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DEVELOPMENT OF RESOURCE-SAVING TECHNOLOGIES OF FINISHING STRENGTHENING PROCESSING DURING THE MACHINE PARTS MANUFACTURE

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Abstract. The existing methods of finishing strengthening processing (FSP) are considered in this article. The perspective way of sound of resonance finishing strengthening processing in the quasi-elastic medium (SRFSPQEM) in terms of resource- saving and ecological safety is offered.
Keywords: finishing strengthening processing, resonance, quasi-elastic medium, deterioration, surface structure.

1. Introduction

The major reserve of material and natural resources, energy efficiency and environmental safety economy is the use of new resource-saving and environmentally friendly technologies of FSP machining. The parameters of the surface layer (SL) significantly affect the parameters of reliability and performance of parts: wear capability, fatigue resistance and corrosion resistance. To ensure the specified property of the SL of parts it is necessary to ensure the characteristics of the surface which directly affect the necessary properties, namely the equilibrium roughness that is functionally oriented indicator peculiar to performance properties of the friction unit. Researches, aimed at improving of the surface quality and increasing its durability through the application of modern high-tech, are relevant to the different sectors of national economy.

The purpose of the work is developing of progressive resource-saving technology of machine parts finishing that allows reducing running-in time during parts operation and increases durability of working surfaces of coupling parts.

Innovative technologies that reduce cost of energy and resources, provide the best manufacturability, improve wear capability, fatigue strength and corrosion resistance are based on different methods of processing metals. Resource-saving technologies allow saving natural resources and preventing pollution [1]. A large number of methods of FSP of machine parts are known [2]. Each of them has its advantages and disadvantages. Modern methods of finish machining allow obtaining of given accuracy but do not always provide sustainable quality of the working surface of a part. The applied methods of finishing, hardening and applying of wear-resistant coatings are not always possible to obtain the satisfactory combination of the required level of performance with acceptable tribosystems manufacturability, maintainability and efficiency of manufacturing processes and component overhaul.

The research analysis has shown the powerful capabilities of vibrational FSP processing in the area of improving of service performance of the parts working surfaces. Quasi-elastic medium is widely used. Establishing of equilibrium roughness, reducing running-in time, replacement of expensive materials and equipment to less expensive provide resource conservation during production and reduction of production costs.

2. The block diagram and physical nature of SRFSPQEM

Taking into account the tasks, the most perspective energy-saving technologies of FSP are vibrating combined processing methods in quasi-elastic medium. The methods are based on the technological process of surface plastic deformation (SPD) that allows giving desired surface quality with minimal costs by varying technological modes of processing and composition of the working environment [3].

Finishing strengthening processing at ductile active medium as a kind of FSP technology reduces dynamic force in the surface layer by forming thin wear-resistant layers on the contacting surfaces of the parts. However, this oscillation process in the oil layer is completely damped and increases its impact on the bearing capacity and the operational reliability of parts. Vibro-processing in the quasi-elastic medium is a quite promising direction. It is opening up vast prospects of surface quality control.

The applying of the parts finishing method depends on several factors:

- the friction pairs working conditions;
- wear mode and rate of wear.

In developing the new energy-saving method of FSP the following objectives were set:

- to eliminate wasteful energy losses;
- to reduce energy costs and complexity of finishing and strengthening operations, and as a result to reduce the cost of finishing parts;
- to eliminate the use of scarce and expensive materials;
- to use the energy of natural processes.

Block diagram of SRFSPQEM that allows controlling of obtained characteristics is shown in the Fig. 1

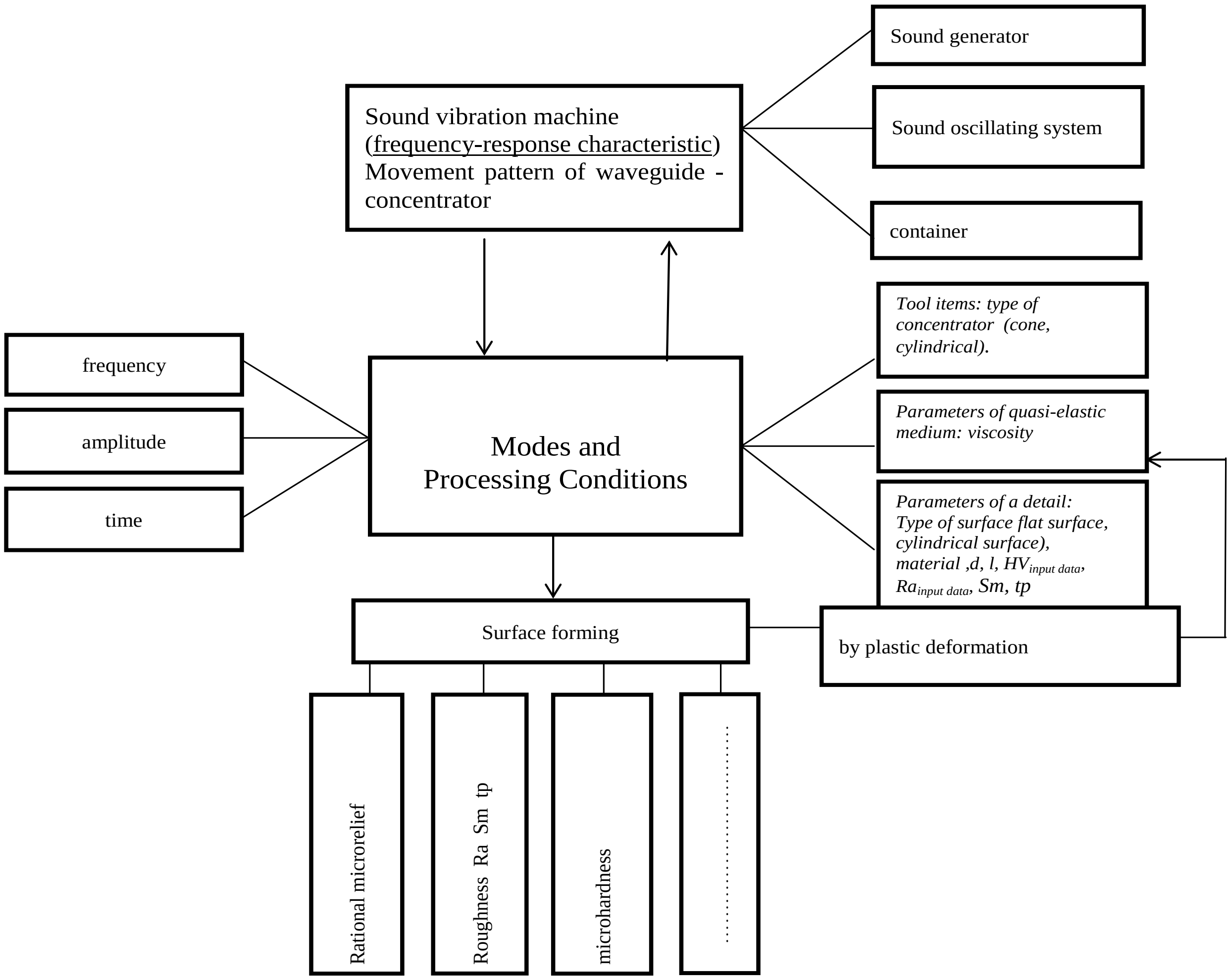


Fig. 1. Block diagram of the process control of SRFSPQEM

The physical nature of SRFSPQEM is the following: the part is immersed in a container with working fluid and performs harmonic oscillations in quasi-elastic medium, affecting the particle boundary layer of the medium, and forcing them to perform forced oscillations. Working medium near the body, which oscillates in the resonant mode, is deformed and elastic forces appear there. In the interaction with the medium profile of the surface layer parts plastically deformed and the surface micro geometry approaching equilibrium (operational) state. The compressive stresses arise in the surface layer, which increase the fatigue strength and wear capability, significantly decreases the surface roughness of the finished part.

The parameters affecting the quality of the surface wear capability and durability of the parts are achieved at the stages of machining and finishing processing. Model of technology process planning is shown in the Fig.2

During the parts oscillation there is tension in the surface layer enhanced by the resistance exerted by the quasi-elastic medium. The peculiarity of the method is that the medium will become easy to form a processed surface, which ensures relatively evenly finishing processing and the ability to handle the parts of a complex shape [4].

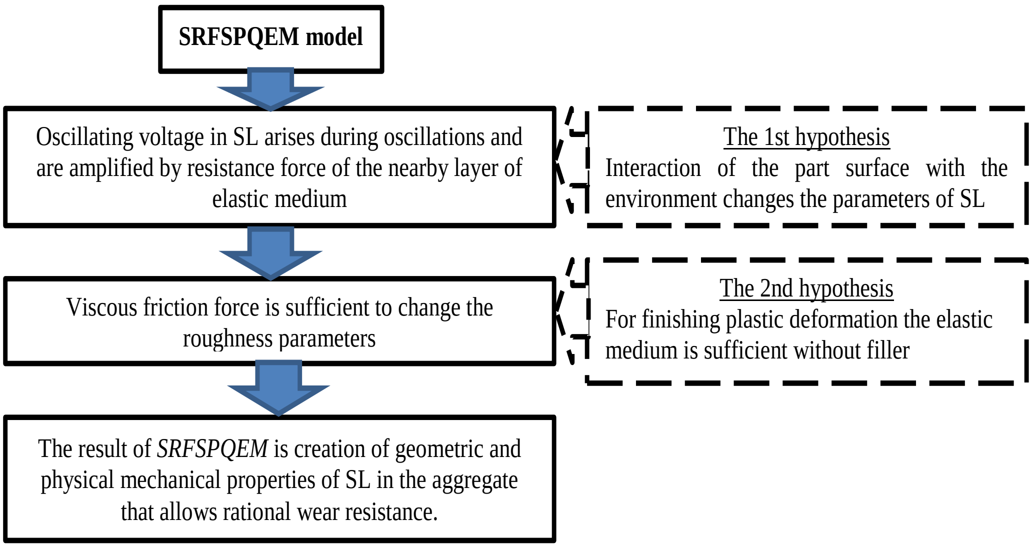


Fig. 2. SRFSPQEM mode

The scheme of developed installation of SRFSPQEM is shown in Fig. 3.

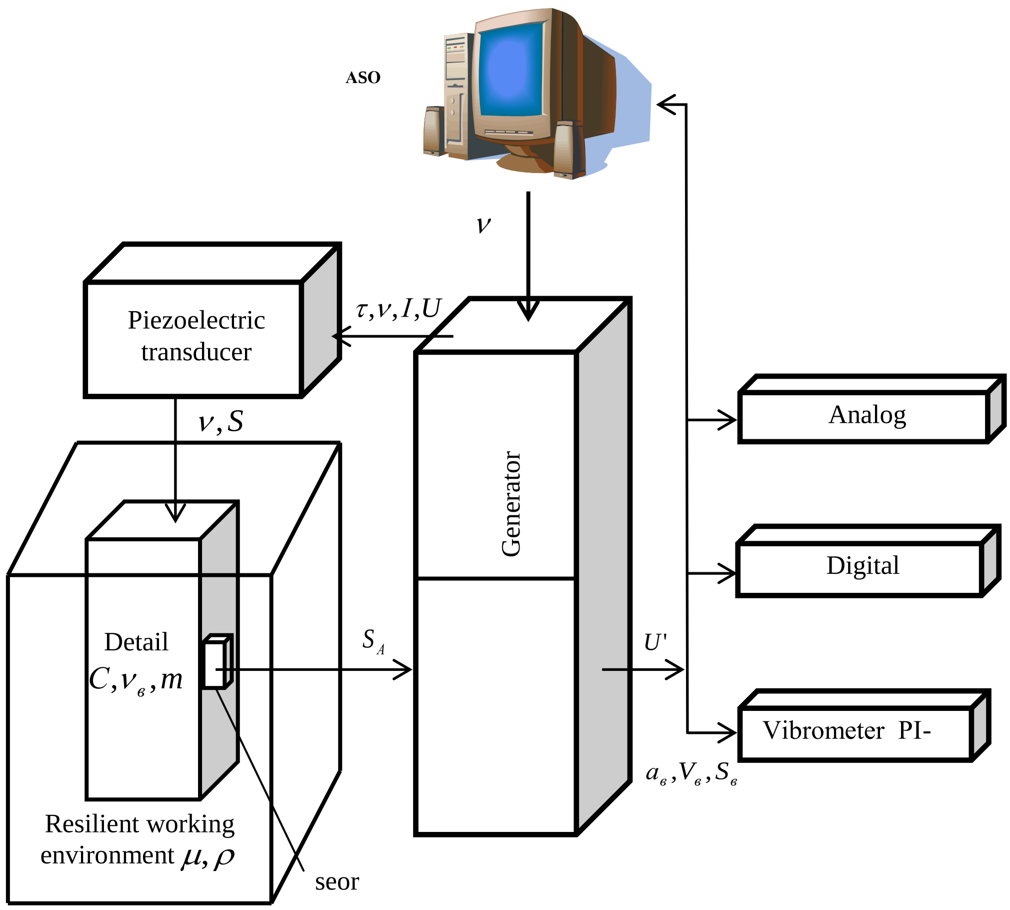


Fig. 3. Schematic diagram of the vibration machine

The advantage of the proposed vibration device is a high efficiency, low cost, ecological clearness, simplicity of design and technological processing. The use of the proposed vibration device allows realizing functional possibilities of vibroprocessing in an elastic environment without using abrasive materials [5, 6].

Processing is carried out at one of the natural frequencies of the parts in a resonant mode. The moment of resonance occurrence in the generator – part system is fixed by the system PC-based control, with the implementation of the automatic adjustment of the resonant frequency, and then the ultrasonic vibrating system operates at the frequency of forced oscillations. Full use of forced impulse signal provides rigid connection of a part with the hub of piezoelectric converter. The pulse generator produces short powerful pulses, which are fed to piezoelectric converter. The mechanical impulse is transmitted to workpiece and causes forced oscillations with amplitude up to 50 microns, and it is fixed by vibratory sensor becoming an electrical signal which is amplified and fed to the inputs of the measuring equipment [7].

Acoustic signal from the detail is admitted by the vibration sensor DN-3, which converts mechanical vibrations into alternating voltage of the same frequency that is amplifying and measuring by voltmeter. Fulfillment of the conditions in the studied acoustic system responses the resonance peak in the amplitude-frequency characteristic. To configure the system generator-piece to resonance, in the generator UZH 04 piezoelectric transducer and micro ammeter are placed. The input of the amplifier can be connected with sensors of DN-3 type to join the workpiece. To the output of amplifier micro ammeter and instrumentation connectors for measuring devices are connected.

The main element of a vibration machine is driving generator with the following specifications: supply voltage generator ~ 65 V, 50 Hz; maximum power of generator 0.4 kV·A; pulse power 0.1-30 kV·A; pulse duration 20-25 ms; power control circuits of 0.1 kV·A.

The oscillation amplitude can be controlled by the thickener geometry, which is part of piezoelectric transducer. Investigation of physical and technical characteristics of ultrasonic concentrator was conducted with the use of mechanic device of entire environment in three-dimensional setting. To form the problem we have to make a closed system of equations describing the movement and status of the entire environment with regard to its physical and mechanical properties of external power factors and it allows us to find all functions defining the movement and the state of the environment based on the coordinates and time. In this work three-dimensional shear concentrator is simulated. Thus mass distribution on elements is considered to be homogeneous and the size of the elements is selected on such the wave that spread could be spatially resolved. Concentrator construction is designed allowing bringing factor of amplitude rising from 4 (cone-shaped) to 20.

The calculation of different ultrasound-stepwise radial oscillatory systems with different lengths and diameters steps of concentrator is given. For modeling quadratic final element SOLID92 is used, which is defined by ten units having three degrees of freedom at each unit: moving towards is specified in the axis of the unit coordinate system.

Any permanent load that varies cyclically generates feedback of model cyclical changing (harmonic feedback). Calculation of forced oscillations allows to predict the behavior of periodically excited system, allowing thus to check the model structure for the presence of resonance, tiredness and other negative effects of periodic excitation. Analysis of forced vibrations is a way of determining sustainable process of response of linear model for loading changing sinusoidally in time (harmonic) law. The sense of the calculation is in the process modeling at developed cascade of evolutionary network based on blacksimiliar elements, enabling to make calculation of response function of processing parameters from frequency. Peak values are also determined in graphics displayed depending on the frequency of peak values.

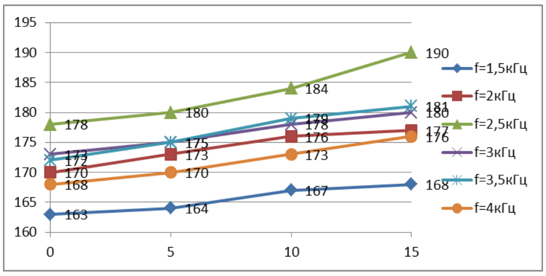
The numerical analysis of defined parameters showed that when approaching to the resonant frequency components of displacements lie in a plane perpendicular to the axis of the concentrator are going to zero, and the components of displacement that are parallel to the axis symmetry of the concentrator increase rapidly, indicating that the transition of longitudinal oscillations is in a resonant mode. We can also affirm that the main idea of the approach is that in the longitudinal vibration resonance cross sections are flat, it is fair. The scope of the amplitude of the output units on the intersection of the concentrator for studying the details is about 120 microns. If you change the length of the concentrator and step thickness vary significantly step resonant frequency of longitudinal oscillations, whereas the gain fluctuations is about 20.

The processing time is 6-15 minutes; it depends on the grade of the metal and preliminary mechanical processing. Formation of new structures and micro geometry within PS SRFSPQEM causes change in the physical and mechanical properties, which increases the wear capability and fatigue strength of the working surfaces of friction pairs.

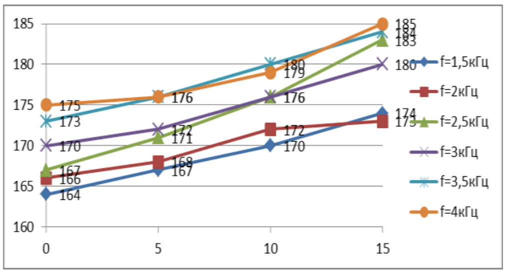
The vibratory of aluminum alloy and steel 45 samples result in a slight increase in the micro hardness 10-15% at a depth of 100-250 m. Processing allows to obtain compressive residual voltage of 100-120 MPa at a depth of 0.3-0.6 mm. The roughness is reduced by 20-30%. The top of the microscopic irregularities of the surface layer is flattened. The quality of the surface at SRFSPQEM approaches to the equilibrium state.

3. The surface layer hardness dependence on the modes of SRFSPQEM

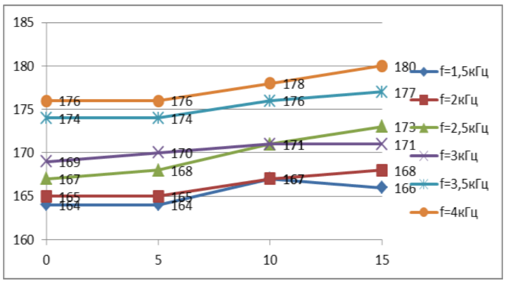
Research results of the plate sample micro hardness with characteristics 150x30x2mm, steel 40, resonance f = 2500Gts are shown in Fig. 4-7.



a)



b)



c)

Fig. 4. Dependence of the SL hardness on the processing time in the working medium:
a) Oil I-40
b) Oil I-40+ metallic powder
c) water + surface acoustic wave

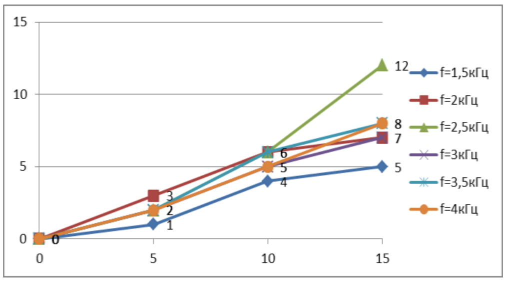


Fig. 5. The dependence of surface hardness increase on processing time in the working medium, oil I-40

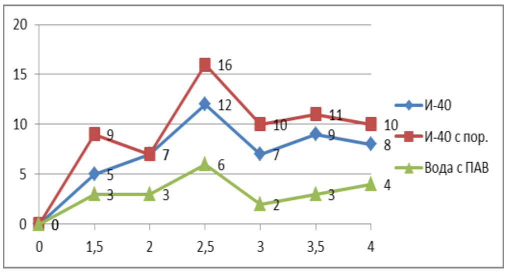


Fig. 6. The dependence of surface hardness increase on the processing frequency with time t = 15 min

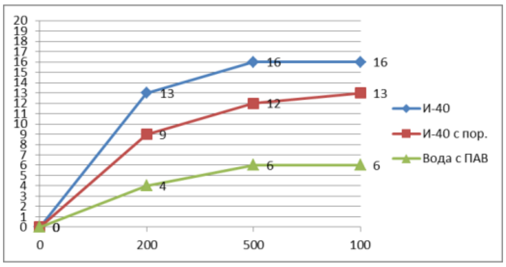


Fig. 7. The dependence of surface hardness on volume medium.

Having reviewed and assessed characteristic curve, we can make the following conclusions:

- the biggest effect is observed in processing at the resonant frequency within 10 minutes. Although, it is possible that with time increasing the hardness values will continue to increase or decrease vice versa (less rapidly);
- increasing of working medium volume has a positive effect on the hardness of treatment surface while volume reduction exerts influence on roughness parameters;
- the largest increase in hardness is observed in resonant mode.

4. Dependence of the parameters of SL and wear due to processing time

Statistical analysis of experimental data was in the regression ratings calculating using the method of the least squares, checking its significance, evaluating reproducibility of experiments and establishing the adequacy of the obtained regression equation. The statistical tests of Cochran, Student and Fisher were used (confidence coefficient is 95%).

Parabolic regression model (over the variable t) was more appropriate because the coefficient of determination is $R^2 = 0{,}92$ and all the coefficients are significant.

$$R_a = b + a_0 R_a^0 + a_1 t + a_2 t^2$$

The regression equations that adequately describe dependences of processing parameters of the processing time have the following form:

- for a plate:

$$R_a = 0{,}776\,R_a^0 + 0{,}020\,t - 0.010\,R_a^0 t$$

$$S_m = 0{,}827\,S_m^0 + 0{,}007\,t - 0{,}009\,S_m^0 t - 0{,}00004\,S_m^0 t^2$$

$$R_v = 1{,}349\,R_v^0 + 0{,}101\,t - 0{,}086\,R_v^0 t + 0{,}002\,R_v^0 t^2$$

- for a cylindrical sample

$$R_a = 1{,}255\,R_a^0 - 0{,}042\,t + 0{,}004\,t^2 - 0{,}038\,R_a^0 t$$

$$R_{sm} = 2{,}240\,R_{sm}^0 + 0{,}010\,t - 0{,}292\,R_{bib}^0 t + 0{,}010\,R_{sm}^0 t^2$$

$$R_p = 1{,}152 R_p^0 + 0{,}167 t - 0{,}098 R_p^0 t + 0{,}003 R_p^0 t^2$$

$$R_v = 1{,}994\,R_v^0 + 0{,}085\,t - 0{,}221\,R_v^0 t + 0{,}009\,R_v^0 t^2$$

$$t_p 20\% = 1{,}067 t_p 20\% + 0{,}161 t - 0{,}055 t_p 20\%^0 t$$

$$t_p 50\% = 2{,}145 t_p + 0{,}976 t - 0{,}161 t_p{}^0 t + 0{,}005 t_p t^2$$

Summing up what had been said as a result of theoretical researches the formula for finding the basic parameters of SRFSPQEM on the basis of engagement factors and treatment was obtained. The range of coefficients values that allows assigning processing modes to ensure the SL rational values were also defined.

The wear capability of processed samples is increased. You can see dependence of the relative wear for samples made of steel 45 at the Fig. 8 and 9.

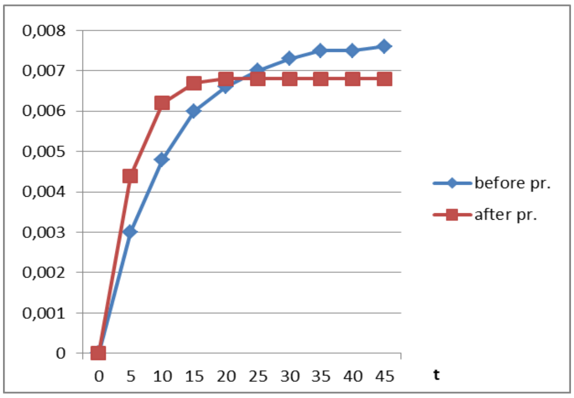


Fig. 8. Dependence of the relative wear on the size (S) over time (t)

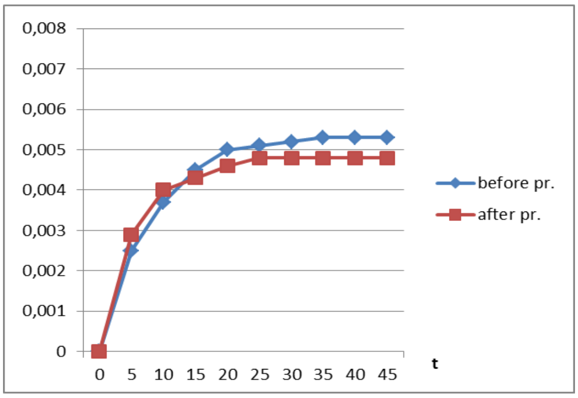


Fig. 9. Dependence of the relative wear on the weight (m) over time (t)

The time of running-in of the samples is 20 minutes after processing and 30 minutes before. The relative wear is 1.15 times less after processing.

5. Conclusions

The process SRFSPQEM is characterized by a complex effect of the factors caused by vibration in a resonant mode on the parts and its SL. Micro-percussion plurality of pieces of process fluid in different directions provides the equal effect on the entire surface. As a result, the conditions for multiple deformation processes are created.

The goal of parameters formation is reduced to obtain the equilibrium of the complex parameters of the SL working surfaces of interfaces parts. This processing method allows you to create the industrial processing technology that allows you to obtain the (approximate to the operational) quality of SL, at the lowest cost of energy and resources.

SRFSPQEM processing may be used for working surfaces of the critical parts of friction units: parts of the drive and control gear, wheels, plugs, pins, etc. All parts can be processed with the central through-hole used for fixing bases and with the concentrator.

You can handle the parts with cylindrical, conical, and other curved surfaces An urgent task is the development of theoretical and experimental dependences of the parameters SRFSPQEM while ensuring operational parameters of the surface, i.e., functionally-oriented processing. This will allow choosing of optimal processing modes in terms of quality and energy efficiency for the given conditions.

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