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СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

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EXPERIMENTAL STUDY OF OPTIMAL PARAMETERS OF PNEUMATIC MOTOR OF VIBRATION TABLE FOR INERTIAL VIBROABRASIVE MACHINING THE PARTS ON THE BASIS OF BERYLLIUM OXIDE

Abstract. In this paper, attention is paid to solve a number of issues related to the experimental study of the vibration table of inertial vibroabrasive processing improved by equipping it with pneumatic actuator providing rotary oscillating movement of the tool thanks to the compressed air and ejection of processed products and filtering. For each type of structural arrangement of the holes outside a series of tests were conducted with different values of the cross sectional area outside the holes and different values of supply pressure, while the other parameters were fixed. Studies were carried out to determine the optimal values of the radius of the inlet nozzle, the radius of the atmospheric hole mass of roller. For maximum performance, handling and collection of waste products and their filtering control of the geometric parameters of the air supply was performed.

Keywords: vibrating table, vibroabrasive processing, amplitude, vibration processes, oscillation frequency, optimization.

Introduction. In engineering technology, there are still processes that cannot be fully automated for some objective reasons. Such processes include, for example, surface cleaning parts before coating, polishing surfaces of molds, surface refinement of details covered by non-metallic materials. Finishing in abrasive environments is the most productive method, as it allows to mechanize and automate manual finishing operations descaling, rust, burrs from cast billets, deburring parts after stamping dimensionless grinding, buffing and polishing, and surface preparation for electroplating and coatings. And you can make processing of the details from a few fractions of a gram to large forgings and castings. Vibratory equipment is used for the treatment of a wide range of parts in mass and serial production [1].

Improving the efficiency and intensification of production processes is largely due to their automation and mechanization. Achieving these goals is accompanied by extensive use of vibration technology. For the implementation of vibration exposure there are widely used vibration machines - vibrators used in industry technologies: transportation, vibration compaction, dosing of loose materials, etc. Excitation of vibrations at various frequencies and given laws force effects in various technologies is concerned with certain technical features associated with the applicable principles for the formation of the vibrator [2, 3]. Thus, the experimental research towards optimizing the parameters of the vibration actuator of the pneumatic vibration table designed for high-performance and safe handling of parts based on beryllium oxide is relevant.

Methods and results. Vibrotable for vibroabrasive surface treatment of parts with a pneumatic vibration actuator was developed after a study of the interaction of the flow of compressed air with a roller, placed freely in the swirl chamber [4-6]. Rounding the roller along the inner wall of the swirl chamber occur due to uneven distribution of pressure on its surface. Process possibility of using this type of device for surface treatment - applying pasty coating, their smoothing or cutting them after polymerization, and the abrasion. Complex planetary motion tool provides high-quality treatment, and because there is no need for mechanical fixing it excludes time on the sticker and plywood products [7]. Studied process led to the idea of creating a simple and efficient pneumatic actuator of the vibrating table shown in figure 1.

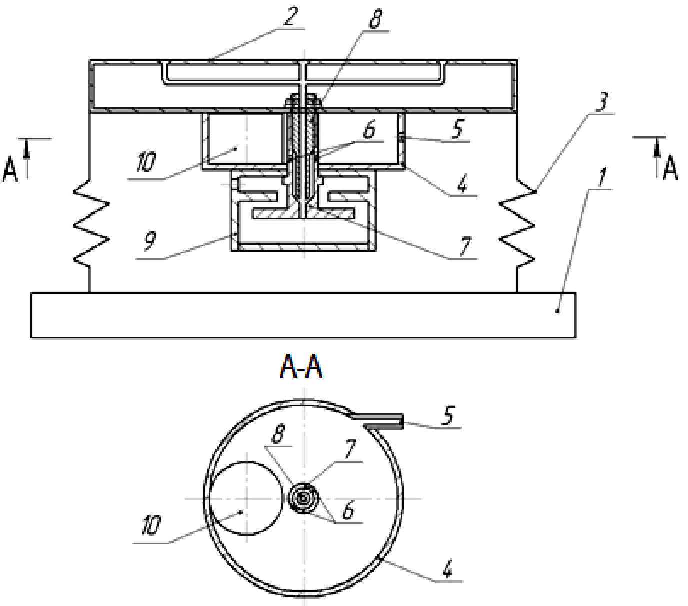

Figure 1 – Scheme of pneumatic vibration table

Vibrating table for vibroabrasive treatment (figure 1) is a structure consisting of a base 1, a movable frame 2 fixed on elastic supports 3, housing of vibration unit 4, inlet 5 and outlet holes 6, external 7 and internal 8 tubes of the tubular element, cylindrical chamber 9, unbalanced mass 10. Vibrotable operates as follows: the unbalanced mass 10, driven by a flow of compressed gas supplied through the tangential inlet 5 rolling off the inner cylindrical surface of the body of a vibroblock 4 forms vibration that, accordingly, makes movable frame 2, 3 fluctuate on elastic supports, mounted on a base 1 Exhaust gas is discharged through outlet openings disposed tangentially in the outer tube 6 of the tubular element 7. Further twisting gas slips through the annular gap formed by the end face of the inner tube 8 and the inner annular tapered bore of the outer tube 7, forming thereby an ejection nozzle that creates a low pressure area in front of the end face of the inner tube 8 which is connected on the other side with the outer surface of the movable frame on which vibro - treatment of workpieces takes place and processing waste is pulled. The swirling gas mixed with processing waste flows into a cylindrical chamber 9 with the inner contoured surface defining a centrifugal filter, on the walls of which the elongated process waste is deposited, and the purified exhaust gas is discharged through an opening in the upper part of the cylindrical chamber 9.

Figure 2 shows a diagram of the assembly of a vibration motor. To reduce the contact area with the cylinder body during rolling off and to improve the starting and kinematic characteristics of the vibration motor an annular groove depth of 0.5 mm is made on the inner surface of housing.

Adjustment of vibration parameters can be made either by changing the supply pressure, either by changing the weight of the cylinder. For weight reduction - cylinder has axial bore for all other constant parameters (height and radius). Designed pneumatic vibration table is easy to manufacture, operate and maintain, reliable, easy to disassemble (all junctions are separable) and compact. It is known that the frequency of vibrations acting on a pneumatic roller, it is possible to obtain on the basis of the equation of balance of forces [8, 9].

Figure 2 – Diagram of the assembly of a vibration motor pneumatic vibration table

This vibration motor is unpretentious in work, not picky about the quality of compressed air and does not require lubricant. For experimental research vibration table has been made on the basis of pneumatic motor prototype. Experimental vibration table consists of a pneumatic vibration drive with the exhaust nozzle in the central tubular member, a support flange, spring- writing element with a spring in the face, and writing element is free to move along the axis of the drive, air preparation unit, consisting of a compressor, receiver, pressure regulator, gauge and sheet of heavy paper.

Applying compressed air to the tangential supply nozzle, the latter begins to vibrate in a horizontal plane at a frequency f and amplitude Δ. When moving with approximately constant speed vibrating spring- writing element on the sheet of paper it imprints spiral - waveform trace on the piece of paper. Vibration frequency is calculated by dividing the number of turns of the waveform to the corresponding time during which measurements are made, at the same time, the origin of coordinates is selected provided when the system reaches a steady mode. Experimental determination of the structure of the exhaust nozzle of the motor of the vibration table [10-12]. Vibration motor for the highest frequency characteristics must possess optimum design parameters, in particular, must have optimal location of the outlet nozzle and its orifice [13]. For this it was decided to conduct experiments in order to find the optimal location of atmospheric holes. For the experiments we used a prototype pneumatic vibration motor with a roller weighing 0.1 kg. For the study three of the exhaust nozzle design shakers with different locations outside the hole were set up: Type A - three holes in the lid body of the vibration motor, figure 3a. Type B - tangential hole in the cylindrical shell of the vibration motor, figure 3b. Type C - the radial holes in the central tubular member of the vibration motor, figure 3c.

For research experimental vibration table was used. For each entry nozzle type, series of experiments with different values of radius and the outlet at different pressures of supplied compressed air were conducted. The experimental results shown on graphs are plotted in figures 4-7, describing the dependence of the frequency-amplitude characteristics of pneumatic motor on the ratio of migratory areas of inlet and outlet nozzles at different supply pressures.

a b c

Figure 3 – Design of the output nozzle of the vibration drive with a different location of the atmospheric hole:
a - output nozzle according to type A, three holes in the housing cover of the vibration motor;
b - output nozzle according to the type B, the tangential opening in the cylindrical shell of the vibration motor;
c - output nozzle according to type C, the radial holes in the central tubular member of the vibration motor

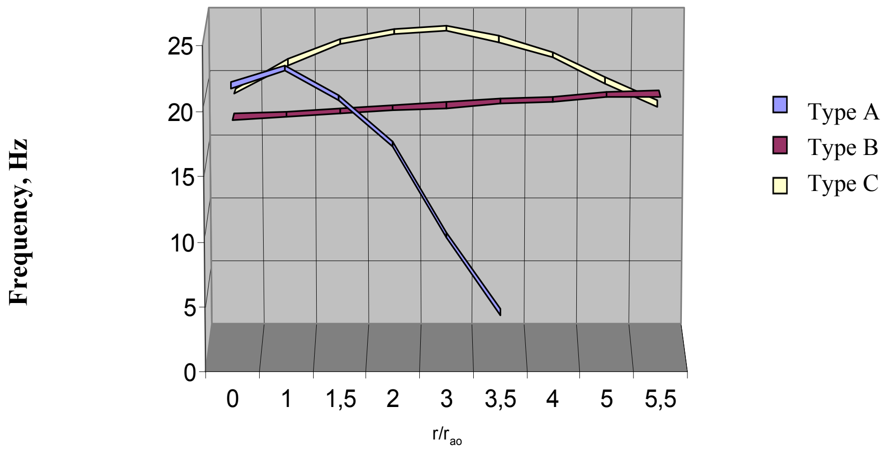

Figure 4 – Dependence of the vibration frequency on the ratio of the radius of the inlet nozzle to the outlet, the supply pressure is 100 kPa, the radius of the supply nozzle is 2 mm

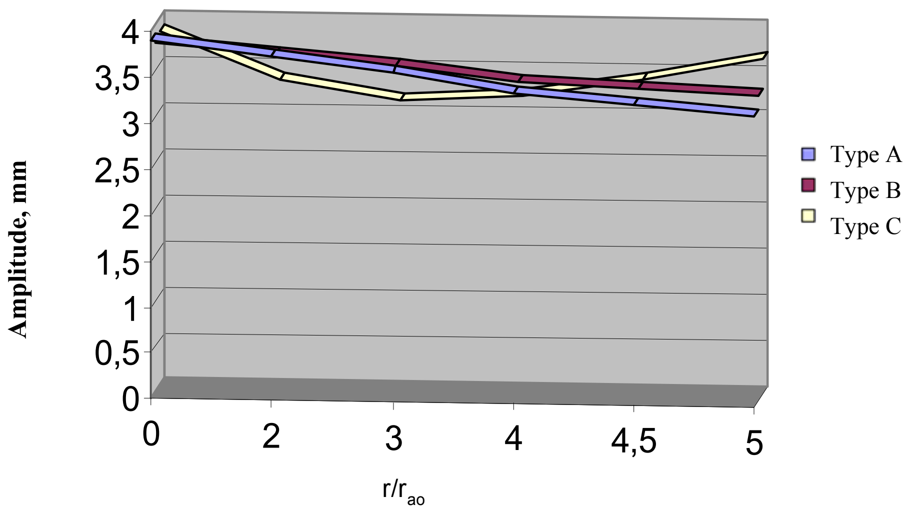

Figure 5 – Dependence of the vibration amplitude on the ratio of the radius of the inlet nozzle to the outlet, the supply pressure is 100 kPa, the radius of the supply nozzle is 2 mm

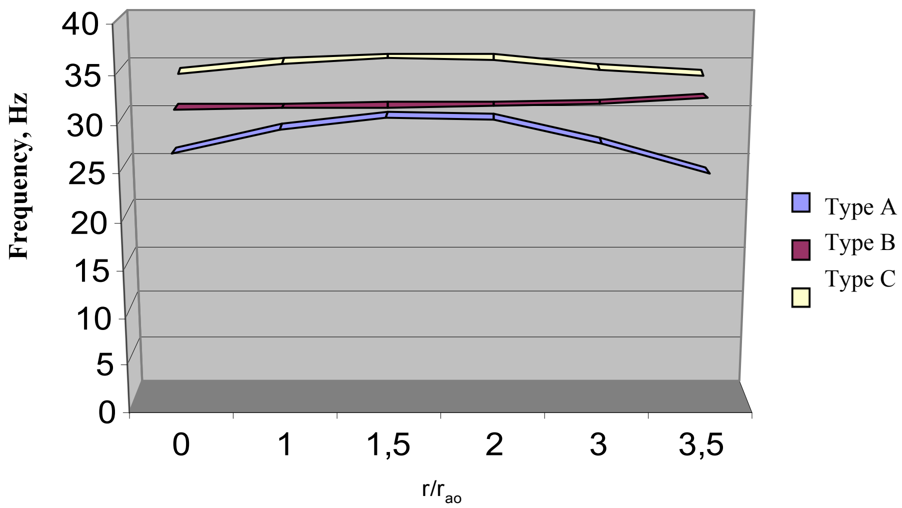

Figure 6 – Dependence of the vibration frequency on the ratio of the radius of the nozzle inlet to the outlet, the supply pressure is 200 kPa, the radius of the supply nozzle is 2 mm

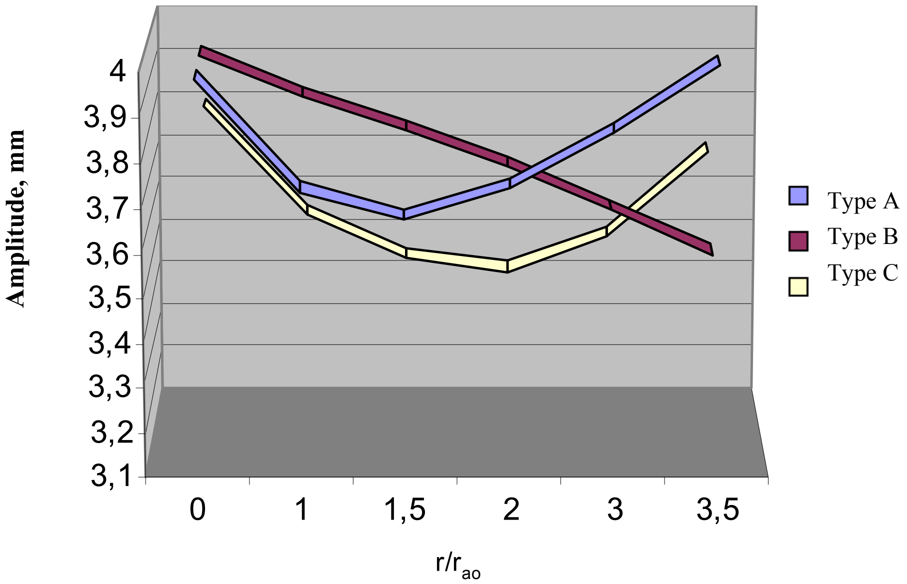

Figure 7 – Dependence of the vibration amplitude on the flow radius of the exhaust nozzle, the supply pressure is 200 kPa, the radius of the supply nozzle is 2 mm

Relative error of the experiments is as follows [14, 15]:

$$S_{в} = \frac{f_{max} - f_{min}}{2f} = \frac{19,72 - 18,3}{2 \cdot 19,08} \cdot 100\% = 3,8\ \%, \qquad (1)$$

which is quite acceptable in the present case.

Analyzing the charts it has been seen that the highest frequency characteristics at the same parameter is given by the nozzle according to type C, so this type of outlet is accepted as a basis for the design of the vibration motor.

Determination of the ratio of depression in the inner tube of the tubular element on the pressure for different values of the gap ejector [16, 17]. It is experimentally and analytically determined that the amount of dilution is affected by the gap ejector. The optimal value of this gap has critical effect on the dust extraction, so to maximize efficiency of removal of processing waste it was decided to adjust the gap on the vibrating table and to experimentally determine the dependence of vacuum in the inner tube of the tubular element of pressure for different values of the gap ejector. For the experiments to study the ejector

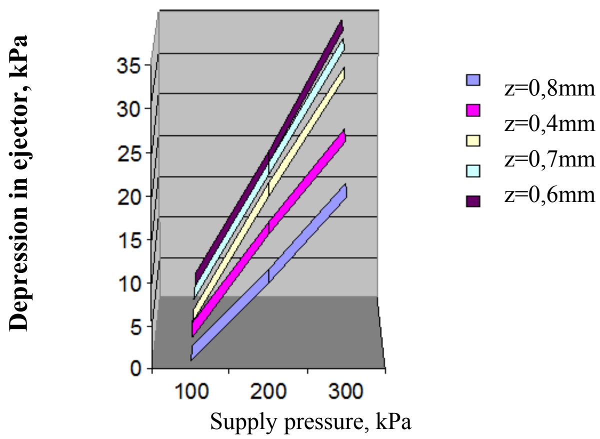

Figure 8 – Dependence of the vacuum in the inner tube of the tubular element on pressure for different values of the gap of the ejector

the experimental vibration table with attached compressor, pressure gauge and vacuum gauge was used. When turning on the experimental vibration table in the central channel there was created vacuum, that was recorded by the vacuum gauge. Initialy, the minimum gap was set equal to 0.4 mm, then by adjusting the value increased by 0.1 mm to 0.8 mm. The results of the experiment are plotted in figure 8.

The results of the experiment are presented in table.

Negative pressure in the inner tube of the tubular member for various values of the gap of the ejector

	P = 100 кPa	P = 200 кPa	P = 300 кPa
P_i, kPa (z=0,4 mm)	5	17	23
P_i, kPa (z=0,5 mm)	10	23	32
P_i, kPa (z=0,6 mm)	10	22	31
P_i, kPa (z=0,7 mm)	7,5	20	30
P_i, kPa (z=0,8 mm)	5	13	19

Performance of the material removal. Many of the smaller component parts, such as the base substrate holders for discrete devices such as diodes, transistors, integrated circuits, solid-state circuits, microchips, etc. made of beryllium oxide. During the manufacturing process, all these parts are subjected to the flat grinding treatment, which is characterized by low processing capacity compared to vibro-abrasive treatment [18, 19].

Tests were conducted on ceramic insulators. During processing there is dust of about 120 cm^3 per side. Beryllium oxide is toxic in powdered state (the first class of hazard), for this reason the machine is hermetically sealed in a tanker. The maximum permissible concentration (MPC) for beryllium oxide is 0.0006 mg/m^3. Beryllium oxide dust content in the existing production in the atmosphere inside the hopper is 0.0024 mg/m^3 outside is 0.0014 mg/m^3, which is 2.3 times higher than the MPC.

The concentration was determined by the reference exhaust to the local filter and its combustion and subsequent chemical analysis and determination of the amount of matter captured [20].

Proposed pneumatic vibration table can be used without sealing tanker. Drafting air with processing products comes directly from the work area and then partially being filtered using a centrifugal filter misses the exhaust filter-ventilating system, reducing the concentration of beryllium oxide in the working area of the rooms to 0.0004 mg/m^3, which is 1.5 times lower than the MPC and 3.5 times lower than in the existing production.

Conclusions. On the basis of these results we can draw the following conclusions:

1. Experimentally proved that the best frequency response (with the same parameters) has a vibration motor design, in which the output radial holes are formed in the central tubular member shakers.

2. Experimentally established that the highest productivity of processing waste dust removal of parts of selected class of the developed pneumatic vibration table gives the ratio of the gap of ejector to the inner radius of the tubular member within 3...3.5. With optimal parameters of pneumatic vibration table maximum capacity of dust collection is 97 %, which can be considered satisfactorily and with increasing vertical load on vibro-tanker pneumatic vibration table from 10 N to 100 N vibration amplitude decreases and the vibration frequency remains unchanged.

3. It is analytically identified and experimentally proved that to increase the rate of compressed air through the inlet air pressure in the cylinder chamber of the pneumatic vibration motor should be reduced , and to increase the ejection of dust processing waste - increase .

4. It was established experimentally that the proposed pneumatic vibration table eliminates the need for sealing tanker and the drafting air with products processed comes directly from the treatment area and then partially being filtered using a centrifugal filter falls into the exhaust system of filtering, reducing the concentration of beryllium oxide in the working area of the rooms to 0.0004 mg / m^3 which is 1.5 times lower than the MPC and 3.5 times lower than in the existing production.

5. New multifunctional technological equipment for inertial vibroabrasive machining based on beryllium oxide was developed, which eliminates the time for the sticking and plywood of parts, increases productivity, industrial and environmental safety, due to the simultaneous vibrational rotational movement of the tool, the ejection of products processed and filtering.

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БЕРИЛЛИЙ ОКСИДІ НЕГІЗІНДЕ ТЕТІКТЕРДІ ИНЕРЦИЯЛЫҚ ДІРІЛДІ АБРАЗИВТІК ӨҢДЕУ ҮШІН ДІРІЛДІ ҮСТЕЛДІҢ ПНЕВМАТИКАЛЫҚ ЖЕТЕГІНІҢ ТИІМДІ ПАРАМЕТРЛЕРІН АЛУ БОЙЫНША ЭКСПЕРИМЕНТТІК ЗЕРТТЕУЛЕР

Аннотация. Мақалада сығылған ауа есебінен құралдың ротациялық тербелмелі қозғалысын, өңдеу өнімдерінің эжекциясы мен олардың сүзгіленуін қамтамасыз ететін пневматикалық жетекпен жабдықтау арқылы жетілдірілген инерциялық дірілді абразивтік өңдеу үшін арналған дірілді үстелді эксперименттік зерттеумен байланысты бірнеше сұрақтарға көңіл бөлінген. Атмосфералық тесіктің құрылымдық орналасуының әрбір түрі үшін атмосфералық тесіктің көлденең қимасының әртүрлі өлшемі және қысымның әртүрлі мәндері бар бірқатар эксперименттер орындалды, сонымен бірге қалған параметрлер бекітілді. Енгізу саңылауының радиусын, атмосфераның тесіктің радиусын, роликтің массасының оңтайлы мәндерін анықтау үшін зерттеулер жүргізілді. Қалдықтарды және сүзгіні максималды өңдеуді және жинауды қамтамасыз ету үшін ауаны беру жүйесінің геометриялық параметрлері реттелді.

Түйін сөздер: дірілді үстел, дірілді абразивтік өңдеу, тербеліс амплитудасы, дірілді процесс, тербеліс жиілігі, оңтайландыру.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ПО ПОЛУЧЕНИЮ ОПТИМАЛЬНЫХ ПАРАМЕТРОВ ПНЕВМАТИЧЕСКОГО ПРИВОДА ВИБРОСТОЛА ДЛЯ ИНЕРЦИОННОЙ ВИБРОАБРАЗИВНОЙ ОБРАБОТКИ ДЕТАЛЕЙ НА ОСНОВЕ ОКСИДА БЕРИЛЛИЯ

Аннотация. В работе уделено внимание решению ряда вопросов, связанных с экспериментальным исследованием вибростола для инерционной виброабразивной обработки усовершенствованного за счет оснащения его пневматическим приводом, обеспечивающим за счет подачи сжатого воздуха ротационное колебательное движение инструмента, эжекцию продуктов обработки и их фильтрацию. Для каждого типа конструктивного расположения атмосферного отверстия была проведена серия опытов с различной величиной площади поперечного сечения атмосферного отверстия и различными величинами давления питания, при этом остальные параметры были зафиксированы. Были произведены исследования по определению оптимальных величин радиуса входного сопла, радиуса атмосферного отверстия, массы ролика. Для обеспечения максимальной производительности обработки и сбора образующихся отходов и их фильтрации проводилось регулирование геометрических параметров системы подачи воздуха.

Ключевые слова: вибростол, виброабразивная обработка, амплитуда колебаний, вибропроцесс, частота колебаний, оптимизация.

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