ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

The Basis of Theoretical Parameters in Belt Drive with Variable Transmission Ratio

D. A. Mamatova, A. Djuraev

Doctor of Technical Sciences, “Engineering science and Service”department , Tashkent Institute of Textile and Light Industry, 5 Shohjohon str., Yakkasaray District, Tashkent,100100,Uzbekistan
Professor, Engineering science and Service”department , Tashkent Institute of Textile and Light Industry, 5 Shohjohon str., Yakkasaray District, Tashkent,100100,Uzbekistan

ABSTRACT: The article presents design schemes and the principle of operation on the developed mode of transmissions with compound pulleys with elastic elements.

Theoretical studies are considered to determine on the elongated of transmission branches, angular vibrations of compound pulleys in influence of belt deformation, as well as the transfer deposition of transmission in an eccentric tension roller.

KEYWORDS: belt drive, compound pulleys, rubber plug, stiffness, dissipation, oscillation, frequency, amplitude, torque, elongation, transmission ratio.

I.INTRODUCTION

In a number of technological machines is required uneven rotation of the working element with the required amplitude and frequency. Rotation of a driven shaft (working element) with variable angular rate in some technological processes leads to an increase in the effect of machine. For example, a service to the working elements of unequal rotation increases the quality of loosening and cleaning of fibrous material. For this purpose are used to belt drives with a transmission with variable transmission ratio. [1÷5]

Belt drive with variable transmission ratio are used as a drive element of various machines and mechanisms providing rotation of the driven shaft with a variable angular rate: vibromachines, machines for processing fibrous and loose materials, mining and drilling machines, etc.

II. METHOD

A. Development of effective schemes of belt drive with variable parameters

To ensure the movement of the driving pulley with a variable angular rate at the required positions (or time), by controlling the movement of the tension roller is recommended an additional kinematic connection between the driving pulley and the tension roller.

Driving pulley 1 by means of belt 3 informs the rotation of the driving pulley 2 is causing the tension roller 4 to rotate (Fig. 1).

Herewith due to the eccentricity of the tensioning roller 4 varies cyclically the tension of the belt 3. This results in a variable angular rate of the driving pulley 2. In the work process between the belt 3 and the tension roller 12 occurs a slip. This leads to some shift in the law of variation of the driving pulley 2.

This shift is largely eliminated by the kinematic coupling between the pulley 2 and the tension roller 4.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

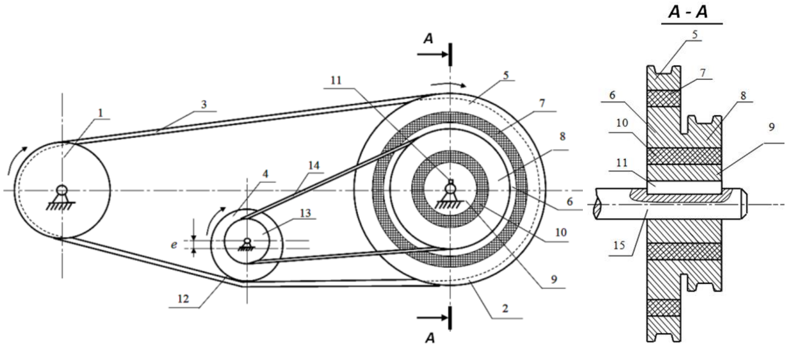


Fig.1. Belt drive

In this case, the transmission ratios of the main and additional belt drives should have the following connection:

$$U_{2,4} = \frac{\dot{\varphi}_2}{\dot{\varphi}_4} = \frac{\dot{\varphi}_5}{\dot{\varphi}_{13}};\ U_{8,13} = \frac{\dot{\varphi}_8}{\dot{\varphi}_{13}};\quad \dot{\varphi}_5 = \dot{\varphi}_8 = \dot{\varphi}_2; \tag{1}$$
$$\dot{\varphi}_4 = \dot{\varphi}_{13};\ U_{2,4} = U_{8,13};$$

It is possibility to expand the kinematic of belt drive and obtain the necessary laws of the variable in the angular rate of the driven pulley by making the cam belt tension eccentric with the required profile (Fig. 2).

In the recommended the design of belt drive, the tension roller can also be made integral with a rubber plug [6, 7, 8].

III.RESULTS AND DISCUSSION

A. Analysis of variable in belt tension with an eccentric tensioning roller

Changes in the length branches of the belt drive are determined from the expressions:

$$\Delta l_1 = \Delta\sigma_1\left[\frac{1}{E} + \frac{D_2}{2fE}\left(1 - e^{-f\varphi_0}\right)\right],\ \Delta l_2 = \Delta\sigma_2\left[\frac{1}{E} + \frac{D_1}{2fE}\left(e^{-f\varphi_0} - 1\right)\right] \tag{2}$$

where, $\Delta\sigma_1$, $\Delta\sigma_2$-changes in belt tension in the branch of transmission, Pa; E- modulus of belt elasticity, Pa; D_1,D_2-leading diameters and driven pulleys, mm; f -coefficient of the belt friction on the surface of pulleys; φ_0- is the angle of elastic slip.

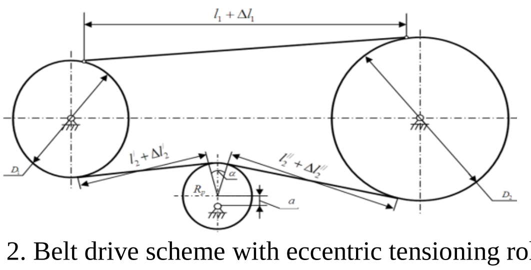


Fig. 2. Belt drive scheme with eccentric tensioning roller

Differential equations are describing to have form the motion of belt pulleys.

$$J_1\frac{d^2\varphi_1}{dt^2} + \frac{k_3FD_1^2}{4}\varphi_1 - \frac{k_3D_1D_2F}{4}\varphi_2 = M_g,\ J_2\frac{d^2\varphi_2}{dt^2} - \frac{k_3D_1D_2F}{4}\varphi_1 + \frac{k_3D_2^2F}{4}\varphi_2 = M\sin\omega t \tag{3}$$

где, $k_3 = (k_1 + k_2)\frac{1}{k_1k_2}$; $k_1 = \frac{1}{E} + \frac{D_2}{2fE}(1 - e^{-f\varphi_0})$; $k_2 = \frac{1}{E} + \frac{D_1}{2fE}(e^{f\varphi_0} - 1)$, $M_g = M_1\sin jt$.

M_g -driving moment on the drive pulley shaft, M_1,M_0–amplitudes oscillations of the driving and disturbing moments.

The solution of the system (3) on the differential equations of the belt drive is sought in the form:

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

$$\varphi_1 = \varphi_{10} \sin \omega t\,, \qquad \varphi_2 = \varphi_{20} \sin \omega t \tag{4}$$

Substituting (4), respectively (3), we obtain expressions for determining the values of the amplitudes forced oscillations of belt pulleys:

$$\varphi_{10} = \frac{A}{B}\left[\frac{B\left(\frac{M_1 \sin jt}{\sin \omega t} + J_1\omega^2\right) + A\left(J_1\omega^2 + M_0\right)}{A^2 - B^2}\right] - \frac{J_2\omega^2 + M_0}{B},$$

$$\varphi_{20} = \frac{B\left(\frac{M_1 \sin jt}{\sin \omega t} + J_1\omega^2\right) + A\left(J_1\omega^2 + M_0\right)}{A^2 - B^2}; \quad A = K_3\frac{D_1^2 F}{4};\ B = K_3\frac{D_1 D_2}{4}F; \tag{5}$$

In this case, the tension changes will be

$$\Delta\sigma_{10} = \frac{R_1\varphi_{10} - R_2\varphi_{20}}{k_1},\ \Delta\sigma_{20} = \frac{R_2\varphi_{20} - R_1\varphi_{10}}{k_2} \tag{6}$$

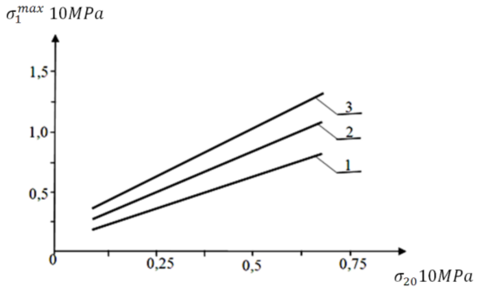
Then we get the total tension in the branches of the belt drive

$$\sigma_1 = \sigma_{10} + \Delta\sigma_{10}\sin\omega t,\ \sigma_2 = \sigma_{20} + \Delta\sigma_{20}\sin\omega t \tag{7}$$

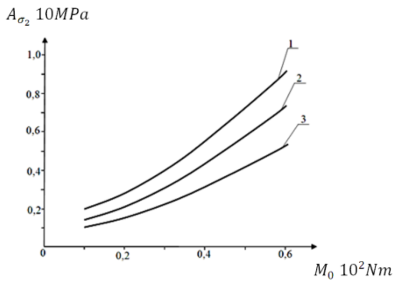
The numerical solution and analysis of the changes results σ_1 and σ_2 were carried out with the following initial values of the parameters of the belt drive with variable transmission ratios:
$R_1=1{,}5\cdot10^{-3}$ *m*; $R_2=2{,}0\cdot10^{-3}$ *m*; $I_1=0{,}02$ *kgm*^{2}; $I_2=0{,}033$ *kgm*^{2}; $F=2{,}5$ *sm*^{2}; $\sigma_0=2{,}2$ *MPa*; $\omega=0{,}75\ P_2$; $\sigma_{10}=4{,}0$ *MPa*; $\sigma_{20}=4{,}0$ *MPa*; $M_0=25$ *Nm*; $E=120$ *MPa*; $l=0{,}185\cdot10^{-3}$*sm*; $M_1=8{,}5$ *Nm*.

Studies have shown that the nature of the tension fluctuation in the driving belt branch does not actually affect the pre-tension value σ_{20}.

In Fig. 3 shows the dependence of the change σ_1^{max} from increasing σ_{20} with variationM_0.



1-M_0=30Nm; 2-M_0=40Nm;
3-M_0=50Nm;



1-at $I_1=0{,}050$ kgm^2; $I_2=0{,}075$ kgm^2;
2-at $I_1=0{,}035$ kgm^2; $I_2=0{,}055$ kgm^2;
3-at $I_1=0{,}02$ kgm^2; $I_2=0{,}035$ kgm^2

Fig. 3. The pattern of change in the maximum value of the tension in the driven path of the belt transmission from the change tension with the preloading of the driven path (a) and the amplitude of the oscillations tension in the driven path of the transmission from the variation M_0

It can be seen from the graphs that as the σ_{20} increases, the tension increases linearly.

Thus, when increasing in the value σ_{20} from 0,82 MPa to 7,5 MPa kg/sm^2 the maximum value of tension σ_1^{max} in driven path of the belt driven increases from 1,45 MPa to 5,8 MPa at $M_0=30$ *Nm*. At $M_0=50$*Nm*, the maximum value of the tension in the driven belt path increases to 12,9 MPa.

In order to reduce the tension in the driven path σ_1^{max} is expedient to reduce the resistance on the driven pulley, as well as pre-tension the belt.

Acceptable limits for changing parameters for a belt drive with the initial parameter values considered are $M_0\le(40\ldots45)$*Nm*, $\sigma_{20}\le(3{,}0\ldots4{,}5)$ MPa. [9,10,11].

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

B. The analysis interaction of a tension roller with a belt at its alternating tension

The initial tension of the belt is determined from the expression:

$$S_0 = \frac{\gamma_p \cdot b_p \cdot h_p}{g} \vartheta^2 \tag{8}$$

Consider the counting scheme shown in Fig. 4. According to this scheme, we determine the force of interaction of the tension compound roller with the belts:

$$Q_p = \frac{\omega_3^2 R_3^2 \cdot \gamma_p \cdot в_p \cdot h_p}{g \cos\Delta_p} \cdot \left(\sin\alpha_3' + \sin\alpha_3''\right) \tag{9}$$

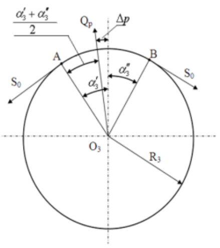


Fig. 4. The calculation scheme of the interaction belt with the compound tension roller

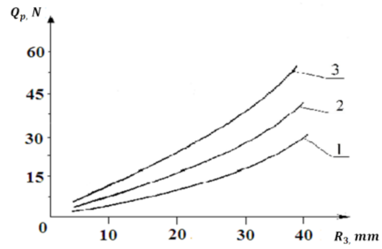


Fig.5. The pattern of change in the interaction force of the tension compound roller with the belt at the variation of the radius in the tension roller

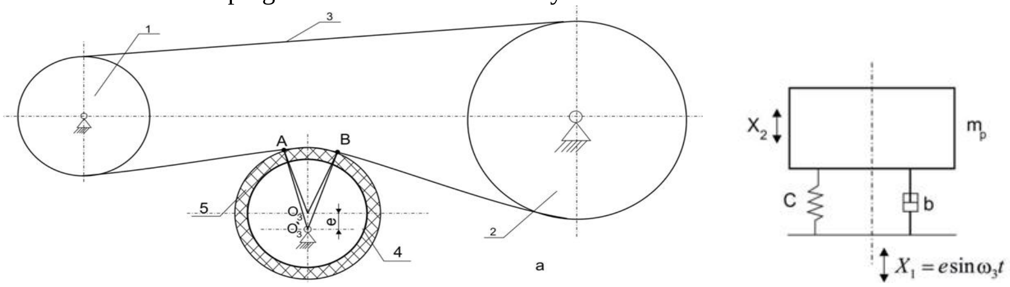
Where , 1-at $\Delta_p = \pi/10$; 2-$\Delta_p = \pi/6$; 3-$\Delta_p = \pi/4$

Where, α_3' ,α_3'' - arrange in the angle of the girth of the elastic plug in compound tension roller; Δ_p- angle between forces Q_p and the vertical axis of the belt.

During the interaction of the belt with the elastic plug of the compound tension roller, the elastic plug is deformed in the vertical direction. It can be seen from the graphs (Fig. 5) that the increase in the radius of the tension roller due to the increase area of contact with the belt by nonlinear law-dimensionality increases the force of interaction. So, with the radius of the 10 mm compound tension roller, the force of interaction with the belt reaches 13.8 *N*, and with an increase in the radius of the composite tension roller to 35 mm this force increases to 53.7 N. The increase in the force Q_p provides the necessary change in the angular rate of the driven pulley. In this case, for the belt driven being considered, the recommended parameters are: ($\alpha_3' + \alpha_3''$)=1,1÷*1,3;R_3=(25÷35)mm; C=(410÷530)·N/mm.*

C. Oscillation of the driven path when interacting with a compound tension roller

In Fig. 6 *a*shows a belt drive of scheme with a variable transmission ratio comprising a compound tension roller with an elastic plug and mounted eccentrically about the axis of rotation.



b

Fig. 6: a-kinematic scheme of belt drive with compound eccentric tensioning roller; b - the calculate scheme of oscillations the part of a driven path of a transmission belt

It is important to research the oscillations of the driven path of the belt 3, which contacts the rubber plug 5 of the tensioning roller 4. Fig. 6 b is a calculate diagram of the oscillations of the driven belt path 3. The greatest amplitude of the angular rate oscillation of the driven pulley depends not only on the values of the displacement *e*, but

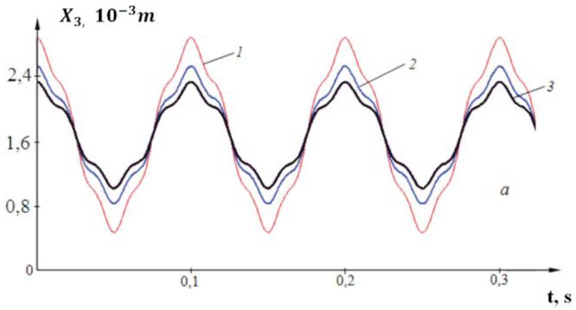
ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

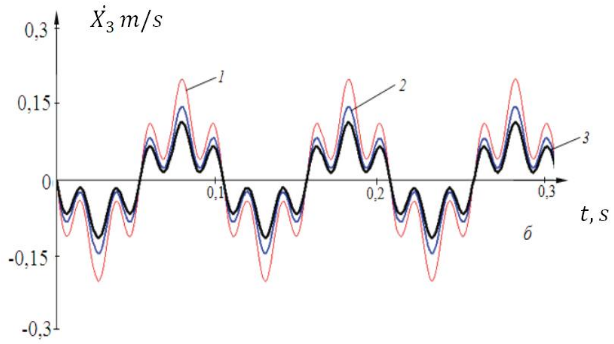
also on the parameters of the elastic sleeve. The maximum value of mass oscillations m_p occurs in the absence of dissipation b = 0. In this case, the oscillation equation of the driven belt path will be

$$m_p\ddot{x}_2+\frac{\omega_3^2R_3^2Y_pb_ph_p}{\delta_p g\cos\Delta_p}(\sin\grave{\alpha}_3+\sin\alpha_3^{''})x_2=\frac{e\omega_3^2R_3^2Y_pb_ph_p}{\delta_p g\cos\Delta_p}(\sin\grave{\alpha}_3+\sin\alpha_3^{''})\sin\omega_3 t \quad (10)$$

where ω_3, R_3 - angular rate and radius of the tension roller; Y_p,b_p,h_p,–the weight, width and thickness of the belt; g-acceleration of gravity; $\alpha_3^{'}, \alpha_3^{''}$–the components of the angle on the belt grip of the tension roller (elastic plug); Δp-angle between the vertical axis and the reaction force of the tension roller; e-eccentricity.

The oscillation of the driven belt path of the transmission belt was determined with the following values of the parameters: R_3=(2,0÷3,0)·10^{-2}m; ω_3 =(210÷250)s^{-1}; $\grave{\alpha}_3+\alpha_3^{''}$ = (0,8÷2,0)radius; $\delta_3=(0{,}4\div2{,}0)\cdot10^{-3}m$; $g_3=9{,}8\frac{m}{s^2}$; Δ_3= (0,1÷0,4) radius; l=(2,0÷45)10^{-3}m; m_p=(0,014÷0,03) kg; h_p=(3,5÷10)10^{-3}m; b_p=(40÷60)10^{-3}m. Based on a numerical solution of expression (14), the regularities of the transverse oscillations of the driven belt path are obtained. In Fig. 7 shows the patterns of changes, speed and acceleration of the belt when interacting with the elastic plug of the eccentric tension roller for different values of roller eccentricity. In Fig. 8 shows the graphs on the pattern of changes in the amplitude and the speed of the roller oscillations as a function of the eccentricity values and the stiffness coefficient of the elastic plug of the tension roller. It should be noted that the nature of the oscillations in the driven path of the transmission belt directly affects the law of angular displacement of the driven pulley. Therefore, based on the requirements of the technology carried out by the working elements of receiving movement directly from the driven pulley, it is possible to select the necessary eccentricity and stiffness values of the elastic plug on the tension roller from the graphs shown in Fig. 8.





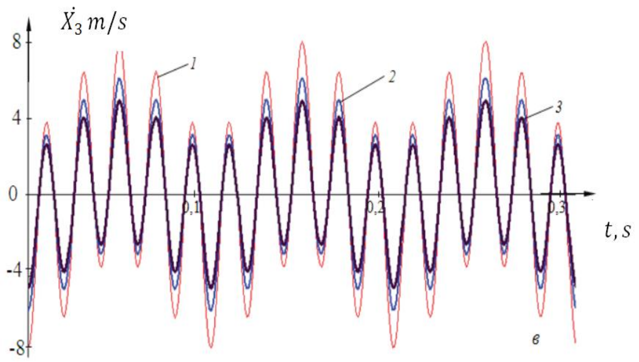


Fig. 7-Patterns of belt oscillations during interaction with an eccentric transfer tension roller with a variation in eccentricity:a-movement; b-speed; в-acceleration

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

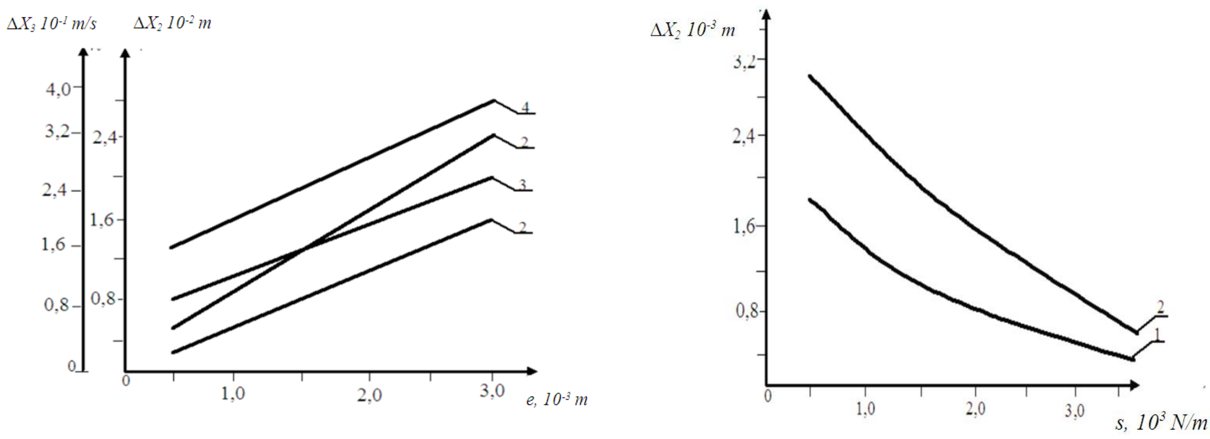
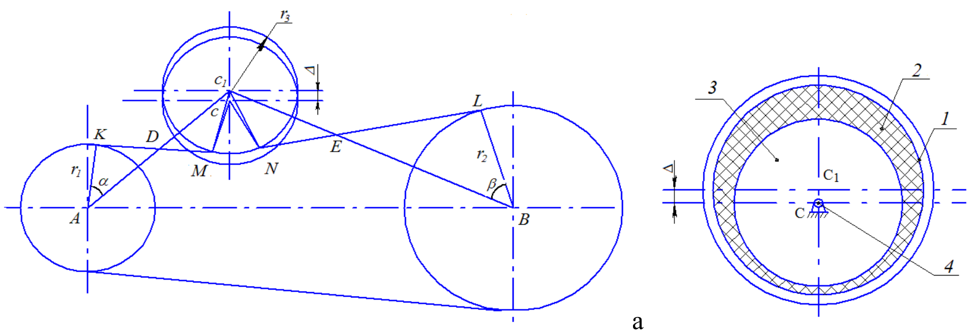


Fig. 8- The pattern of changes of $\Delta X_2$with the variation of displacement and the stiffness coefficient of the elastic plug of the tension pulley of the driven belt

D. Influence on the displacement outer plugs of the tension roller on the variable transmission ratio of the driven belt

In the recommended belt drive of the tension roller is made in a composite, including an elastic plug of rubber. Consider the kinematics of the belt drive for a certain movement of the rim 1 of the tension roller due to deformation of the elastic plug 2 by the value "Δ" (see Fig. 9a). Then, in factually the axis of rotation on the outer plug (rim) 1 moves upwards by an amount "Δ" relative to the axis 4 (see Fig. 9.b.). With the continuous of belt tension on the distance "Δ" also remains constant in the process of work on the belt drive. But, the change in belt tension results in a change on the position of the C_1 axis.



a b

Fig. 9. a- Scheme of the belt drive with a compound tension roller, b - tension roller, with a shifted position of the outer plug due to deformation of the elastic plugs 2

When moving the axis of the rim on the tension pulley of the belt drive, the polar radius of the tension roller, , $r_{3,1}$ and $r_{3,2}$ will change due to changes in the positions of the tension roller. For the transmission in question, an expression was obtained for determining the transmission ratio:

$$U_{1,2} = \frac{r_3 \cos(arctg\gamma_1) + \sqrt{r_3^2(\cos^2 \gamma_1 - 1) + \Delta^2}}{r_3 \cos(arctg\gamma_2) + \sqrt{r_3^2(\cos^2 \gamma_2 - 1) + \Delta^2}} \cdot \frac{r_2}{r_1} \quad (15)$$

where, r_1, r_2, r_3- are the radius of the driving and driven pulleys, the tension pulley; $r_{3,1}$, $r_{3,2}$ - polar radius of the tension roller; γ_1- angle between the radius r_3 and$r_{3,1}$; γ_2- angle between radius r_3 and $r_{3,2}$;

Based on the solution on the problem, the pattern of changes on the angular rate, the angular acceleration of the driven pulley, and the transmission ratio of the belt transmission were obtained. At the same time, the main variable parameters of the belt transmission were the radius and the displacement of its axis due to deformation Δ of the elastic

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

element on the tension roller. An increase in the radius of the tension roller leads to an increase in the displacement Δ, and thus to an increase in the nonlinear regularity (Fig.10). Therefore, in order that the change in the radius of the tension roller does not affect the swing oscillation of the angular rate on the driven pulley, it is necessary to increase the displacement Δ (the deformation of the elastic plug) of the tension roller by a corresponding value.

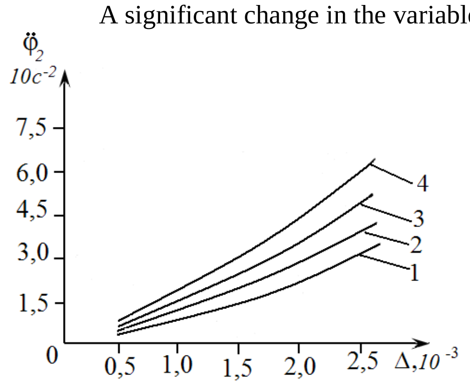
With an increase in the radius of the tension roller from $3{,}0\cdot10^{-2}m$ to $4{,}5\cdot10^{-2}m$ at $\Delta=1{,}5$ *mm* the amplitude oscillations of the angular rate driven pulley on belt drive increases from $0{,}24\cdot10^{2}s^{-2}$, and when $\Delta=2{,}5$ *mm*, $A\varphi_2$ increases from $0{,}36\cdot10^{2}s^{-2}$ to $0{,}57\cdot10^{-2}$ s^{-2}. In addition, in order to reduce the swing oscillation of the angular rate of the driven pulley of the belt drive $\Delta\le1{,}5\div20$ *mm*. Based on task of the kinematic analysis considered on belt transmission, it is important to study the pattern of the change in the variable transmission ratio.

In this case, the pattern of changes on the angular rate variation of the driven link (pulley) corresponds to the pattern of the change in the variable transmission ratio of the belt drive. From the obtained graphs (Fig. 11) it can be seen that the variations of U_{12} and $\dot{\varphi}_2$ and mainly depend on the diameter and displacement Δ of the tension roller. Therefore, when solving the problem of determining the pattern of the change $\dot{\varphi}_2$, $\ddot{\varphi}_2$, and U_{12} were obtained in the function of changing the angular displacement φ_p of the belt tensioning pulley.

In Fig. 11 shows the pattern of the change in the variable transmission ratio of the belt drive with a variation in the displacement Δ. The average value of the variable transmission ratio of the belt drive is 1.375.

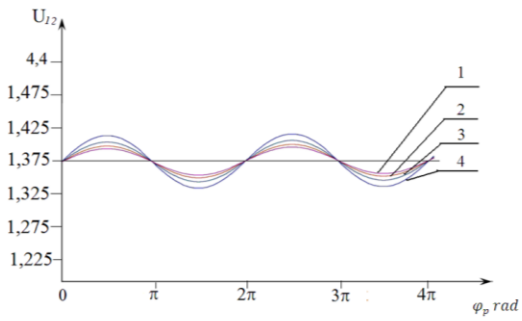
When the tensile roller is moved (deformation of the elastic element) Δ=2.0 mm, the amplitude oscillation of the variable transmission ratio of the belt transmission reaches 0.045 [9].

A significant change in the variable transmission ratio can negatively affect the transmission longevity.



Where,1-$r_p=3{,}0\cdot10^{-2}$ m; 2-$r_p=3{,}5\cdot10^{-2}$ m; 3-$r_p=4{,}0\cdot10^{-2}$m; 4- $r_p=4{,}5\cdot10^{-2}$m;

Fig. 10. Graphical dependencies of the swing oscillation variation of the angular rate on the driven pulley from the change for movement of the tension pulley of the belt drive



Where, 1-at Δ=0,5 mm; 2-Δ=1,0 mm; 3-Δ=1,5 mm; 4-Δ=2,0 mm;

Fig. 11. The pattern of changes on variable transmission ratio of the belt drive with tensioning device

IV. CONCLUSIONS

New design schemes of belt drive with variable transmission ratio have been developed.Taking into account the elastic elements of the compound pulleys and the tension roll, the pattern of changes on the pulley motion and stresses in the transmission paths are theoretically determined.The character of the interaction of the compound tension roller with the belt is determined, the character of the vertical oscillations of the driven belt path in the zone of interaction with the elastic rolls is revealed.The regularities of the change in the swing oscillation of the angular rate of the driven pulley and the variable transmission ratio of the transfer from the vertical displacement of the compound tension roller are revealed.The task of the dynamics of the five-mass drive of the sewing machine is solved using the recommended belt drives. The parameters of the system are justified.

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 5, Issue 9 , September 2018

REFERENCES

[1] StanislavGramblicka, Robert Kohar, Marian Stopka Dynamic analysis of mechanical conveyor drive system // Procediya Engineering 192, 2017, p. 259-264.

[2] M. di Napoli, M strahle, S. ruzimov Intelligent Belt Drive Systems in Hybrid // IFAC-Papers OnLine. 49-21. 2016. p. 47-53.

[3] TakenoriAtsumi Relationship between Flying-height and tracking-position control with thermal actuators for magnetic heads in HDDs // IFAC-Papers OnLine. 49-21 -2016. p. 26-31.

[4] Yu.Vetyukov, V.Eliseev, M.Krommer Modeling the Dynamics of a Flexible Belt Drive Using with Discontinuities // IFAC-Papers OnLine. 48-1. 2015. p. 604-609.

[5] A.Djuraev, R.Kh.Maksudov, V.M. Turdaliev "Kinematic and dynamic analysis of belt drive with variable transmission ratios" / / Monograph. Ed. "Science", Tashkent, 2013, p. 168.

[6] D.A. Mamatova, M. Ergashov, M. Salimov Belt drive The patent R. Uz. No. IAP 03341. bulletin No. 4. 2007

[7] D.A.Mamatova, A.Djuraev and others. Belt drive. Patent R. Uz. No. UZ FAP 00645 bulletin No. 8. 2011

[8] D.A.Mamatova, A.Djuraev and others. Belt drive . Patent R. Uz. No. UZ FAP 00676 bulletin No. 12. 2011

[9] D.A.Mamatova,A.DjuraevAnalysis of Belting Stiffness Transmission Impact on Rotating Mass Motion Law of Technological Machines // Journal of Machinery Manufacturing and Automation (JMMA)China.2016,Vol.lss.1,PP. 15-20.

[10] D.A.Mamatova, A.DjuraevThe analysis of change belt tension in the slack side of belt transmission // European Science ReviewAustria.“ East West” Association forAdvanced Studies and HigherEducation GmbH.№ 1-2. 2017.

[11] D.A.Mamatova, A.DjuraevAnalysis of Changes in Tension in Leading Branch Belt Drive // Journal of Textile Science & Engineering The USA2017.OMICSGroupISSN: 2165-8064Volume 7 Issue 1.