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[1.] Slobodan STEFANOVIC

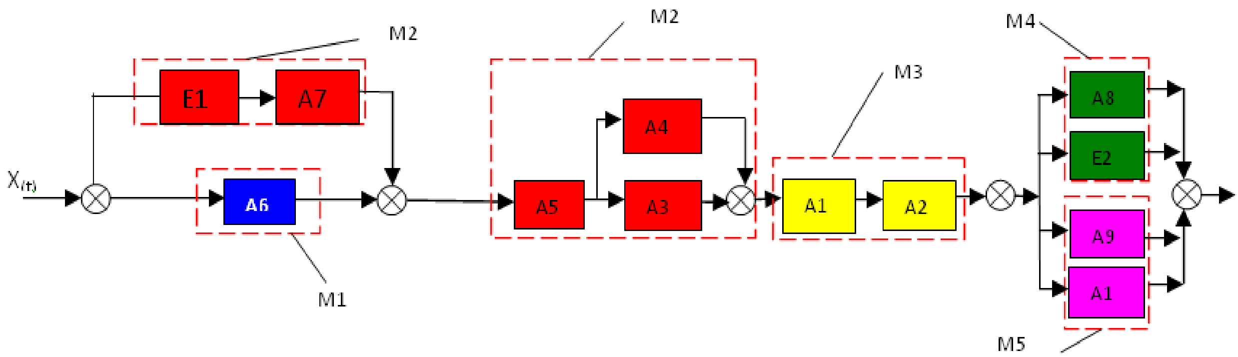
THE ANALYSIS OF FUNCTIONING OF BASIC COMPONENTS OF OE - TECHNICAL SYSTEM

[1.] ADVANCED (HIGH) SCHOOL OF APPLIED PROFESSIONAL STUDIES, VRANJE, SERBIA

ABSTRACT: The analysis of functioning of basic components of technical system is the basic type of monitoring systems and analyzing of state. Based on this, there are procedures of preventive maintenance, which have the grades of real state of work and components of technical system. This work contains co-relation between levels of mechanical oscillations (vibrations) of components in the system and their influence on the cause of system mallfunction. Corelation is based on forming the universal optimal working model for analyzing the system on chosen measurement points based on the influence of mechanical oscillations (vibrations). The methodology of state tracking has levels of amplitude spectrus of measurement values and oscillating the components of analyzed systems for those results. The values are the input for basic universal optimal model for different time intervals of system work, and based on those values the model dependence in the time oscillations (t), which represents the dependence of frequent safety of sub - system in function of their work)).These dependence is supported in the functioning of basic components of analyzed system in the case of their work with and without the basic maintenance.
KEYWORDS: Technical system OE – refractor, Safety of functioning, Reliably, Maintenance, Diagnostics, Optimal model, Safety frequency

INTRODUCTION

The analysis of the model included the methodology of using the algorithm in determining safety of the functioning constituent components of analyzed complex (complex box spinning) of OE – spinning machines (Picture 1).



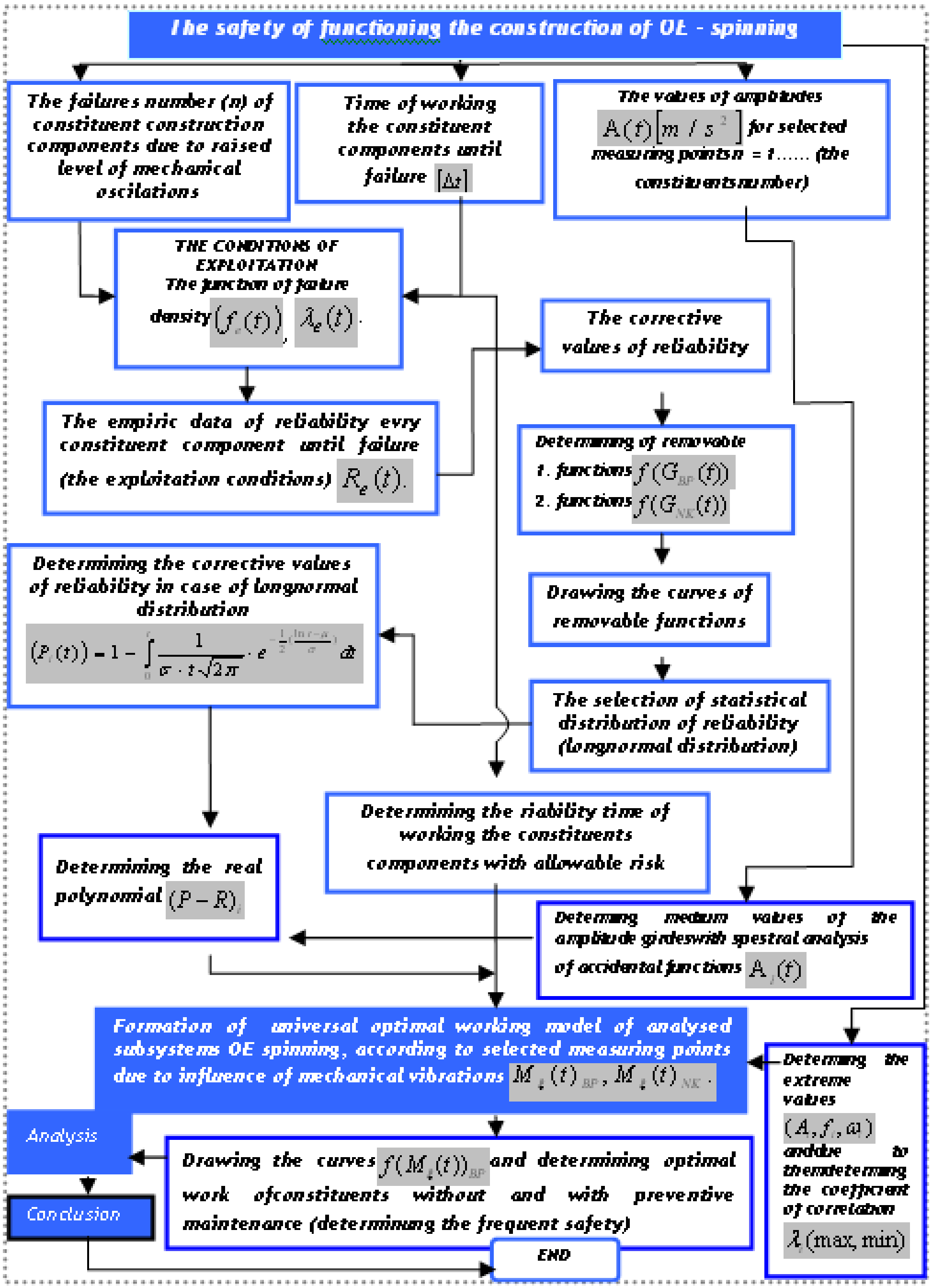
Picture 1. Display of spinning box complexes through structural blocks

where: **M1** – measuring point of the level of oscillations at the introductory channel,
M2 - measuring point of the level of oscillations on the lid of the rotor,
M3 - measuring point of the level of oscillations on the slanted part of the rotor lid,
M4 - measuring point of the level of oscillations on the branch of the wheel for keeping yarn
M5 - measuring point of the level of oscillations on mechanism of paraffin yarn .

The methodology included the construction of the monitoring system (Picture 2).

FORMATION OF UNIVERSAL OPTIMAL MODEL OF BOX SPINNING WORK ACCORDING TO SELECTED MEASURING POINTS BASED ON THE INFLUENCE OF MECHANICAL OSCILLATIONS - DETERMINATION OF FREQUENT SAFETY

In order to form universal optimal model of safety functioning it was necessary to determine all the parameters listed above theoretical and experimental analysis in algorithm of safety functioning, and then connect the same in mathematical form. This is done in analytic way in form of transfer functions of the optimal model $M_{\xi}(t)_{BP}$ that will define the frequent safety of work of analyzed complex (detailed mathematical expressions will be explained in this paper).

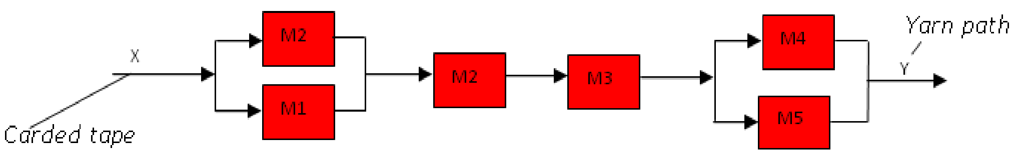


Picture 2. Monitoring system (algorithm) of methodology of determination of safety functioning of analyzed complex – OE spinning machines

Analysis of the model is carried out step by step in determining the submodels by selected measurement points for determining level of mechanical oscillations, and then it was made structure of block diagram connecting submodels that a way of moving of the processing from the entrance (carded tape) to the exit (yarn path).

Structural block diagram of transmission on selected measuring points is shown in picture 3.

With the introduced measurement markings of Mi (i = 1...5) transformation of the structure of the block diagram looks like the following (picture 3).



Picture 3. Transformed block diagram of transmission by submodel of complex box spinning

Note: This block diagram structure will be further used to determine the general form of transfer function of optimal model $M_{\xi}(t)_{BP}$ which will be defined as the frequent safety of boxes spinning.

In order to complete general form of transfer function of optimal model, it is necessary to determine the expressions for submodels (M_i) that are included in locations of measurement points for level oscillations.

***1)** Measurement point 1, includes component - an introductory channel (A6), which is a static component so that $\omega_{A6}=0$, so as authoritative speed which affects on level of oscillations $\omega_{A_6}(t)=f\left(A_1(t)_{A_6}\right)$ takes the input speed of carded tape $\vartheta_{iz}(t)$ which amounts as much as the speed of electromagnetic clips $\omega_{A_6}=\omega_{E_1}\neq\omega_1$.*

$\omega_1(t)$- is the angular circular speed of the complex on measurement point 1, as a function of oscillation amplitude $A_1(t)_{A_6}$.

$$\vartheta_{izl.}(t)=\vartheta_{K.T}=\vartheta_{A6}=\vartheta_{E1}=0{,}2\div 0{,}8\,[m/mm]$$

$$\vartheta_{A6}=\vartheta_{E1}\Rightarrow\omega_{A6}=\omega_{E1}=\frac{\vartheta_{A6}}{d_{E1}}=\frac{\vartheta_{E1}}{d_{E1}}\neq\omega_1(t).$$

Equation of submodel 1 is:

$$\boxed{\mathrm{M}_I=\frac{R_{A6}(t)\cdot \mathrm{A}_1(t)_{A_6}}{\omega_{E_I}=f(\omega_1)}\cdot t_1=\frac{(P-R)_{A_6}(t)}{\omega_1}\cdot t} \tag{1}$$

$R_{A6}(t)$ - reliability of work of the introductory channel in a useful period of work;

$\mathrm{A}_1(t)_{A_6}[m/s^2]$ - amplitude of oscillation of introductory channel in useful period of work on measurement point 1;

$\omega_{E1}[rad/s]$ - circular speed of electromotive clips;

$t_1[s]$- uptime components - introductory channel;

$(P-R)_{A_6}(t)$- polynomial with real coefficients which gives dependence of the reliability of component work of introductory channel in function of values of mechanical oscillations of levels on measurement point 1.

***2)** Measurement point 2, include components: electromagnetic clip (E1), cylinder for opening clumps of tape (A7), nozzles - rotor lid (A3), the outlet pipe (A4), and the intake box (A5). Given that the components: nozzles, the outlet pipe and the intake box are static components, as authoritative speed will be taken circular speed of roller (ω_{A7}).*

$$\vartheta_{A3}=\vartheta_{A4}=\vartheta_{A5}=const\Rightarrow\omega_{A3}=\omega_{A4}=\omega_{A5}=\omega_{E1}=\omega_{A7}\neq\omega_2.$$

$\omega_2(t)$- is the angular circular speed of complex on measurement point 2, and is in function of oscillation amplitude $A_2(t)_{E_1}, A_2(t)_{A_7}, A_2(t)_{A_3}, A_2(t)_{A_4}, A_2(t)_{A_5}$.

The first part for components E1 and A7 amounts :

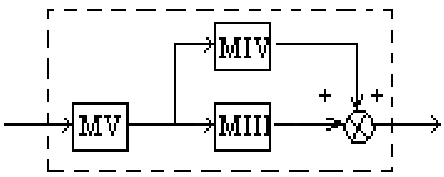
$$\mathrm{M}_{EI}=\frac{R_{E1}(t)\cdot \mathrm{A}_2(t)_{E1}}{\omega_{E1}=f(\omega_2)}\cdot t_2=\frac{(P-R)_{E_1}(t)}{\omega_2}\cdot t,$$
$$\mathrm{M}_{VII}=\frac{R_{A7}(t)\cdot \mathrm{A}_2(t)_{A7}}{\omega_{A7}=f(\omega_2)}\cdot t_3=\frac{(P-R)_{A_7}(t)}{\omega_2}\cdot t, \tag{2}$$

$(P-R)_{E1,A7}(t)$- polynomials with real coefficients, which give the dependence of the reliability of component work for electromagnetic clip (E1) and for clumps tape opener (A7), is in the function of level values of mechanical oscillations on measurement point 2.

Expression for resulting first part of submodel 2 is:

$$\boxed{M'_{III}=\mathrm{M}_{EI}\cdot\mathrm{M}_{VII}} \tag{3}$$

The second part is for integral components A3, A4, A5 and is (picture 4).



Picture 4. The second part of submodel 2

$$\mathrm{M}_{III}=\frac{R_{A3}(t)\cdot \mathrm{A}_2(t)_{A_3}}{\omega_{A7}=f(\omega_2)}\cdot t_4=\frac{(P-R)_{A_3}(t)}{\omega_2}\cdot t\ ,$$
$$\mathrm{M}_{IV}=\frac{R_{A4}(t)\cdot \mathrm{A}_2(t)_{A_4}}{\omega_{A7}=f(\omega_2)}\cdot t_5=\frac{(P-R)_{A_4}(t)}{\omega_2}\cdot t, \tag{4}$$
$$\mathrm{M}_{V}=\frac{R_{A5}(t)\cdot \mathrm{A}_2(t)_{A_5}}{\omega_{A7}=f(\omega_2)}\cdot t_6=\frac{(P-R)_{A_5}(t)}{\omega_2}\cdot t;$$

$(P-R)_{A_{3,4,5}}(t)$ - polynomials with real coefficients, which give the dependence of the reliability of component work for nozzle - rotor lid (A3), the outlet pipe (A4) and the intake box (A5) is in the function of level values of mechanical oscillations on measurement point 2.

So, expression for resulting second part of submodel 2 is:

$$\boxed{M''_{III}=\mathrm{M}_V\cdot\left(\mathrm{M}_{III}+\mathrm{M}_{IV}\right)} \tag{5}$$

The final equation of submodels 1 and 2, to the submodel 3 is:

$$\mathrm{M}_{1,2}=\left(M_1+M'_{III}\right)\cdot M''_{III}=\left(\mathrm{M}_1+\left(\mathrm{M}_{EI}\cdot\mathrm{M}_{VII}\right)\right)\cdot\left(\mathrm{M}_V\cdot\left(\mathrm{M}_{\mathrm{III}}+\mathrm{M}_{IV}\right)\right)=$$

$$\mathrm{M}_{1,2}=\begin{bmatrix}\dfrac{R_{A6}(t)\cdot A_1(t)_{A6}}{\omega_{E1}}\cdot t_1+\left(\dfrac{R_{E1}(t)\cdot A_2(t)_{E1}}{\omega_{E1}}\cdot t_2\cdot\dfrac{R_{A7}(t)\cdot A_2(t)_{A7}}{\omega_{A7}}\cdot t_3\right)\cdot\\ \cdot\left(R_{A5}(t)\cdot t_6\left(R_{A4}(t)\cdot t_5+R_{A3}(t)\cdot t_4\right)\cdot\dfrac{A_2(t)_{A5,A4,A3}}{\omega_{A7}}\right)\end{bmatrix}=\begin{bmatrix}\dfrac{(P-R)_{A_6}(t)}{\omega_1}\cdot t+\left(\dfrac{(P-R)_{E_1}(t)}{\omega_2}\cdot t\dfrac{(P-R)_{A_7}(t)}{\omega_2}\cdot t\right)\cdot\\ \cdot\left(\dfrac{(P-R)_{A_5}(t)}{\omega_2}\cdot t\cdot\left(\dfrac{(P-R)_{A_3}(t)}{\omega_2}+\dfrac{(P-R)_{A_4}(t)}{\omega_2}\right)\right)\end{bmatrix}. \tag{6}$$

3) *Measurement point 3, include components: rotor (A1), and aero bearing (A2). How aero bearing is the static component of authoritative speed, that affects on level of mechanical oscillations, rotor speed is* $\vartheta_{A1}=\vartheta_{rot}=115000\left[{}^{0}\!/_{\min}\right]$.

$$\omega_{A1}=\omega_{A2}=\frac{2\pi\,n_{rot.}}{60}=\frac{\pi\cdot n_{rot.}}{30},\omega_{A1}=\omega_{A2}=\frac{2\cdot\pi\cdot n_{rot.}}{3600}\cong 200\left[{}^{0}\!/_{\sec}\right]\neq\omega_3.$$

$\omega_3(t)$ *- is angular circular speed of complex on measurement point 3, and is in function of oscillation amplitude* $A_3(t)_{A_1},A_3(t)_{A_2}$.

Equation of submodel 3 is:

$$\mathrm{M}_3=\mathrm{M}_{\mathrm{I}}\cdot\mathrm{M}_{\mathrm{II}}=\frac{R_{A1}(t)\cdot A_3(t)_{A1}}{\omega_{A1}=f(\omega_3)}\cdot t_7\cdot\frac{R_{A2}(t)\cdot A_3(t)_{A2}}{\omega_{A1}=f(\omega_3)}\cdot t_8=\frac{(P-R)_{A_1}(t)}{\omega_3}\cdot t\cdot\frac{(P-R)_{A_2}(t)}{\omega_3}\cdot t=\frac{t^2}{\omega_3^2}\left((P-R)_{A_1}(t)\cdot(P-R)_{A_2}(t)\right). \tag{7}$$

$(P-R)_{A_{1,2,}}(t)$ *- polynomials with real coefficients, which give the dependence of the reliability of component work for rotor (A1) and aero bearing (A2), is in the function of level values of mechanical oscillations on measurement point 3.*

4) *Measurement point 4, include components – an electronic reader (E2) which is a static component and a wheel for conducting yarn (A8), their circular speeds are determining based on liferation speed (output speed) which is:*

$$\upsilon_{izl}=25\div 220\left[{}^{m}\!/_{\min}\right]\Rightarrow\omega_{izl.1}\neq\omega_4.$$

$\omega_4(t)$*- is angular circular speed of complex on measurement point 4, and is in function of oscillation amplitude* $A_4(t)_{E_2},A_4(t)_{A_8}$.

Equation of submodel 4 is:

$$\mathrm{M}_4=M_{EII}+M_{VIII}=\frac{R_{E2}(t)\cdot A_4(t)_{E2}}{\omega_{izl}=f(\omega_4)}\cdot t_9+\frac{R_{A8}\cdot A_4(t)_{A8}}{\omega_{izl}=f(\omega_4)}\cdot t_{10}=\frac{(P-R)_{E_2}(t)}{\omega_4}\cdot t.+\frac{(P-R)_{A_8}(t)}{\omega_4}\cdot t=\frac{t}{\omega_4}\left[(P-R)_{E_2}(t)+(P-R)_{A_8}(t)\right]. \tag{8}$$

$(P-R)_{E_2,A_8}(t)$ *- polynomials with real coefficients, which give the dependence of the reliability of component work for an electronic reader (E2) and a wheel for conducting yarn (A8), is in the function of level values of mechanical oscillations on measurement point 4.*

5) *Measuring point 5, include components – the yarn tensioner (A9) and mechanism for paraffin yarn (A10). Yarn tensioner performs harmonic-cyclic movement with 60 cycles per minute (cycle includes the movement of tensioner for certain angle and then return to its original position, as authoritative speed will be taken liferation speed (output speed).*

$$\vartheta_{lif.}=\vartheta_{izl.}\neq\omega_5.$$

$\omega_5(t)$ *- is angular circular speed of complex on measurement point 5, and is in function of oscillation amplitude* $A_5(t)_{A_9},A_5(t)_{A_{10}}$.

Equation of submodel 5 is:

$$\mathrm{M}_5=M_{IX}+M_X=\frac{R_{A9}(t)\cdot A_5(t)_{A9}}{\omega_{izl}=f(\omega_5)}\cdot t_{11}+\frac{R_{A10}\cdot A_5(t)_{A10}}{\omega_{izl}=f(\omega_5)}\cdot t_{12}=\frac{(P-R)_{A9}(t)}{\omega_5}\cdot t.+\frac{(P-R)_{A10}(t)}{\omega_5}\cdot t=\frac{t}{\omega_5}\left[(P-R)_{A9}(t)+(P-R)_{A10}(t)\right]. \tag{9}$$

The general form of universal equations of optimal model of complex spinning box is:

$$M_{\xi}(t)_{BP}=M_{1,2}\cdot M_3(M_4+M_5)=\begin{bmatrix}\dfrac{(P-R)_{A6}(t)}{\omega_1}\cdot t+\left\{\dfrac{t^2}{\omega^2{}_2}(P-R)_{E1}(t)\cdot(P-R)_{A7}(t)\right\}\cdot\\ \cdot\dfrac{(P-R)_{A5}(t)}{\omega_2}\cdot\dfrac{t}{\omega_2}\left\{(P-R)_{A3}(t)+(P-R)_{A4}(t)\right\}\cdot\\ \cdot\dfrac{t^2}{\omega^2{}_3}\left\{(P-R)_{A1}(t)\cdot(P-R)_{A2}(t)\right\}\cdot\\ \cdot\left[\dfrac{t}{\omega_4}\left\{(P-R)_{E2}(t)+(P-R)_{A8}(t)+\dfrac{t}{\omega_5}\left\{\begin{matrix}(P-R)_{A9}(t)+\\(P-R)_{A10}(t)\end{matrix}\right\}\right\}\right]\end{bmatrix} \tag{10}$$

By introducing shifts:

$$(P-R)_{A6}(t)=\xi_1;(P-R)_{E1}(t)\cdot(P-R)_{A7}(t)\cdot(P-R)_{A5}(t)=(P-R)_{E1,A7,A5}(t)=\xi_2;(P-R)_{A3}(t)=\xi_3;$$

$$(P-R)_{A4}(t)=\xi_4;(P-R)_{A1}(t)\cdot(P-R)_{A2}(t)=\xi_5;(P-R)_{E2}(t)=\xi_6;$$

$$(P-R)_{A8}(t)=\xi_7;(P-R)_{A9}(t)=\xi_8;(P-R)_{A10}(t)=\xi_{9.}$$

We get the general shift form of universal equation of optimal model of safety functioning of complex spinning box:

$$M_{\xi}(t)_{BP} = \frac{Y(t)}{X(t)} = \left[\left(\frac{t}{\omega_1}\cdot\xi_1 + \left(\frac{t}{\omega_2}\right)^3\cdot\xi_2(\xi_3+\xi_4)\right)\right]\cdot(\frac{t}{\omega_3})^2\cdot\xi_5\cdot\left\{\frac{t}{\omega_4}(\xi_6+\xi_7)+\frac{t}{\omega_5}(\xi_8+\xi_9)\right\} = \left(\frac{t^2}{\omega_3}\right)^2\xi_5\left\{\frac{1}{\omega_1}\xi_1+\frac{t^2}{\omega^3{}_2}\cdot\xi_2(\xi_3+\xi_4)\right\}\cdot\left\{\frac{1}{\omega_4}(\xi_6+\xi_7)+\frac{1}{\omega_5}(\xi_8+\xi_9)\right\}. \quad (11)$$

The introduction of circular speed in line of dependence of the oscillation amplitude from frequency – by introducing correlation coefficients $(\lambda_1,\lambda_2,\lambda_3,\lambda_4,\lambda_5,\lambda_6,\lambda_7)$ we get the general form of universal equations of transfer functions of optimal model of safety work of spinning box by selected measuring points based on the influence of mechanical oscillations.

$$M_{\xi}(t)_{BP} = \frac{Y(t)}{X(t)} = \lambda^2 3\cdot t^4\cdot\xi_5\left\{\lambda_1\cdot\xi_1+\lambda^3 2\cdot t^2\cdot\xi_2(\xi_3+\xi_4)\right\}\cdot\left\{\lambda_4\cdot(\xi_6+\xi_7)+\lambda_5\cdot(\xi_8+\xi_9)\right\}. \quad (12)$$

SUMMARY IN TESTING OF THE MODEL

Testing of the optimal model $M_{\xi}(t) = f(t)$ was carried out in the construction of the diagram on which are drawn curves of dependence of optimal model of safety functioning of work of analyzed complex OE – spinning according to selected measuring points on which were performed measurements of mechanical oscillations level. Testing included analysis of complex – spinning box of analyzed transmissions on which were not implemented actions of preventive maintenance technology and on those in which these proceedings are conducted in the case which involved extreme correlation values $(\lambda_{min},\lambda_{max})$.

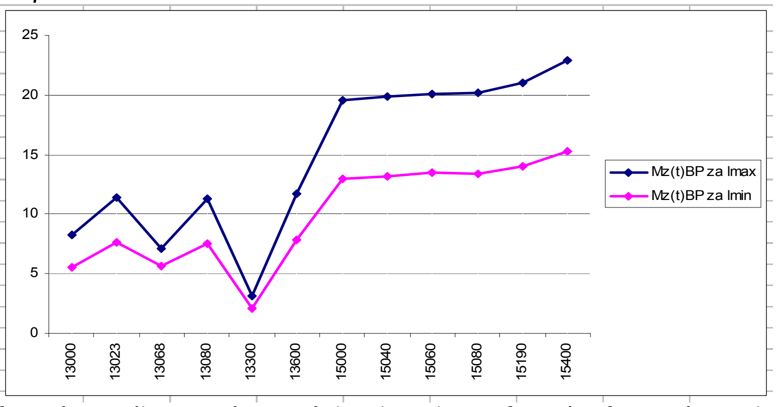
TESTING OF THE MODEL ON COMPLEX OF SPINNING BOX

Testing of the model on complex of spinning box was done according to the obtained numerical values of the factor of optimal model of safety functioning of his work. Based on them, boundary curves are constructed, as shown on the diagrams (pictures 5 and 6).

Picture 5 showes curves of frequent safety dependence of the exploitation time of work of constituent components of spinning box for optimal model of safety. Optimal model of safety includes the value of work of components within allowed risk. Displayed picture clearly showes the belt of absolutely safe work of analysed complex and it is located between values of shown curve dependencies $M_{\xi}(t)_{BP} = f(t)$. From the obtained diagram it clearly concludes that the risk of safe functioning of work of complex spinning box at the time of his work is 13 300 (h). Therefore it is essential to pay attention in this exploitation period. Over this period to provide continual testing of amplitude value of mechanical oscillations on selected measuring points. Also, on displayed diagram are indicated time periods of replacement of all necessary components of subsystem in order to obtain the greatest value of safety functioning.

It must be mentioned that the optimal model of safety functioning of work of spinning box formed in the areas of constituent components with allowed risk, because with unauthorized risk enters in the risk field of work of complex so you should immediately intervene in the part of replace of worn components or overhaul of coplex.

	Mz (t)BP za l max	Mz (t)BP za l min
13000	8.274	5.517
13023	11.37	7.59
13068	7.145	5.69
13080	11.3	7.537
13300	3.184	2.123
13600	11.7	7.803
15000	19.524	13.015
15040	19.836	13.222
15060	20.062	13.491
15080	20.15	13.437
15190	21.053	14.033
15400	22.863	15.243

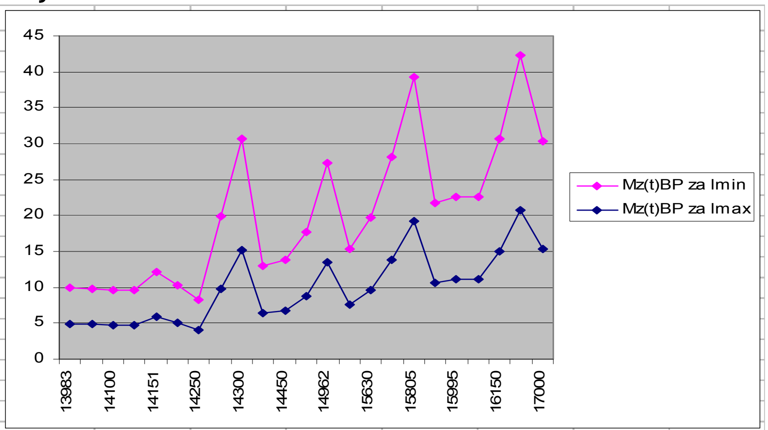


Picture 5. Diagram of frequent safety depending on the exploitation time of work of complex spining box components over which are without preventive technology-optimal model

Picture 6 shows curves of frequent safety dependence of the exploitation time of work of constituent components of spinning box for optimal model of safety. Optimal model of safety includes the value of work of components within allowed risk. Displayed picture 6 clearly shows the belt of absolutely safe work of analyzed complex and it is located between values of shown curve dependencies $M_{\xi}(t)_{BP} = f(t)$. From the obtained diagram it clearly concludes that the risk of safe functioning of work of complex spinning box at the time of his work is 14 250 (h). Therefore it is essential to pay attention in this exploitation period. Over this period to provide continual testing of amplitude value of mechanical oscillations on selected measuring points. Also, on displayed diagram are indicated time periods of replacement of all necessary components of subsystem in order to obtain the greatest value of safety functioning.

It must be mentioned that the optimal model of safety functioning of work of spinning box formed in the areas of constituent components with allowed risk, because with unauthorized risk enters in the risk field of work of complex so you should immediately intervene in the part of replace of worn components or overhaul of subsystem.

h	Mz (t)BP za l max	Mz (t)BP za l min
13983	4.89	5.05
14001	4.9	4.95
14100	4.69	4.842
14128	4.7466	4.9
14151	5.938	6.124
14200	5.048	5.211
14250	4.0571	4.153
14251	9.818	10.138
14300	15.09	15.57
14301	6.399	6.6
14450	6.81	7.023
14600	8.7	8.97
14962	13.442	13.86
15000	7.519	7.837
15630	9.624	10.031
15730	13.777	14.36
15805	19.224	20.037
15905	10.673	11.15
15995	11.04	11.53
16000	11.06	11.55
16150	14.983	15.648
16300	20.658	21.577
17000	15.295	14.97



Picture 6. Diagram of frequent safety depending on the exploitation time of work of complex spining box components over which are not implemented procedures of preventive maintenance technology-optimal model

COMPLEX OF BOX SPINNING

***a)** Without procedures of preventive maintenance technology*

From constructed diagrams for curves $M_{\xi}(t)_{BP} = f(t)_{\lambda_{max}}, M_{\xi}(t)_{BP} = f(t)_{\lambda_{min.}}$ it can be concluded that the overall risky belt of exploitation time of analyzed complex in the period $t \approx 13300(h)$ which indicares that in this period of exploitation should be made constant checking of amplitude values of mechanical oscillations. Values of dependence of safety functioning for this exploitation period are $M_{\xi}(t)_{BP_{\lambda\,max.}} = 3{,}184 \cdot 10^{10}$ and $M_{\xi}(t)_{BP_{\lambda\,min.}} = 2{,}123 \cdot 10^{6}$. The best safety starts in the period of $t_I \approx 15190(h)$ and has a value $M_{\xi}(t)_{BP_{\lambda\,max.}} = 21{,}053 \cdot 10^{10}$ i $M_{\xi}(t)_{BP_{\lambda\,min.}} = 14{,}033 \cdot 10^{6}$. Total percentage of risk decrease or increase of safety functioning is $R_{(t_I - t)} = (21{,}053 \cdot 10^{10} - 14{,}233 \cdot 10^{6}) - (3{,}181 \cdot 10^{10} - 2{,}123 \cdot 10^{6}) = 1{,}79 \cdot 10^{11}.$ This analysis showes that particular attention should be given to the implementation of diagnosis because total percentage amount is very big in a part of risk for the specified belt of exploitation time of $t \approx 13300(h)$.

Also, on constructed diagrams on curves of dependence are specified times of replacement of components of coplex, because exploitation after mentioned time creates risk in its operation.This applies to all components of analyzed complex.

***b)** With the impletation of procedures of preventive maintenance technology*

From constructed diagrams for curves $M_{\xi}(t)_{BP} = f(t)_{\lambda_{max}}, M_{\xi}(t)_{BP} = f(t)_{\lambda_{min.}}$ it can be concluded that the overall risky belt of exploitation time of analyzed complex in the period $t \approx 14250(h)$ which indicares that in this period of exploitation should be made constant checking of amplitude values of mechanical oscillations. Values of dependence of safety functioning for this exploitation period are $M_{\xi}(t)_{BP_{\lambda\,max.}} = 4{,}0571 \cdot 10^{12}$ and $M_{\xi}(t)_{BP_{\lambda\,min.}} = 4{,}153 \cdot 10^{8}$. The best safety starts in the period of $t_I \approx 16150(h)$ and has a value $M_{\xi}(t)_{BP_{\lambda\,max.}} = 14{,}983 \cdot 10^{12}$ and $M_{\xi}(t)_{BP_{\lambda\,min.}} = 15{,}648 \cdot 10^{8}$.

Total percentage of risk decrease and increase of safety functioning is $R_{(t_I - t)}^{*} = (14{,}983 \cdot 10^{12} - 15{,}648 \cdot 10^{8}) - (4{,}0571 \cdot 10^{12} - 4{,}153 \cdot 10^{8}) = 1{,}09 \cdot 10^{13}.$ This analysis showes that particular attention should be given to the implementation of diagnosis because total percentage amount is very big in a part of risk for the specified belt of exploitation time of $t \approx 14250(h)$.

Overall efficiency of the increasing of safety functioning for complex spinning box which at the same time represents and reduction of risk, is:

$$\bigcup srM_{\xi}(t)_{(\lambda_{min.}, \lambda_{max.})BP} = \frac{R_{(t_I - t)}^{*} - R_{(t_I - t)}}{R_{(t_I - t)}^{*}} = \frac{1{,}09 \cdot 10^{13} - 1{,}79 \cdot 10^{11}}{1{,}09 \cdot 10^{13}} \approx 0{,}98 \approx 98\%. \qquad (13)$$

CONCLUSIONS

Safe of functioning is defined by introducing an algorithm of monitoring systems (expert systems) that describes procedures for obtaining referent curves of frequent safety for cases of monitoring the state with technology actions of preventive maintenance and without them.

Based on the values of all parameters involved (which are determined by analytic or experimental way) in the formation of universal optimal model of work of components of analyzed complex – spinning box OE of spinning machine for the selected measuring points an analysis of universal optimal model of safety functioning of analyzed complex is performed. It was conducted step by step in determining submodels by selected measuring points with measuring level of mechanical oscillations, and then it was performed connecting of submodels in structural block schemes – structural block diagrams. Based on the analytical approach, mathematical expressions of submodels are determined, that are included by locational measuring points of mechanical oscillations level and it was conducted their interconnection based on structural block schemes, by which are determined analytical general formes of the transfer functions of optimal work of the model $M_\xi(t)_{BP} = f(t)$ *which defined frequent safety of work of analyzed complex – spinning box.*

By establishing a universal optimal model, determines values of frequent safety of work of analyzed complex in every exploitation period of work and based on that it can be predicted its operating conditions.

By determining frequent safety of work of analyzed complex it was conducted testing of the model which included construction of curves of dependence of optimal model of safety functioning work of analyzed complex in function of its work, in the time period of monitoring the work of complex when it has safe and proper operation. Diagrams are constructed in system and with them are determined areas that limits dependence of frequent safety from exploitation work of analyzed complex with allowed risk.

The analysis is conducted in two cases, on analyzed complex where procedures of preventive maintenance technology are not implemented and on one on which these procedures are implemented. Based on the constructed diagrams, boundary conditions of safe functioning of work of analyzed complex are determined and it was determined the effect of increase of safety of his functioning, for complex box of spinning. The effect of increasing the safety of functioning is defined as the quotient: differences of safety functioning of extreme values with technology of preventive maintenance procedure and without these procedures (the numerator) and with the values of safety functioning of extreme values with technology of preventive maintenance procedures (in the denominator) and is expressed:

$$\cup_{\max.} M_\xi(t) = \frac{M_\xi(t)\max.(\text{with the maintenance}) - M_\xi(t)\max.(\text{without maintenace})}{M_\xi(t)\max.(\text{with the maintenance})}\{for \cdot \lambda_{\max}\} \quad (14)$$

$$\cup_{\min.} M_\xi(t) = \frac{M_\xi(t)\min.(\text{with the maintenance}) - M_\xi(t)\min.(\text{without maintenace})}{M_\xi(t)\min.(\text{with the maintenance})}\{for \cdot \lambda_{\min}\} \quad (15)$$

With analysis of referent boundary curves (Pictures 5 and 6) which gave dependence of frequent safety from exploitation work of analyzed complex with allowed risk, came to the following conclusions: the effect of increasing safety functioning by application of universal model of safe functioning for complex of box spinning is:

$\cup_{\max.} M_\xi(t)_{BP} = 0{,}9889(98{,}89\%)$ *to values* $\lambda_{\max.}$*,*

$\cup_{\min.} M_\xi(t)_{BP} = 0{,}993(99{,}3\%)$ *to values* $\lambda_{\max}$*,*

$\cup_{\max.} M_\xi(t)_{BP} = 0{,}9929(99{,}29\%)$ *to values* $\lambda_{\min.}$*,*

$\cup_{\min.} M_\xi(t)_{BP} = 0{,}99488(99{,}488\%)$ *to values* $\lambda_{\min}$

Mean values of effect with maximum value of the correlation coefficient $\lambda_{\max.}$*:*

$$\cup sr.M_\xi(t)_{BP} = \frac{\cup_{\max.} M_\xi(t)_{BP} + \cup_{\min.} M_\xi(t)_{BP}}{2} = \frac{99{,}3\% + 98{,}89\%}{2} \cong 99{,}1\%. \quad (16)$$

Mean values of effect with minimum value of the correlation coefficient $\lambda_{\min.}$*:*

$$\cup sr.M_\xi(t)_{BP} = \frac{\cup_{\max.} M_\xi(t)_{BP} + \cup_{\min.} M_\xi(t)_{BP}}{2} = \frac{99{,}488\% + 99{,}29\%}{2} \cong 99{,}4\%. \quad (17)$$

From the analysis of the effect it is concluded that increase of safety by using optimal model increases its mean value: Complex – of box spinning to:

$$\cup sr.M_\xi(t)_{BP(\lambda_{\max.},\lambda_{\min.})} = \frac{99{,}1\% + 99{,}4\%}{2} = 99{,}25\%.$$

This justifies the introduction of this model in the security of functioning of components of analyzed complex because its making significant savings, increases productivity of OE spinning machine in values that includes shown effects.

Analysis of the model showed up to which limits analyzed complex has proper and safe operation. Constructed boundary curves determined dependence of frequent safety in function of *exploitation work of analyzed complex with allowed risk – optimal work of analyzed complex. Values of frequent safety $M_{\xi}(t)_{BP,NK} = f(t_R)$ above the boundary curves represent the state of work of analyzed complex with risk that is not allowed, its unauthorized state of correctness.*

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