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ANALYSIS OF CHARACTERISTICS OF HARDWARE MEANS FOR SOFTWARE CONTROL OF THE LONGITUDINAL FEED OF THE GRINDING WHEEL

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Abstract: *The purpose of the work is to create productive hardware based on modern software to control technological processes' parameters. Laplace transforms are performed to mathematically model the delayed components. For the first time a mathematical model of a computing block is proposed in the form of sequentially connected zero-order extrapolators and an aperiodic delay circuit, which is determined by the duration of the input signal processing process. A block diagram of programmable control system of the longitudinal feed of the grinding wheel is constructed and the transfer function is obtained. An information technology for adjusting the frequency characteristics of hardware using the neural network technology method is developed, which is to regulate the length of information links between the components of the transfer function. It is established that the change in the gain of the aperiodic chain affects the transmission coefficient of the control system and the phase characteristic does not change. Based on the discrete Laplace transform using the Matlab software environment with the Simulink extension, a scheme of computer simulation of the conversion process by the input hardware is constructed. The method of identification of the parameters of mathematical models of hardware for controlling the longitudinal flow of the grinding wheel is proposed.*

Key words: *frequency response method, hardware, performance, mathematical and computer simulation.*

1. INTRODUCTION

Implementation of hardware means for software control of the technological process' parameters is intended to shorten the machining time of a workpiece and to obtain specified surface roughness. Well-known hardware means are of a wide range of input signals, physical nature of data channels, measurement errors and information processing. Production environment of the diamond grinding process is characterized by an increased level of interference and backlash of mechanical joints inherent to gears. These features of the diamond grinding process lead to poor hardware accuracy of programmable setting of its parameters. Therefore, development of the concept of programmable movements to achieve the goal, creation of theoretical foundations and methodology for building hardware with improved input processing performance will ensure the economic efficiency of technological processes [1-4].

1.1 Literature data analysis and problem statement

To automate mathematical calculations, modern computer mathematics offers a complete set of integrated software systems and application packages: Eureka, Gauss, Derive, MathCAD, Mathematical, Maple V, Matlab, Scilab, and others [5-8]. The basis for their development is the matrix operations that solve the problems of linear algebra, hardware mathematical modeling, as well as establish accuracy and speed of input information processing. Matlab software with Simulink extension provides ample opportunities for investigating the dynamics of the control processes automatically with the help of appropriate systems.

Known methods of analysis and synthesis of hardware tools, as well as metrological characteristics and productivity of input information processing are outlined in [9-10]. The basis of their development is the computing capabilities provided by Matlab software environment with Simulink extension. The method of frequency characteristics in hardware synthesis uses the representation of the input signal in the form of Fourier transform. The computational procedure for calculating the output signal of the automatic control system (ACS) is quite complicated, so this method is usually applied to the analysis of simple expressions of transmitting functions. By virtue of the use of the graphical integration method, it is possible to increase the productivity of the process of calculating the output ACS signal [11]. The technique [12-15] of hardware synthesis, accuracy and speed of processing of set input signals, solves a number of tasks: mathematical modeling of components; definition and research of the transfer function; construction of computer simulation of the information conversion process; measuring the quality, accuracy and speed of the hardware tools. Its practical implementation involves the use of a sufficiently large amount of manual labor, which significantly reduces the productivity of the process of synthesizing hardware tools of software control of the parameters of technological processes.

1.2 The purpose and directions of the study

The purpose of the work is to create efficient hardware means for software control of the longitudinal feed of the grinding wheel on the basis of modern software environments.

To achieve the goal the following problems need to be solved:

- get a mathematical model of the performing mechanism (PM) of the main drive of a machine tool;
- build a structural diagram of ACS and conduct mathematical modeling of its components;
- develop a technique for investigation of ACS frequency characteristics;
- develop information technology for correction of ACS frequency characteristics based on the methods of neural network technologies;
- construct a scheme of computer simulation of the process of hardware conversion of the input signal.

2. RESEARCH MATERIALS AND METHODS

The authors employed continuous and discrete Laplace transform as a mathematical apparatus of research. Software for processing the results of theoretical studies of the dynamics of the automatic control of the longitudinal flow of the grinding wheel is developed on the basis of the computational capabilities provided by the Matlab software environment with the Simulink extension.

2.1 Mathematical modeling of hardware tools

The authors used a direct current motor as a PM. Instantaneous rotational speed of the engine shaft is an output signal, the stability of which provides ACS. The behavior of the engine is described by the following transition function [17]

$$W_1(p) = W_e(p) W_m(p) \approx \frac{k_1 k_2}{(T_1 p + 1)(T_2 p + 1)}. \quad (1)$$

where for the engine type DPU 160-180-3-Д33 there is: $k = k_1 k_2 = 1.143 \times 7.754 = 8.863$ – the coefficient of engine conversion; $T_1 = L/R = 0.000574\,C$, $T_2 = J\,R/(c_1 c_2) = 0.0149\,C$ are electromagnetic and mechanical constants of time respectively.

Expression (1) is used for the development of the structural scheme of ACS of the longitudinal feed of the grinding wheel (Fig. 1). The basis of its construction is the principle of deviation control. The scheme is composed of such elements: database (DB) of optimal operating modes; zero-order extrapolator (E); computing unit (CU) based on the STM32F745 microcontroller; thyristor rectifier (TR); PM control voltage amplifier (A); analog to digital converter (ADC). So development of hardware mathematical models and analysis of the structural scheme of ACS is performed in order to obtain an expression for the transfer function.

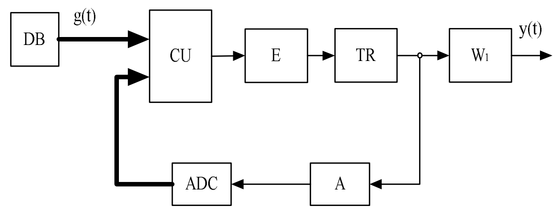

Fig. 1. Block diagram of ASC

CU component compares the current of the engine control with the optimal value out of the DB block. Information technology of signal processing is as follows: transformation of the output signal of the amplifier into a digital code, comparison of the obtained information, calculation of control influence for the PM. Computational procedures take a certain period of time, the duration of which is calculated based on the number of commands of the control program and the clock frequency of the system generator of the microcontroller. So CU when performing computational procedures is submitted in the form of a proportional chain with a delay. Output CU signal is a control one for the PM. Thus, based on expression (5), representation of the transfer function of the CU is the following

$$W_3(p) = \frac{k_1 k_3 e^{-p\tau_3}}{T_1 p + 1}. \qquad (2)$$

where $\tau_3 = 0.001\,C$ is CU lagging, and $k_3 = 0.1$ is a transformation coefficient.

Given that $e^{p\tau_3} \approx 1 + p\tau_3$, after a simple mathematical transformation, the CU transfer function is the following

$$W_3(p) = \frac{k_1 k_3}{(p\tau_3 + 1)(pT_1 + 1)}. \qquad (3)$$

The transfer function of the block E is described by the expression [16]

$$W_4(p) = \frac{1 - e^{-p\tau_e}}{p}. \qquad (4)$$

where $\tau_e = 0.001\,C$.

After simple mathematical transformations, expression (4) acquires the following form

$$W_4(p) = \frac{\tau_e}{1 + p\tau_e}. \qquad (5)$$

Specificity of the work of the TR block as a SAC of the longitudinal feed of the grinding wheel allows to submit it in the form of an aperiodic chain [11]

$$W_5(p) = \frac{k_5}{T_5 p + 1}. \qquad (6)$$

where $k_5 = 25, T_5 = 0.01\,C$.

Information about the optimal values of the tool feed is located in the DB block. Therefore, we submit it in the form of a proportional chain with the following transfer function

$$W_6(p) = 1. \qquad (7)$$

Operational specifics of the ADC and A blocks as a part of ACS of the longitudinal feed of the grinding wheel allows to submit them in the form of a proportional chain with a delay. The transmission function of this chain is of the following configuration [11]

$$W_7(p) = k_7 e^{-p\tau_7}. \qquad (8)$$

where $k_7 = (k_1 k_3 \tau_e k_5)^{-1}, \tau_7 = 0.00045\,C$ are selected subject to the normalization of the corresponding conversion rates.

The transmission function of ADC and A blocks after mathematical transformations takes on the following configuration

$$W_7(p) = \frac{k_7}{1 + p\tau_7}. \qquad (9)$$

After establishing the components' transfer functions of the ACS of the longitudinal feed of the grinding wheel, it is time to proceed to the development of the information technology for the research of its frequency characteristics within the Matlab software environment.

2.2 Information technology for frequency characteristics research

Calculation of frequency characteristics of the ACS of the longitudinal feed of the grinding wheel is performed in command mode. The corresponding transfer functions of the components are the source data for the Matlab environment. They are presented as follows

W1=tf([k],[T1*T2 T2+T2 1]);
W3=tf([k1*k2],[τ3*T1 τ3+T1 1]);
W4=tf([τe],[τe 1]);
W5=tf([k5],[T5 1]);
W7=tf([k7],[τ7 1]).

Capabilities of the Matlab environment allow defining the transfer function of ACS. To calculate it the following command is used
W=W1*W3*W4*W5/(1+W3*W4*W5*W7).

The information technology for calculating frequency characteristics of ACS of the longitudinal feed of the grinding wheel consists of the following computational procedures:

- in Matlab environment, the logarithmic amplitude and phase-frequency characteristics (LAPFC) are constructed using the bode command (W);
- using the command *nyquist* (W) the Nyquist hodograph is defined;
- using the command *margin* (W) the margin of amplitude stability is calculated;
- transient ACS response is built using the command *step* (W);
- impulse transient ACS response is built using the command *impulse* (W);
- similar calculation results are obtained using the command *ltiview* (W), with the appropriate settings in the «Plot Configuration» menu.

Results of LAPFC calculations, the Nyquist hidographer, transient and pulse transition characteristics of the ACS are obtained using the command *ltiview* (W), with the appropriate settings in the «Plot Configuration» menu and is shown in Fig. 2.

Obtained data for the search for zeros and poles of the transfer function (*zero* and *pole* commands) is shown in Table 1.

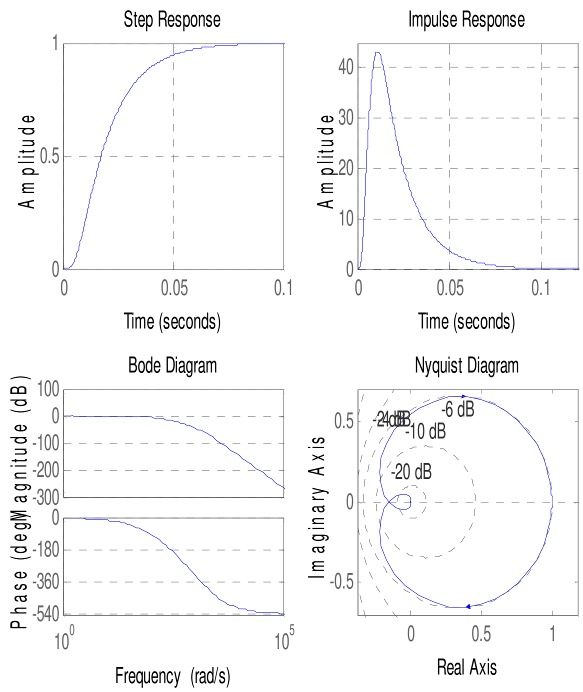

Fig. 2. ACS characteristics

Table 1

Zeros and poles of the transfer function

Zero	Pole
-2222.2	-2368.0 + 0.0000i
-1742.2	-1543.2 + 505.5i
-1000.0	-1543.2 - 505.5i
-1000.0	-1742.2 + 0.0000i
-100.0	-1742.2 + 0.0000i
	-1000.0 + 0.0000i
	-1000.0 + 0.0000i
	-305.0 + 176.0i
	-305.0 - 176.0i
	-100.0 + 0.0000i
	-67.1 + 0.0000i

Analysis of data in Table 1 allows to draw the following conclusions:

- all the roots of the characteristic equation satisfy the condition of stability of ACS of the longitudinal feed of the grinding wheel;
- the roots of the numerator and denominator of the transfer function approximately matched by value are reduced;
- the roots one, two and three affect the beginning of the transition process, so they can be excluded from the presentation of the transfer function;
- ACS of the longitudinal feed of the grinding wheel is represented by the following transfer function

$$W_8(p) = \frac{1}{(p+67.1)\left[(p+305.0)^2 + 176.0^2\right]}. \quad (10)$$

After simple mathematical transformations, the expression (10) takes on the following form

$$W_8(p) = \frac{1}{1.202 \cdot 10^{-7} p^3 + 8.138 \cdot 10^{-5} p^2 + 0.02p + 1}. \quad (11)$$

The features of the Matlab software environment make it possible to compare the expressions for the transfer function of ACS of the longitudinal feed of the grinding wheel. Comparison results are obtained in the form of charts (Fig. 3) by using the following command W8=tf([1],[1.202*10^-07 8.138*10^-05 0.02 1]); step(W,W8); grid

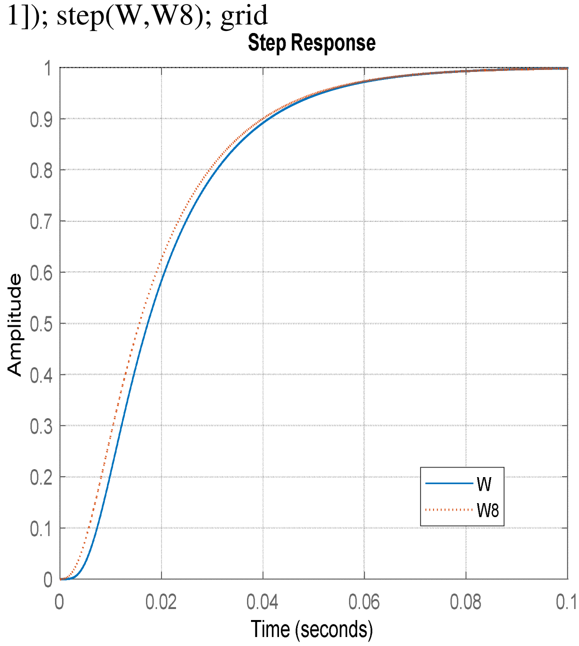

Fig. 3. Comparison of transient characteristics

The results of the analysis of the graphs make it possible to draw the following conclusions: simplification of the transfer function expression of the ACS of the longitudinal feed of the grinding wheel is quite correct. By using the command *margin* (W7) the ACS stability margin by amplitude is calculated (fig. 4).

As a result of the analysis of the obtained graph, it is established that the ACS transparency band by the longitudinal flow of the grinding wheel is 0 - 408 rad/s. Such ACS transparency bandwidth satisfies the requirements of the frequency spectrum of the measurement information signal. Let us proceed to the development of a computational procedure for identifying the parameters of the ACS mathematical model.

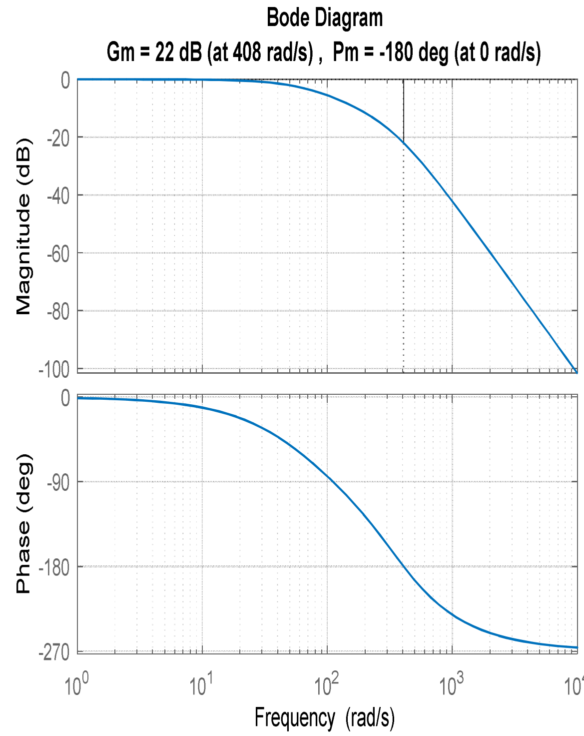

Fig. 4. Calculation of the ACS stability margin by amplitude

2.3 Identification of the parameters of ACS mathematical model

The Learning Model Method [13] was conveniently applied by the authors to identify the parameters of the mathematical model of ACS of the longitudinal feed of the grinding wheel. Based on the methods of neural network technologies [18], the following methodology was developed for performing the procedure specified below:

- decomposition of the expression of the transfer function onto simple multipliers;
- summation of the multipliers of the transfer function is performed using coefficients that change the length of the links;
- tuning of the length of the links is made by comparing the output signal of the model with the signal received as a result of experimental data processing.

Decomposition of the transfer function into simple multipliers gives the expression

$$W_9(p) = \frac{A_1 T_{11}}{T_{11}p+1} + \frac{A_2}{\left(a_8^2+b_8^2\right)\left(\frac{1}{a_8^2+b_8^2}p^2+\frac{2a_8}{a_8^2+b_8^2}p+1\right)}. \quad (12)$$

where the coefficients are determined by means of the following system of algebraic equations

$$\left.\begin{aligned} A_1 T_{11} + \frac{A_2}{a_8^2+b_8^2} = 1 \\ 2a_8 A_1 + A_2 = 0 \end{aligned}\right\}. \quad (13)$$

As a result of solving it the following expressions for calculating the coefficients are obtained

$$A_1 = -\frac{A_2}{2a_8}, \quad A_2 = \frac{2a_8\left(a_8^2+b_8^2\right)}{2a_8 - T_{11}\left(a_8^2+b_8^2\right)}$$

Subject to the change in the length of links between simple multipliers, expression (12) takes on the following form

$$W_9(p) = \frac{1.493\mu_1}{T_{11}p+1} - \frac{0.493\mu_2}{\frac{1}{a_8^2+b_8^2}p^2+\frac{2a_8}{a_8^2+b_8^2}p+1}. \quad (14)$$

where μ_1, μ_2 are scale factors that change the length of the links between transfer function components.

The method of correcting the frequency characteristics of ACS of the longitudinal feed of the grinding wheel are considered on the example of LAPFC with the following values of coefficients: $\mu_1 = 1.5, \mu_2 = 1$. The command line is of the following view

W11=tf([2.24],[0.0149 1]);
W12=tf([-0.493],[8.064*10^-6 4.919*10^-3 1]);
W13=W11+W12.

Transformation of these expressions by the Matlab software environment makes the transfer function of the ACS of the longitudinal feed of the grinding wheel to take the following figuration

$$W_{13}(p) = \frac{1.747}{1.202\cdot10^{-7}p^3+8.136\cdot10^{-5}p^2+0.0198p+1}. \quad (15)$$

Comparison is performed using the following command:
bode (W8,W13); *grid*.

The comparison results are presented as a graph (Fig. 5). An increase in the A_1 coefficient influences gain of the ACS of the longitudinal feed of the grinding wheel, while its LAPFC does not change.

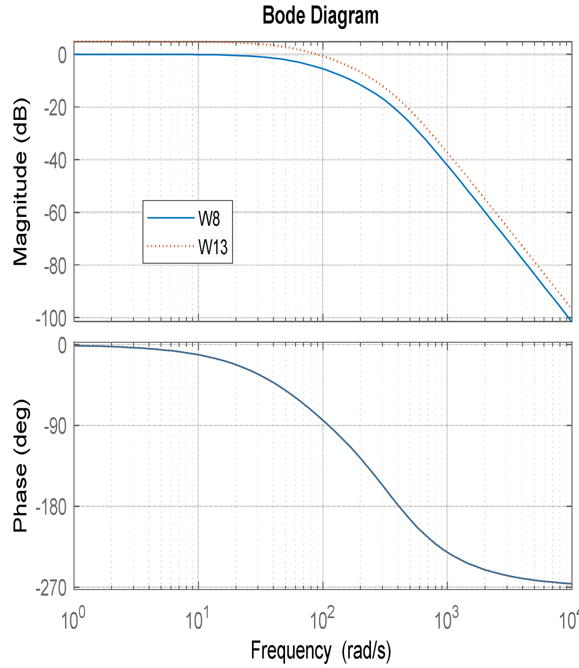

Fig. 5. Comparison of LAPFC

For the coefficients' values $\mu_1 = 1.0, \mu_2 = 1.5$ the command line of the link length change between the components of the transfer function is as follows

W14=tf([1.493],[0.0149 1]);
W15=tf([-0.7395],[8.064*10^-6 4.919*10^-3 1]);
W16=W14+W15.

Transformation of the latter expressions by the Matlab software makes the transfer function of the ACS of the longitudinal feed of the grinding wheel to take the following figuration

$$W_{16}(p) = \frac{0.7535}{1.202\cdot10^{-7}p^3+8.136\cdot10^{-5}p^2+0.0198p+1}. \quad (16)$$

The comparison is performed by the following command:
bode(W8,W16); grid.

The results of the comparison are presented in the form of a graph (Fig. 6). Increase of the A_2 coefficient of amplification of the oscillating circuit reduces the transmission coefficient of the ACS of the longitudinal feed of the grinding wheel, but its LAPFC does not change.

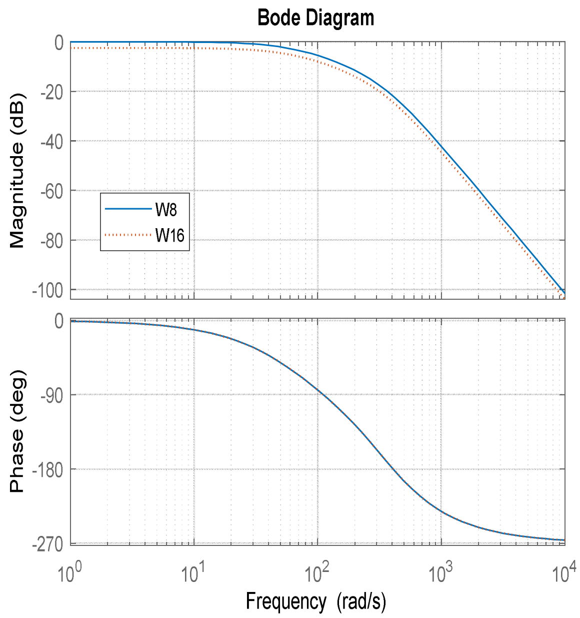

Fig. 6 Comparison of LPFC

Let's move on to a scheme of computer simulation of the process of transformation of ACS input signal by hardware means. For this purpose the mathematical apparatus of z-transformations is used.

2.4 Development of computer simulation scheme

To research the process of converting the input signal by hardware means of ACS of the longitudinal feed of the grinding wheel, Matlab software environment with Simulink extension is utilized. In accordance with the z-transform table, the expression (12) takes on the following form

$$W_{14}(z)=\frac{A_1 z}{z-f}+\frac{A_2 zf\sin bT}{z^2-2zf\cos bT+f^2}. \quad (17)$$

where $f=e^{-aT}$, $T=0.005\ C$ is quantization period.

After simple mathematical transformations the discrete transmitting function acquires the following form

$$W_{15}(z)=\frac{b_1^{\circ}z+b_2^{\circ}z^2+b_3^{\circ}z^3}{a_0^{\circ}+a_1^{\circ}z^1+a_2^{\circ}z^2+a_3^{\circ}z^3}. \quad (18)$$

where $a_0^{\circ}=-e^{-Tp_{10}}e^{-2Ta_5}$,

$a_1^{\circ}=e^{-Ta_5}\left(e^{-Ta_5}+2e^{-Tp_{10}}\cos b_5 T\right)$;

$a_2^{\circ}=-\left(2e^{-Ta_5}\cos b_5 T+e^{-Tp_{10}}\right)$; $a_3^{\circ}=1$;

$b_1^{\circ}=e^{-Ta_5}\left(A_1 e^{-Ta_5}-A_2 e^{-Tp_{10}}\sin b_5 T\right)$,

$b_2^{\circ}=-e^{-Ta_5}\left(2A_1\cos b_5 T-A_2\sin b_5 T\right)$; $b_3^{\circ}=A_1$.

The results of the coefficients' calculations give the expression (13) the following form

$$W_{16}\left(z^{-1}\right)=\frac{1.493z^3-0.497z^2+0.13z}{z^3-0.992z^2+0.246z-0.034}. \quad (19)$$

Based on the last expression, a scheme of computer simulation of the process of hardware conversion of input information is made (Fig. 7). The results of computer simulation are given in Fig. 8.

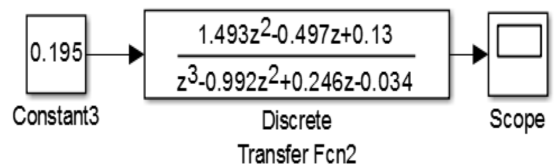

Fig. 7. Scheme of computer simulation

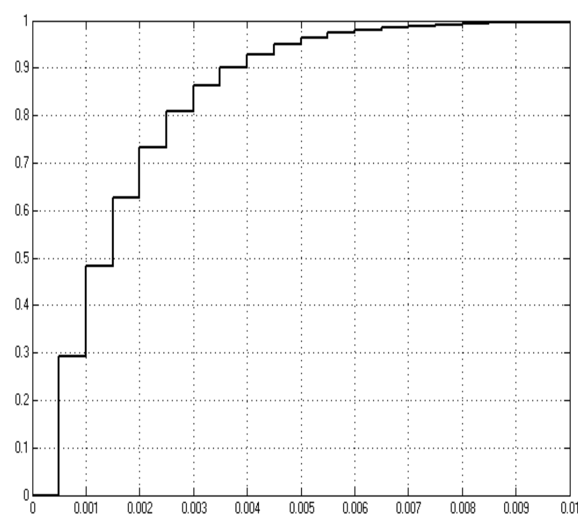

Fig. 8. Computer simulation results

Analysis of the results of computer simulation allows the authors to make the following statements:

- comparison of the graphs in Fig.3 and Fig.8 testifies to the correctness of the scheme of computer simulation of the process of transformation of input information by hardware means;

- the nature of the hardware output signal from the ACS of the longitudinal feed of the grinding wheel is an aperiodic one;
- there is no distortion of the output signal from the hardware;
- the transformation speed of the ACS of the input signal by hardware means is 0.008 s, which meets the specified requirements;
- the quality of the transient process meets the requirements of the ACS of the longitudinal feed of the grinding wheel.

3. DISCUSSION OF THE RESEARCH RESULTS

A transfer function of the PM in the form of a serial connection of two aperiodic circuits is proposed, which establishes information links between the control signal and the instantaneous speed of the shaft rotation. On this basis, the structural scheme of the ACS of the longitudinal feed of the grinding wheel was developed. For the first time, a sequentially coupled zero-order extrapolator and an aperiodic delayed chain were proposed as a CU mathematical model. This view is correct enough because the load on the output link of the CU is a DC motor. The information technology for frequency response studies is built on the capabilities of the Matlab software environment for relevant calculations. Based on the use of neural network techniques, the information technology of frequency response of the ACS of the longitudinal feed of the grinding wheel was developed and the influence of the change in the link length between simple factors of the transfer function was investigated. It was established that the change in the gain of the aperiodic chain affected the transmission coefficient of the ACS, while its LAPFC did not change. It is found that the increase of the oscillation gain of the oscillatory circuit decreases the signal transmission coefficient of the ACS hardware, and its LPFC does not change. Based on the discrete Laplace transform, a scheme for computer simulation of the conversion process of the input hardware was constructed. Processing of computer simulation data resulted in satisfactory conversion speed of the hardware input and compliance of the transient process with the technical requirements. Confirmation of high performance of the computational procedure for the study of the frequency characteristics of the ACS of the longitudinal feed of the grinding wheel was obtained.

4. CONCLUSION

1. On the basis of the transfer function of a direct current motor, a software system for controlling the longitudinal feed of the grinding wheel has been developed. Mathematical models of hardware have been constructed.

2. A mathematical model of a computing block in the form of sequentially connected zero-order extrapolator and an aperiodic chain with delay has been proposed for the first time. The constant of time of the chain is determined on the base of loading the corresponding link of communication, and the delay is calculated as a result of summation of execution time of the commands of the control software.

3. Based on the capabilities of the Matlab environment, a method and an information technology for the research of frequency characteristics of the system of software control of the longitudinal feed of the grinding wheel have been developed. A method of simplification of expressions of transmitting functions has been proposed.

4. The influence of the change in the length of the links between simple multipliers of the transfer function has been investigated. It has been established that the change in the amplifier coefficient of an aperiodic chain affects the transmission coefficient of the system of longitudinal feed of the grinding wheel, while the phase characteristic does not change. It is also found that the increase of the oscillatory circuit gain does not affect the appearance of the phase characteristic of the programmable control of the longitudinal feed of the grinding wheel, while the gain of the input signal decreases.

5. As a result of analyzing the output signal of the scheme of computer simulation of the process of converting input information by hardware, satisfactory quality indicators of the system of software control by the main drive of a machine tool has been established.

6. It has been established that the use of the developed techniques and the information technology increases productivity of the process of hardware development.

5. REFERENCES

[1] Gill C., Levine D., Schmidt. *The design and performance of a real-time CORBA scheduling service*, Int. J. Time-Critical Comput. Syst, 1999. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2454&rep=rep1&type=pdf

[2] Martinov G.M., Martinova L.I., Kozak N.V., Nezhmetdinov R.A., Pushkov R.L. *Princip postroeniya raspredelennoj sistemy chpu s otkrytoj modul'noj arhitekturoj [Principles of constructing a distributed CNC system by technological machines using an open modular architecture]*. Engineering Journal, ISSN 2072-3172, No 12, 2011; pp. 44-50. Russian.

[3] Weck M., Wolf J. *Introduction to STEP-NC, A standard providing data for modern NC machining enabling enhanced functionality*. Laboratory for Machine Tools and Production Engineering Aachen University of Technology. Aachen. 2003. February 12. P. 52.

[4] William C. Dunn. *Fundamentals of Industrial Instrumentation and Process Control.* ISBN:9780071457354. McGraw Hill Professional; 2005. USA. DOI: 10.1036/0071466932

[5] Rybin Yu.K. *Measuring Signal Generators, Signals and Communication Technology.* ISSN 1860-4862. Springer International Publishing Switzerland; 2014. DOI: 10.1007/978-3-319-02833-0.

[6] Kiryanov D.V. *Samouchitel Mathcad [Tutorials Mathcad].* ISBN 5-94157-348.0 St. Petersburg, 2003. Russian.

[7] Domnisoru C. *Using Mathcad in Teaching Power Engineering*. ISSN 0018-9359. IEEE Transactions on Education, Vol 48, No 1, 2005, pp. 157-161. DOI: 10.1109/TE.2004.837043.

[8] Klepka A. *Real time estimation of modal parameters of non-stationary systems using adaptive wavelet filtering and recursive least square algorithm.* ISSN 1641-6414. Diagnostyka, Vol. 16, No 1, 2015, pp. 3-8.

[9] Pavlenko I., Trojanowska J., Ivanov V., Liaposhchenko O. (2019) *Scientific and Methodological Approach for the Identification of Mathematical Models of Mechanical Systems by Using Artificial Neural Networks.* In: Machado J., Soares F., Veiga G. (eds), pp. 299-306, ISBN 978-3319-91333-9. Innovation, Engineering and Entrepreneurship. HELIX 2018. Lecture Notes in Electrical Engineering, vol 505. Springer, Cham. DOI: 10.1007/978-3-31991334-6_41.

[10] Pavlenko I., Simonovskiy V., Ivanov V., Zajac J., Pitel J. (2019) *Application of Artificial Neural Network for Identification of Bearing Stiffness Characteristics in Rotor Dynamics Analysis.* In: Ivanov V. et al. (eds), pp. 325-335, ISBN 978-3-31993586-7. Advances in Design, Simulation and Manufacturing. DSMIE 2018. Lecture Notes in Mechanical Engineering. Springer, Cham.DOI:10.1007/978-3-319-93587-4_34.

[11] Dorf R.C., Bishop R.H. *Modern Control Systems.* ISBN-10: 0-13-602458-0, Addison: Wesley: Prentice Hall; 2010.

[12] Kotowski A. *The method of frequency determination of impulse response components based on cross-correlation vs. fast Fourier transform.* ISSN 1641-6414. Diagnostyka, Vol. 17, No 1, 2016, pp.59-64.

[13] Ayasun S, Nwankpa C.O. *Transformer tests using MATLAB/Simulink and their integration into undergraduate electric machinery courses.* Online ISSN:1099-0542 Wiley Periodicals, Inc. Comput Appl Eng Educ, Vol. 14, No.2, 2006, pp. 142–150. DOI 10.1002/cae.20077.

[14] Chaparro L.F. *Signals and systems using MATLAB.* ISBN 978-0-12-374716-7 Elsevier Inc. 2011.

[15] Dyakonov V.P. *Maple 9.5/10 v matematike, fizike i obrazovanii [Maple 9.5/10 in mathematics, physics and education].* ISBN: 5980032584. SOLON-PRESS; 2009. Russian.

[16] Yenikieiev O.F, Abramskaya I.B, Yarovoy R.A. *Komp'yuternaya sistema programmnogo zadaniya poperechnoj*

podachi shlifoval'nogo kruga [Computer system for program specification of the transverse feed of a grinding wheel]. ISSN 1991-3087. Journal of Scientific Publications of Post-Graduate Students and Doctoral Students. Fuel, No 11, 2014, pp. 174 - 181. Russian.

[17] Yenikieiev O.F, Subotin O.V. *Osnovi sintezu i proektuvannya slidkuyuchih sistem verstativ ta promislovih robotiv [Fundamentals of synthesis and design of follow-up systems of machine tools and industrial robots].* DDMA; 2008. Ukrainian. P. 268.

[18] Wassermen F. *Neurocomputer Technology: Theory and Practice*. [Text]. - M .: Mir, 1992. –236 p.

Analiza caracteristicilor hardware-ului pentru controlul programat al alimentării longitudinale a roții de rectificat

Rezumat: Scopul lucrării este de a crea hardware productiv bazat pe utilizarea unor medii software moderne pentru a controla parametrii proceselor tehnologice. Transformările Laplace au fost utilizate pentru modelarea matematică a componentelor întârziate. Pentru prima dată, am propus un model matematic al unui bloc de calcul sub forma unor extrapolatoare de ordine zero conectate secvențial și a unui circuit de întârziere aperiodică, care este determinat de durata procesului de procesare a semnalului de intrare. S-a construit diagrama bloc a sistemului de control programabil al avansului longitudinal al roții de rectificat și s-a obținut funcția de transfer. Tehnologia informației pentru ajustarea caracteristicilor de frecvență ale hardware-ului prin metoda tehnologiei de rețea neuronală a fost dezvoltată, care constă în reglarea lungimii legăturilor de informații între componentele funcției de transfer. S-a stabilit că modificarea câștigului lanțului aperiodic afectează coeficientul de transmisie al sistemului de control și caracteristica de fază nu se modifică. Pe baza transformării Laplace discrete folosind mediul software Matlab cu extensia Simulink, a fost construită o schemă pentru simularea computerizată a procesului de conversie a intrărilor de către hardware. Se propune metoda de identificare a parametrilor modelelor matematice de hardware pentru controlul debitului longitudinal al șlefului.

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