and determined movement of each link mechanism with results and calculations.

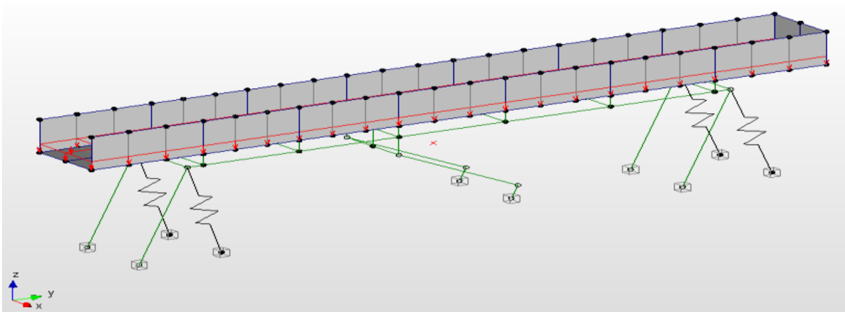


Fig. 2. Vibrating conveyor mechanism 3D model

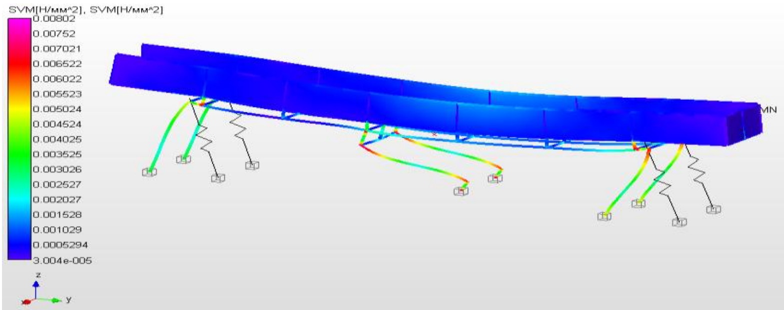


Fig. 3. Computed plot ofthe stress-strain state σ_x .

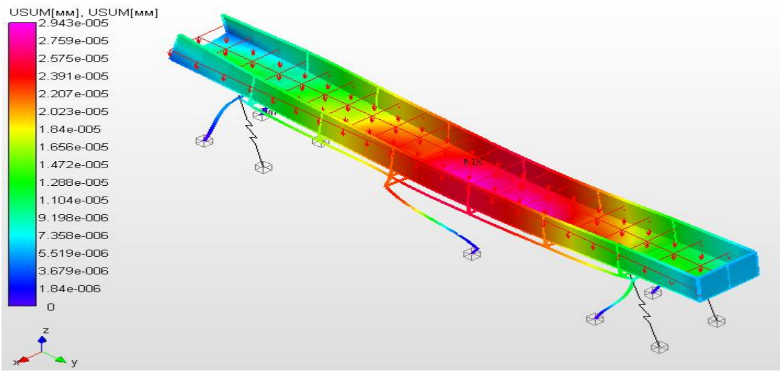


Fig. 4. Computed plot ofthe moving.

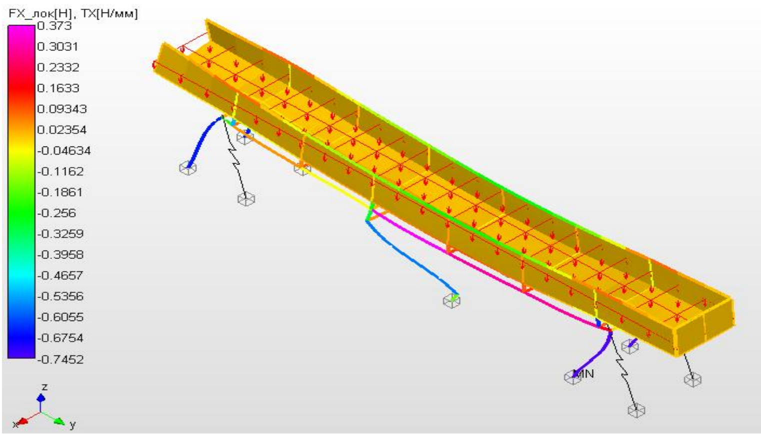


Fig. 5. Computed plot ofthe F_X and T_X .

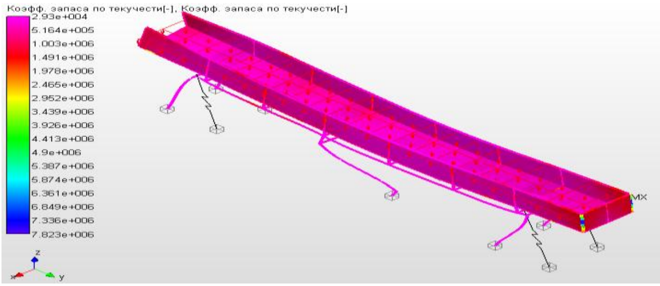


Fig. 6. Computed plot ofthe Safety factor for yield.

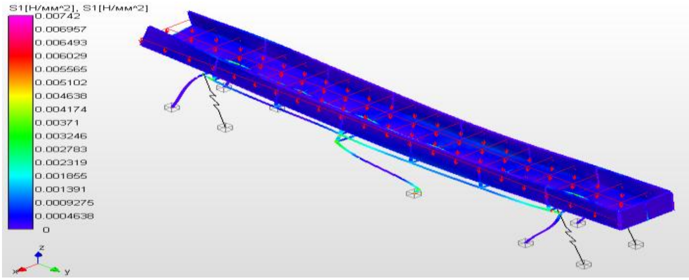


Fig. 7. Computed plot ofthe stress-strain state τ_{YZ} .

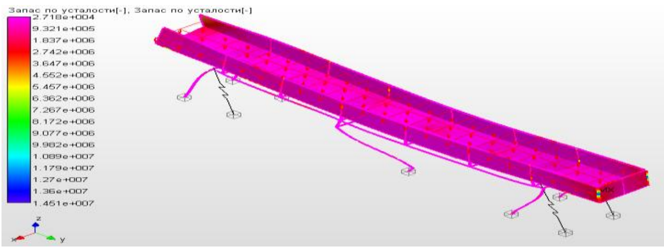


Fig. 8. Computed plot ofthe margin fatigue.

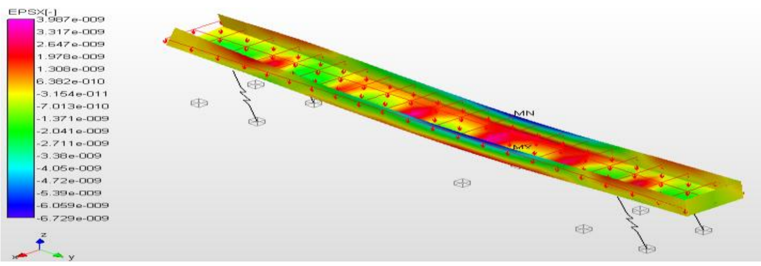
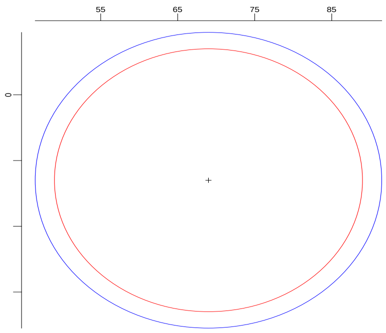


Fig. 9. Computed plot of the main deformation.

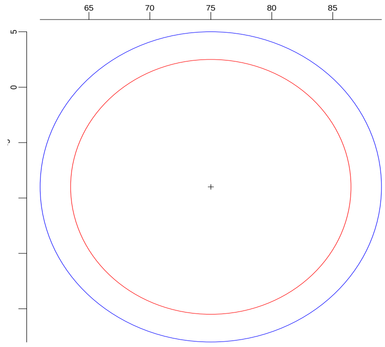
T**able 2.** The reactions in the supports

№ joint	№ node	Reaction R_X [H]	Reaction R_Y [H]	Reaction R_Z [H]	Moment M_X [нм]	Moment M_Y [нм]	Moment M_Z [нм]
1	18	0,0046	0,2484	0,6074	-3,6181	0,6038	-0,3482
2	20	0,0057	0,2141	0,7151	7,2149	0,7702	-0,3027
3	27	0,0045	-0,4624	0,3450	19,72251	0,5502	0,2877
4	47	0	0,0004	0,0001	0	0	0

5	48	0	-0,0005	-0,0002	0	0	0



Tube 45x2.5 GOST 8732-78
Options section
The area of 333.70 square millimeters
The center of mass: X = 69.000, Y = -13.000mm
Moment of inertia:
rel. X axis 75605.68mm^4
rel. Y axis 75605.68mm^4
polar 151211.35mm^4
The angle of the principal central axes 0.00gradus



Tube 28 x 2.5 GOST 8732-78
Options section
The area of 200.23 square millimeters
The center of mass: X = 75.001, Y = -8.999mm
Moment of inertia:
rel. X axis 16434.12mm^4
rel. Y axis 16434.12mm^4
polar 32868.25mm^4
The angle of the principal central axes 0.00gradus

Fig.10. Model information: List of cross section and options section.

The center of gravity model (-0.000000, 919.880834, 469.928355) [мм].
The moments of inertia model (1280707.633013, 159169646.605358, 28044219.772722) [кг*мм*мм].

V. CONCLUSIONS

1. Formulas for the position determination and velocity of conducted links depending on position and velocity of the leading link are received.
2. The differential equations of the link move of the action reduction are received.
3. On the basis of the profiles variation analysis of the angular rate of the leading link it is possible to make the following concluding:

- with the growth of the starting driving moment middle angulator of the action grows;
- with reduction of the starting driving moment middleangular rate of the action is decays;
  with coefficient increase α_0, ω_{cp} grows;

4. The basis of the program APM structure 3D investigated the stress-strain state and determined movement of each link mechanism with results and calculations.

VI. ACKNOWLEDGMENTS

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