ОБМІН ПРАКТИЧНИМ ДОСВІДОМ ТА ТЕХНОЛОГІЯМИ

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INFORMATION TECHNOLOGY OF THE WORK COMPLEXITY OPTIMIZATION FOR METALWORKING MACHINERY WITH FLEXIBLE LOGIC OPERATIONS' DYNAMICS ANALYSIS

The technique for the amplitude and phase frequency characteristics (APFC) of the spindle unit (SU) has been developed based on the results of the metalworking equipment APFC analysis as well as experimental determination of the machine's APFC according to values of its nodes. This allowed developing of the information technology for work complexity optimization during the metalworking machinery with flexible logic (FL) operations' dynamics analysis. Timely and qualitative operations' diagnostics of the equipment through the introducing of the proposed information technology increases equipment performance, provides machining at a high quality level and increases the timing of overhaul cycles by reducing the maintenance time.

Keywords: information technology, metalworking equipment, the amplitude and phase frequency characteristics, personal computer, software, spindle unit.

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ИНФОРМАЦИОННАЯ ТЕХНОЛОГИЯ ОПТИМИЗАЦИИ СЛОЖНОСТИ РАБОТ ПРИ АНАЛИЗЕ ДИНАМИКИ ПРОЦЕССОВ ФУНКЦИОНИРОВАНИЯ МЕТАЛЛООБРАБАТЫВАЮЩЕГО ОБОРУДОВАНИЯ С ГИБКОЙ ЛОГИКОЙ

Техника амплитудно- и фазочастотных характеристик (APFC) блока шпинделя (SU) была разработана на основе результатов APFC анализа металлообрабатывающего оборудования, а также экспериментального определения APFC машины в соответствии с значениями ее узлов. Это позволило разработку информационных технологий для оптимизации сложности работы в металлообрабатывающем оборудовании с гибкой логикой (FL) анализа динамики операции. Диагностика своевременного и качественного выполнения операций диагностики оборудования через введение предлагаемых информационных технологий повышает производительность оборудования, обеспечивает обработку на высоком уровне качества и увеличивает сроки циклов капитального обслуживания за счет сокращения времени обслуживания.

Ключевые слова: информационные технологии, металлообрабатывающее оборудование, амплитудные и фазовочастотные характеристики, персональный компьютер, программное обеспечение, блок шпинделя.

Objectives

For the modern metalworking equipment it's important to provide the high quality of the certain nodes and constructions according to all output parameters (accuracy, stiffness, dynamic compliance, heating temperature, noise level, etc.). Hence development of the information technology for work complexity optimization during operations' dynamics analysis becomes a relevant scientific and technical challenge. The information technology is based on the mathematical analysis of the APFC of the metalworking equipment's entire flexible system as well as development of the techniques for spindle unit's APFC determination and experimental determination of the machine's APFC according to APFC of its nodes.

Dynamic compliance of the flexible system (FS) of metalworking equipment is determined based on APFC and requires additional examination and research.

Complications of the interactions of numerous formatives with auxiliary functional metalworking equipment's nodes with FL are characterized by trend of transition from differential to integral relations in electromechanical control systems and the necessity of improving their reliability. It is required to follow a variety of the consequent or parallel conditions in order to invoke action of the control actuator. These conditions are implemented by different logical operations of the hardware layer in the elementary circuits of the electromechanical system (mode and cycle determination, etc.).

During such researches it is essential to have reliable information regarding dynamical characteristics of the separate nodes of the electromechanical system as well as the entire device. The method which allows obtaining reliable experimental dynamic characteristics has been proposed in this work. These characteristics are represented by APFC of the separate nodes as well as characteristics of the entire FS based on the known parameters of its nodes.

Research and publications analysis

Research of a metalworking equipment of the 6P13F3 model resulted in determination of experimental APFC of the entire FS under the load of forces P_z and F_x that are used as input data to calculate the required experimental APFC of the spindle unit W_{Pz}^{zn} according to the developed technique of the calculation on the personal computer (PC). The research mentioned above is conducted by the authors and presented in the paper [4].

Firstly from the system of two equations

$$\overset{\Box}{W}{}_{zj}^{zn} W_{\eta j}^{zj} + \overset{\Box}{W}{}_{\eta j}^{zn} W_{Fx}^{\eta j} = W_{Fx}^{zn} \quad (1)$$

additional APFC has been calculated $\overset{\Box}{W}{}_{zj}^{zn}$ i and $\overset{\Box}{W}{}_{\eta j}^{zn}$, then according to the formula

$$\overset{\Box}{W}{}_{Pz}^{zn} = W_{Pz}^{zn} - \overset{\Box}{W}{}_{zj}^{zn} W_{Pz}^{zj} - \overset{\Box}{W}{}_{\eta j}^{zn} W_{Pz}^{\eta j} \quad (2)$$

- the main APFC of the spindle unit has been defined.

The complex radial APFC of the machines' FS W_{Pz}^{zn} and APFC of 6P13F3 SU $\overset{\Box}{W}{}_{Pz}^{zn}$ are depicted on the figure 1.

The axial APFC of the SU has been determined based on the same method but using contactless vibrator 2 (figure 2, b):

$$\overset{\Box}{W}{}_{xj}^{xn} = W_{Fx}^{xn}\left(W_{Fx}^{xj}\right)^{-1}; \; \overset{\Box}{W}{}_{Px}^{xn} = W_{Px}^{xn} - \overset{\Box}{W}{}_{Px}^{xn} W_{Px}^{xj}.$$

The simplified method of the FS's APFC determination has been developed. It allows additional APFC of the assembly when load is added to the spindle directly. The mentioned above method is based on the independent coordinates of the FS's SU usage. For SU that makes up the gully system and usually have the axis or plane of symmetry these coordinates (in the considered frequency range 0-600 Hz) are the axial and radial direction or two radial (at 90 °). One of which coincides with the plane of symmetry (in the absence of coordinates' bonds in the assembly due to ovality of bearings' necks, uneven stiffness of the spindle, mandrel, etc.).

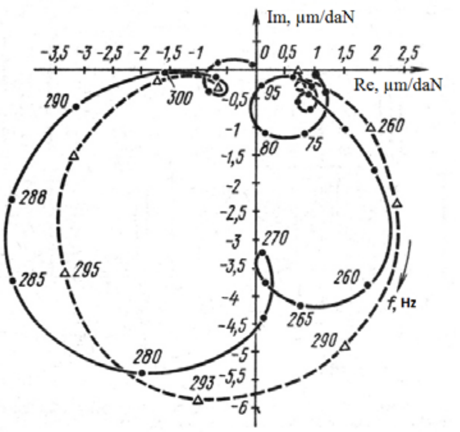
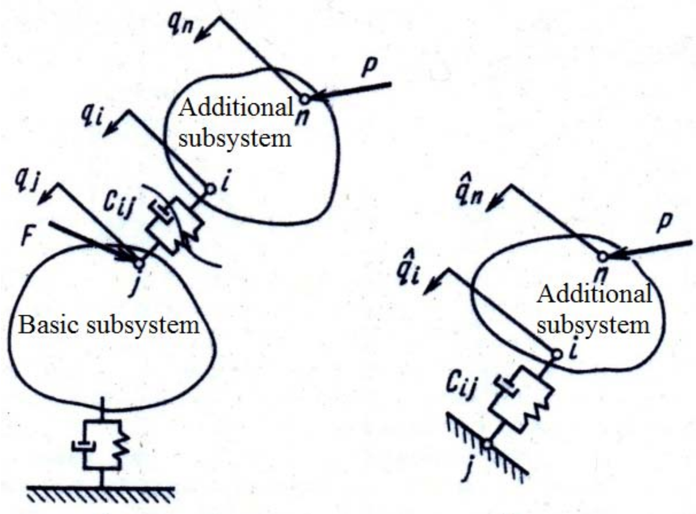


Figure 1 – Experimental radial APFC of the machine (the solid line) and SU (dashed line)



a) b)

Figure 2 – Dynamic models of the linear machinery FS: a – entire FS; b – partial FS.

Herewith the mutual APFC should be determined first (for instance for the radial characteristic W_{Fx}^{zn}, W_{Fx}^{zj}, W_{Fx}^{zj}). The required additional APFC of the SU will be calculated then according to expression (1).

During the experiments the radial APFC have been analyzed as well as axial ones in order to choose the most suitable and optimal construction according to the criteria of the dynamical quality. 6R13F3 turned out to be the best construction of the SU. It is characterized by the minimal static and dynamic compliance and maximum natural frequency (for both radial and axial APFC).

Technique for experimental determination of the machine's APFC according to APFC of its nodes has been proposed:

$$\overset{\Box}{W}{}_P^{an} = W_P^{an} - \overset{\Box}{W}{}_{qj}^{an} W_P^{aj}; \quad (3)$$

$$W_P^{an} = \overset{\Box}{W}{}_P^{an} + \overset{\Box}{W}{}_{qj}^{an}[E - \overset{\Box}{W}{}_{qj}^{qi} + (\overset{\Box}{W}{}_F^{ui})^{-1}\overset{\Box}{W}{}_P^{qi}(\overset{\Box}{W}{}_{qj}^{qi})^{-1}]^{-1}\overset{\Box}{W}{}_P^{qi}; \quad (4)$$

Herein P and F (figure 2, a) – are the components of the external disturbances' vector T; these disturbances are impacting FS at points n and j correspondingly (P - force which simulates the cutting force; F - arbitrary external perturbations, such as obtained by artificial means using vibrator) [4].

The technique is implemented by calculation of the axial APFC of the machinery (model 6R13F3) based on the experimental axial APFC of the SU and APFC's calculations for machinery's carrier system (CS).

The required experimental APFC of the SU $\overset{\Box}{W}{}_{Px}^{xi}$ and $\overset{\Box}{W}{}_{xj}^{xi}$ have been calculated in the same way to the characteristics $\overset{\Box}{W}{}_{Px}^{xn}$ and $\overset{\Box}{W}{}_{xj}^{xn}$ (figure 2, b). The only difference was that sensors of the absolute fluctuations were placed not on the rotating part.

In order to obtain APFC of the CS the dynamical calculations of the FS has been performed using proposed technique [4]. The model of the machine is depicted on the figure 3, a. It includes 17 weights (with 29 degrees of freedom and the corresponding links, some of which are indicated in figure 3, a). Weights 1-11 correspond to FS of the SU while weights 12-17 correspond to CS of the machine. The calculated axial APFC W_{Px}^{xn} of the machine (model 6R13F3) has been obtained on a PC using the kit developed software and depicted on the figure 3, b.

The elements of SU have been omitted by braking link 21 during CS's APFC W_{Fx}^{xi} determination. Force F_x has been applied at point j. Fig. 3, b shows the resulting axial experimental and calculated – experimental APFC W_{Px}^{xn} of the entire FS. The developed software helped to obtain the calculated – experimental APFC. Comparison of these two APFC shows that their parameters are pretty similar (delta of amplitudes is 15-20%, frequency and phase 5-7%). Calculated – experimental APFC are more detailed in comparison with the calculated ones (fig. 3, b) that proves the validity of the system developed.

It is important to note that the given technique considers matrix inversions which consist of experimental APFC as well as solutions of equations and other algebraic operations on these characteristics. It is necessary to increase the accuracy of APFC's determination taking into account their random nature. Thus, in the examples above, the deviation of output APFC (components 2 - 3%) caused 4-6% of APFC's parameters distortion. The experiment's deviations could be reduced using the recommendations listed in papers [5-8].

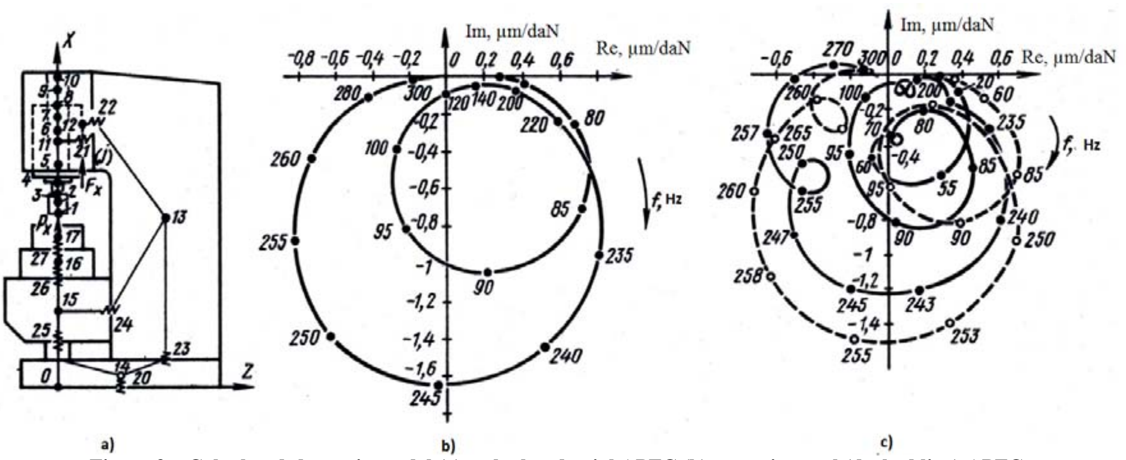


Figure 3 – Calculated-dynamic model (a), calculated axial APFC (b), experimental (dashed line) APFC of the entire FS of the machine (model 6R13F3) (c)

The assessment of the dynamical quality of the machine (model 6R13F3) with 3 options of SU has been tested during the cutting as well. It was established that machines' performance with new SU constructions with front milling of steel 45 increased on the average by 12% when using high-speed SU and by 27% when using power SU compared to the performance achieved with serial SU. These data are consistent with the results of the above analysis of machine's APFC.

The common optimization of the work complexity during metalworking equipment with FL operations dynamics analysis has been performed based on the research conducted. As a result new information technology has been developed (fig. 4).

Timely and qualitative diagnostic of the equipment operations through the introduction of the proposed information technology increases the productivity of the equipment, provides machining at a high level and increases the timing of the overhaul cycles by reducing the time to perform maintenance. This allows to decrease the number of the maintenance staff.

The following formulas should be used in order to determine the necessary number of staff:

mechanics

$$K_м = \frac{\tau_м \cdot \sum_{i=1}^{n} R_{м.i.} \cdot N_{т.р.}}{F_д \cdot T_{ц.р.}} \tag{5}$$

electricians

$$K_е = \frac{\tau_е \cdot \sum_{i=1}^{n} R_{е.i.} \cdot N_{т.р.}}{F_д \cdot T_{ц.р.}} \tag{6}$$

where

$\tau_м$, $\tau_е$ - fixed time of maintenance per unit for part of the equipment with numeric control (for mechanics and electricians per hour).

$\sum_{i=1}^{n} R_{е.i.}$, $\sum_{i=1}^{n} R_{м.i.}$ - the total complexity of the maintenance.

$N_{т.р.}$ - number of ongoing repairs to the repair cycle (pc)

$T_{ц.р.}$ - repair cycle duration (per year)

According to the research conducted the planned maintenance time is decreased from 0, 21 hour to 0, 17 hour per unit of the repair complexity due to information technology described herein. Ultimately it reduces maintenance time up to 18%.

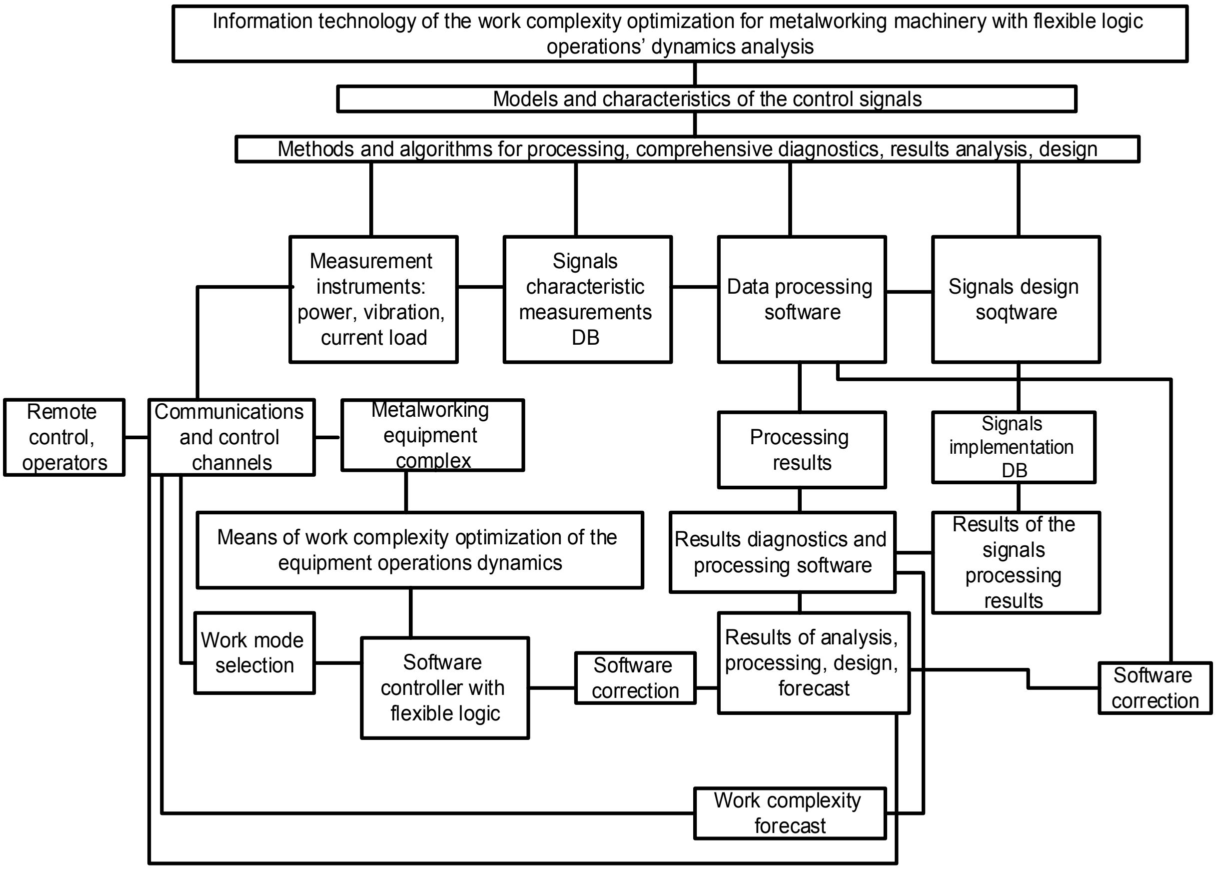


Figure 4 – Design of the information technology of the work complexity optimization for metalworking machinery with flexible logic operations' dynamics analysis

Summary

The examples of the equipment operations reliability enhancement assessment in case of the proposed IT implementation have been considered within this paper. They demonstrate the expediency and efficiency of the developed method and techniques for the node-by-node analysis of the dynamical characteristics of the metal cutting equipment with FL (e.g. machines with computerized management systems).

Unification of the control, management and diagnostics means into the single system has been considered as one of the implementation ways of the developed IT provided increased control fitness of the facilities being diagnosed.

It is recommended to use the new generation of the ant-vibration monitoring systems (both stationary and portable modules for monitoring and diagnostics) during the proposed IT usage for the equipment with computerized control systems. This is also relevant for the comprehensive diagnostics as well as for long-term forecasts of the equipment's technical conditions. It also helps to reduce operation costs as well as number of staff.

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