ISSN 1392-1134 (print)/ISSN 2345-0371 (Online)

MCMXXII
VYTAUTAS MAGNUS
UNIVERSITY

AGRICULTURAL ENGINEERING

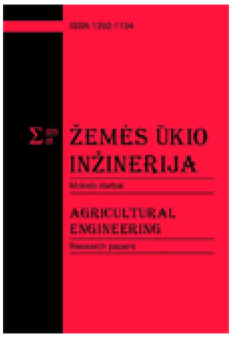
2023, V. 55

ŽEMĖS ŪKIO INŽINERIJA

AGRICULTURAL ENGINEERING
Scientific journal, ISSN 1392-1134/eISSN 2345-0371

Agricultural Engineering ISSN 1392-1134 / eISSN 2345-0371

About the Journal



EurAgEng

Focus and Scope

The journal of ***Agricultural Engineering*** is a research journal published by Vytautas Magnus University Faculty of Engineering. It is an international medium for the publication of multidisciplinary and interface between agriculture engineering and other fields of science works. Language of publication are English.

The ***Aim*** of ***Agricultural Engineering*** publish original unpublished research papers dealing with mechanization of cropping and animal husbandry; green energy engineering; development, maintenance and reliability improvement of agricultural and other machinery; development of agriculture and other problems related to areas covered by agricultural engineering and interface between agriculture engineering and other fields of science.

The main ***Topic*** of the articles are:
Technologies of Cropping
Animal Husbandry Technologies
Technologies of Green Energy
Agricultural Machinery Construction and Reliability
Hydraulic Engineering
Production Storage Technologies
Land Management
Water Resources Engineering

Section Policies

Original Articles

Checked Open Submissions | Checked Indexed | Checked Peer Reviewed

Review articles

Checked Open Submissions | Checked Indexed | Checked Peer Reviewed

Editorials

Checked Open Submissions | Checked Indexed | Unchecked Peer Reviewed

Sharing the experiences

Checked Open Submissions | Checked Indexed | Checked Peer Reviewed

Peer Review Process

Manuscripts submitted to Agricultural Engineering are subject to peer review to maintain the standards of the journal, promote rigorous research within the fields and to offer authors constructive feedback on their submissions.

Agricultural Engineering has a 'double blind' review process: Authors are not told who reviewed their paper, and referees do not know the name of the authors whose papers they review. The peer referees' identity remains unknown to the authors.

Manuscripts are sent out for review electronically, and all correspondence takes place via e-mail. Although the peer review process is accelerated by the use of electronic communication, traditional, high-quality peer-review standards are applied to all manuscripts submitted to the journal.

Peer reviewers are asked to give their opinion on a number of issues pertinent to the quality and suitability of a paper, and to judge papers on grounds of originality and importance. We pride ourselves on providing constructive and formative feedback to authors.

Reviewer Guidelines Reviewers of Agricultural Engineering are asked to consider the following points during their evaluation:
•Does the subject of report correspond to the journal topic?
•What is the scholastic level of presented material? Is it Original article?
•Is the sufficient literature survey for the analysis of the research topic?
•Is the description of research methodology clear.
•Does the analysis/ evaluation have a clear flow and logical argument?
•Does the analysis/evaluation link to an appropriate discussion and conclusions?
• Does the technical preparation of paper iz good (means quality of shedules, diagrams, figures)?

Peer reviewers will have five possible options, for any paper:
1. Accept manuscript (i.e. no need for any revision)
2. Accept after revision (i.e. accepted if the author makes the requested revisions)
3. Revise and resubmit (i.e. accepted or rejected after revisions have been made - paper will be sent out for another peer review round)
4. Reject manuscript (i.e. if the manuscript is not sufficiently developed for publication)
5. See comments (i.e. if the reviewer cannot choose from any of the above)

In addition, papers may be returned to authors by the Editors prior to review, if judged to be out of scope, out of the limits of the word length guidance or not sufficiently prepared for publication.

To facilitate rapid publication, authors are given a maximum of 6 weeks for revision. After 6 weeks, revised manuscripts will normally be considered new submissions.

Open Access Policy

This journal provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

Archiving

This journal utilizes the LOCKSS system to create a distributed archiving system among participating libraries and permits those libraries to create permanent archives of the journal for purposes of preservation and restoration. More...

Author Self-Archiving

Authors are permitted and encouraged to post items submitted to Agriculture Engineering on personal or institutional websites, prior to and after publication (while providing the bibliographic details of the latter).

Indexing

IN 2014 Agricultural Engineering was indexed in Directory of Open Access Journals (DOAJ), EBSCO, Genamics, Google Scholar, IC Journals Master List, Ulrich's periodicals.

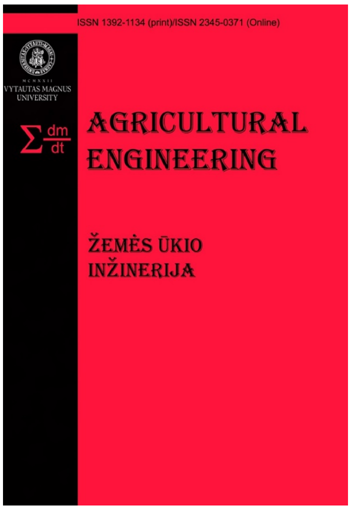
ICV 2014: 85.86
Standardized Value: 8.01

Commercial Reprints & Advertising

waiting...

Agricultural Engineering ISSN 1392-1134 / eISSN 2345-0371

Vol. 55 (2023)



Published: 2023-04-12

Articles

INCREASING THE EFFICIENCY OF CHOOSING A HYDRAULIC IMPULSE DRIVE WITH PROGRAMMABLE CONTROL

Yurii Paladiychuk, Inna Telyatnik

30-43

PDF

Agricultural Engineering ISSN 1392-1134 / eISSN 2345-0371

VYTAUTAS MAGNUS UNIVERSITY
MCMXXII
ISSN 1392-1134/ eISSN 2345-0371
AGRICULTURAL ENGINEERING
2023, Vol. 55, 30-43 p.
https://doi.org/10.15544/ageng.2023.55.4

INCREASING THE EFFICIENCY OF CHOOSING A HYDRAULIC IMPULSE DRIVE WITH PROGRAMMABLE CONTROL

Yury Paladiychuk, Inna Telyatnik

Vinnytsia National Agrarian University, Faculty of Engineering and Technology,
Sonyachna str., 3, Vinnytsia, 21008, Ukraine

Abstract

Modern trends in mechanical engineering require the introduction into production of methods and tools that ensure greater reliability of parts and products as a whole, while reducing production costs.

The reliability of vehicle parts depends primarily on their strength, wear resistance, vibration resistance, heat resistance, etc. These criteria of reliability of vehicle parts are met in various ways and with various measures in their production, such as: Selection of material and various methods to increase strength and wear resistance - thermal processing, processing of various physical methods, surface details and zones of concentration stresses, etc.

The article includes the description of forming metal powders as a technological operation that leads to the formation of a powder molding. The equipment for vibratory pressing of blanks from powder materials is considered and compared. The main vibration and shock vibration technological processes are presented.

Schemes and methods of carrying out vibration forming of powder materials are justified. Classification of vibration forming processes according to the properties of vibration and shock modes is analyzed.

Determination of the main advantages and disadvantages of electromagnetic vibration exciters in comparison with others.

It is proposed to replace the first stage of hydro inertial presses by an electromagnet controlled from the control unit, which allows to clearly reproduce the necessary technological parameters, to simplify the process of readjustment and to carry out the automation of the equipment.

Keywords. *Forming, surface plastic deformation, hydropulse, vibropress – hammer, hydropressure vibration exciter.*

Received 2023-04-09, accepted 2023-06-19

1. Introduction

Description of the problem. One of the ways to increase the fatigue strength and wear resistance of parts is to deform the surface layer of the working surfaces of the parts as a whole and in stress concentration zones. Plastic deformation takes place at a magnification load higher than the strength elasticity of the material, because the metal hardens during deformation [1−12].

Strengthening metal during deformation metal it is called - slander. The main mass of industrial alloys has a polycrystalline structure. During deformation polycrystals absent stage slide, grain deformation immediately begins to slide on several systems and is accompanied bends and twists of the planes slide. General the deformation is small and amounts to 1%, the grains are deformed heterogeneous due to them different orientation in relation to the applied loads. By changing the deformations, the difference between the grains of the material decreases and the microstructure changes: the metal grains are gradually pulled in the direction of the plastic currents, which leads to a change in the crystalline grains of the metal lattice when the density of the defects increases.

Surface Plastic Deformation (SPD) of the material of a workpiece creates multiple point and linear defects (linear and helical dislocations) in the crystal lattice of the surface layers of the workpiece, thereby increasing the resistance of these layers to wear and cracking. The deformation reinforcement of the workpiece surface can be realized in various ways and devices with mechanical, pneumatic and hydraulic drive. The most compact devices can be hydraulic due to the known advantages of hydraulic drive. Considering the known types of hydraulic drives, the greatest preference has a relatively new type of hydraulic drive - hydraulic impulse, which allows to create small devices for deformation strengthening of the surface of the parts, which can be installed directly into the machines of metalworking equipment [1, 2].

2. Study Subject Analysis

Molding of metal powders is a technological process in which the powder is formed into an appropriate shape, i.e. a body with a certain shape, dimension and density. The initial volume of the bulk material decreases under the action of force, and the powder is compacted. The change in initial volume is different from the deformation of a compact body, whose volume remains constant, although its geometric dimensions change. The densification of the powder is ensured by the deformation in metal molds or in elastic shells. Deformation of metal powders is divided into the following processes: Pressing, isostatic forming, verbal forming, rolling, sliding forming, impulse and vibration forming. All metal powder forming processes can be compared to pressing in one way or another [1−3].

Impulse forming of metal powders or powder pressing, in which compaction is performed by shock waves in a time interval not exceeding 1 s, is originally a method for producing large-sized compacts from powders of materials with low plasticity and composites, as well as briquettes with high density.

Vibratory pressing equipment has the same design solutions, as far as the position of the execution bodies is concerned, and differ mainly in the type of drive that excites the vibrations. Therefore, their nomenclature is presented as follows.

Vibratory presses with hydraulic drive, constructed on the basis of ordinary single- and double-column presses (Fig. 1) with upper or lower arrangement of the drive of the working member 1, allow periodic loading of the workpiece 4 on one side. Developments of hydraulic vibratory presses for double-sided pressing are known, but they are not used in practice [2].

The use of various types of hydraulic vibration exciters in the drive of the working link has given rise to a variety of types of hydraulic vibratory presses developed and created by a number of design and research institutions.

All types of hydraulic vibration exciters used or tested in drives of vibratory presses developed on the basis of conventional hydraulic presses can be divided into pulsating and self-oscillating exciters [2].

The pulsating vibratory exciters, based on the principle of generating a periodic pressure in the hydraulic working cylinder, are divided into pump exciters with closed circuit of the working fluid and slide exciters with forced axial movement or rotation of the distribution element by a separate drive.

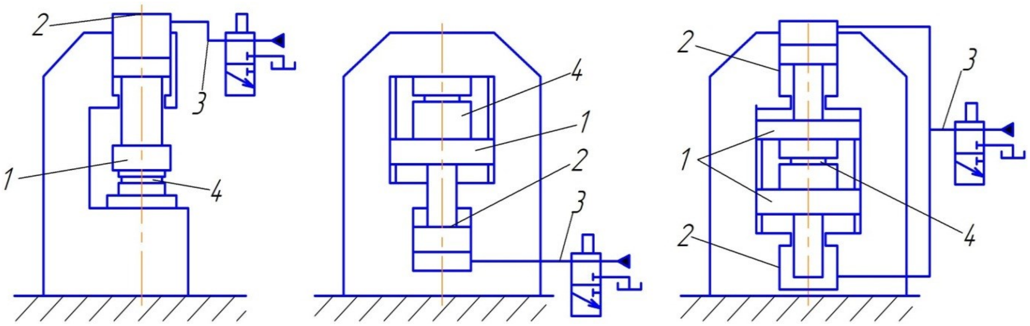


Fig. 1. Vibrating presses with a hydraulic drive: 1− working member, 2 – hinged drive, 3 – pulsator, 4 – workpiece.

The simplicity of the design of pulsating vibratory exciters attracted the attention of designers of vibratory presses, but they have not gained acceptance due to a number of significant shortcomings that occur during operation.

Such disadvantages of pump vibratory exciters are – strong heating of the working fluid in closed hydraulic systems and in valve systems with forced mechanical opening; – significant power losses for throttling the fluid as a result of increasing its supply to the hydraulic system at constant speed of movement or rotation of the distribution element, complexity of the drive and regulation of the amount of energy supplied for one working stroke [2].

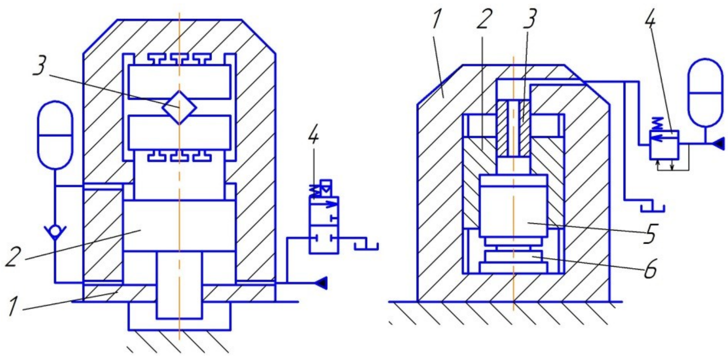
The use of self-oscillating hydraulic vibratory exciters with mechanical and hydraulic feedback in the drive of vibratory presses made it possible to easily expand the possibilities of these presses in setting the load parameters. Despite the dependence of vibration parameters on the load acting on the pistons, noise generation and shock character of the work, self-oscillating hydraulic vibration exciters have become widely used in real designs of hydraulic vibratory presses [2, 3].

The first designs of hydromechanical self-oscillating vibration exciters with a gap in the rigid mechanical feedback for the motion of the working body had limited kinematic and performance characteristics and could only be used in laboratory models of vibratory presses, e.g. Hydro Dynamic Press (HDP) presses.

Exciters with a gap in the mechanical feedback between the distributor element and the servo valve and with a hydraulic feedback based on the pressure drop are the most suitable from the point of view of operational safety, manufacturability and the possibility of realizing the specified load parameters.

These vibration exciters are known in the literature as "pulsators" and "pulsator valves," which is not the recommended classification terminology. "Pulsators" were used in Pulsating Load Press (PLP) -type vibratory presses, and "pulsator valves" were first used in prototype Hydro Inertial Presses (HIP) [3].

Fig. 2 a) shows a schematic diagram of a PLP-type pulsating load press. In the lower part of the two-column table 1 there is the articulated drive 2, which acts on the workpiece located in the removable punch 3. With the help of the pulsator 4, a pressure is generated in the cavity of the hydraulic working cylinder, which periodically changes and causes oscillatory movements of the working member of the press. kN have been used for calibration of light metal profiles [3].



a) b)

Fig. 2. Presses: a – pulsating load (PPN): 1 – two-post bed, 2 – link drive, 3 – stamp, 4 – pulsator; b – hydraulic inertial press (HIP): 1 – bed, 2 – inertial mass, 3 – telescopic pipeline, 4 – pulsator valve, 5 – plunger, 6 – workpiece.

Hydroinertial presses proved to be a fundamentally new solution for vibratory presses. Due to the way the working force acts on the workpiece, they differ significantly from vibratory presses manufactured on the basis of ordinary hydraulic presses. Fig. 2, b shows the schematic of a HIP in which the ram 5 exerts a dynamic force on the workpiece 6 due to the periodic generation of fluid pressure pulses in the cavity of the hydraulic working cylinder (its body is served by an inertial mass 2 that moves relative to the bed 1), which are supplied through the pulsator valve 4 and the telescopic line 3. According to the results of the experiments carried out on the presses HIP, no advantages of the inertia load system were found [3].

So, the vibratory and vibratory impact press occupies a wide place not only in the shaping of metal powders, but also in the methods of their application in the production of blanks from plastics and other powdery materials, in the compaction of molding compounds, surface treatment with abrasive materials, the application of construction and assembly technologies and processing of plastics under pressure, in typical tests, loading and unloading operations, drying, etc. (Table 1).

Depending on the type of work performed, the equipment on which vibration forming is performed is configured and designed differently, so there is a wide range of vibratory equipment, but their design principles have characteristic features [3, 4].

3. Setting out the Basic Material

The energy sources used in the pulsed forming of powders can be the electrohydraulic discharge of a battery of high-voltage capacitors through the water gap between two electrodes, the energy of a pulsed magnetic field, compressed and combustible gasses and liquids, and explosives. Characteristic of this forming method is the use of loading velocities exceeding the velocity of longitudinal elastic waves for powders in the plugged state of 50-100 m/s [3, 4].

Advantages of this method: high density of up to 90% for titanium, tungsten and molybdenum powders; large generating forces > 500 MPa on the performing body; high movement speeds that allow reducing the generated force for better compaction of the workpieces. Disadvantages include: Hazardousness and increased safety requirements due to the use of explosives; high cost; the complexity of the design.

Vibratory deformation has found wide application in various industries. The efficiency of the use of useful vibration allows the production of blanks from low-plasticity powders (e.g. carbides, metal borides, tungsten and titanium powders) with a density of 65-85% with a low force of 0.3-0.6 MPa [4].

Classification of the processes of vibration formation according to the characteristics of vibration and shock vibration modes depends on the component of the load - pulsating or shock (impulse). Schemes of vibration and vibratory impact technologies have found wide application in the production of blanks from powder materials, compaction of molding compounds, surface processing with abrasive materials, implementation of construction and assembly technologies, technologies for processing plastics by pressure and others. Vibratory and vibratory impact molding (pressing) ensures more economical fulfillment of the technical requirements for the blanks compared to other pressing methods.

Table 1. The main vibration and vibration impact technological processes

Technological process	Technological operation	Method processing	Branch of production
Obtaining blanks of products from non-plastic powder materials	Compaction, shaping, pressing	VH*	Metallurgy, mechanical engineering, automobile manufacturing, electrotechnical industry
Obtaining products from plastic materials during pressure treatment	Pulsating hood, draft, stamping, calibration, drawing, rolling	V*	Engineering
Final processing of parts with abrasive materials	Grinding, polishing, strengthening, finishing	V	Engineering
Production of foundry forms	Forming, compaction	VH	Metallurgy, foundry industry
Testing machine parts	Resource, forcing and other typical tests	V, VH	Instrument building, radio engineering, aircraft, tractor and mechanical engineering
Construction and installation work	Sealing of joints, compaction of soil, concrete, etc.	VH	Construction

*VH – vibro hamering; V – vibro.

The latter is explained, in particular, by a significant reduction in the amount of work compared to static pressing, which reduces the wear of the molded parts and also ensures the possibility of their production with thin walls. The particular effectiveness of vibratory pressing is shown in the forming of workpieces with complex configuration and large dimensions [4].

In impact-vibration loading modes, an additional increase in plastic deformation of the workpiece under the influence of a repeated force pulse was found when the primary pulse causes only elastic deformations in the workpiece. The law and the right are characteristic for the cases of Broudary pressing of blanks with low filler content for stable and inertial loading modes.

In addition, for the first cycles the load in id defined likely for learning, and pulse effort for preparing for the part of the punch in terms of time of start and manuals no growth effort on the days of the press - mold container, which testifies to the fact that there is no space speed and gears and pulse load in environments and workpieces due to their physical and mechanical properties. Such special, gears and impulse effort by the workpiece can be explained by them shaft character [4].

Comparing the process of vibro-impulse pressing with conventional pressing, we should also pay attention to the uniformity of pressing, because in conventional pressing the distribution of powder layers is not uniform, which is caused by internal and lateral friction. The result of such distribution is shown in Fig.3.

The complexity of powder movement in the inner surface of the matrix is well illustrated by layers of tracing paper or foil separating parts of the initial volume and oriented perpendicular to the load axis [4].

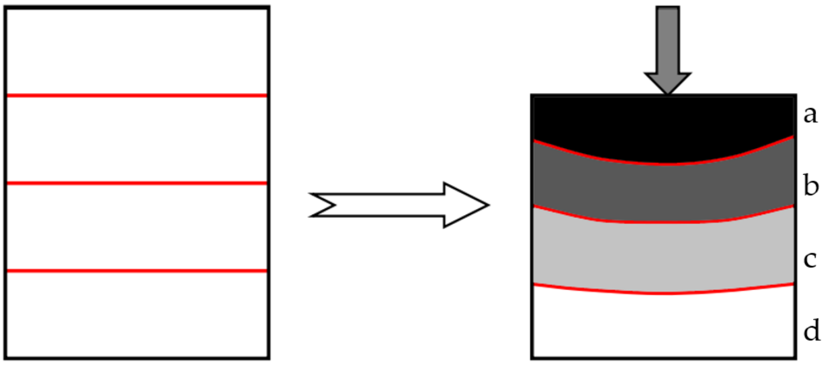


Fig.3. Powder density distribution by volume during pressing. a – zone of greatest deformation; b – medium deformation zone; c – the smallest deformation; d is the zone of minimum deformation.

When the load is increased, the bending of the layers along the pressing axis is observed. If the volume fractions are initially equal, then the upper layers are thinner, i.e., denser than the lower layers. This illustrates the decrease in pressing pressure as one moves away from the punch.

The positive effect of vibration is that it makes it possible to destroy the bulges formed during backfilling, breaking weak bonds between particles and thus bringing the effective coefficient of friction from the outside and between particles close to zero.

During the directed vibratory motion, a low pressure (0.5 - 5 MPa) is applied to the powder particles. At lower values, the backfill is loosened, and at higher values, the movement of the particles is blocked. Usually, such pressure is generated by hydraulic or pneumatic loading devices [4].

For small workpieces consisting of particles larger than 100 μm, vibrations with a frequency of 100 to 200 Hz are considered effective, for molded parts consisting of particles of 1-100 μm - from 200 to 300 Hz, for molded parts consisting of particles smaller than 1 μm - 300 Hz and more. It should be noted that if the frequency is increased and the vibration acceleration is constant at 25 - 30 g, the amplitude should not be smaller than 0.1 - 0.15 mm. If the amplitudes are too small, small displacements of the particles will occur, if they are too large (more than 0.5 mm), the previously formed bond may be broken, which is equivalent to loosening of the powder. The duration of the process should not exceed 30 seconds, because in case of longer exposure, no more change in the properties of the molded parts can be observed. Optimal compaction is achieved in 2 - 10 seconds, and this time practically does not depend on the volume of the compaction material (if the volume of the powder increases from 0.5 to 50 cm 3 , the required duration of vibration exposure increases only by 1.5 times) [4].

The more correct the shape of the particles, the shorter the time required; the more uniform it is, the longer.

Lubricants can be used in vibration molding in the same quantities as in conventional pressing, but their excess has a more negative effect.

The inertia vibratory press hammer (IVPH) (Fig. 4) consists of the lower drive of the table 2 with elastic return elements 3 and a movable crosshead 6 with a variable inertia mass 5 mounted on it, which moves freely along the guide columns forming a rigid frame with the upper and lower crossheads of the bed 1. The IVPH drive uses a self-oscillating vibration exciter (pulsator valve) 7 with pressure feedback and a one-way hydraulic accumulator 8.

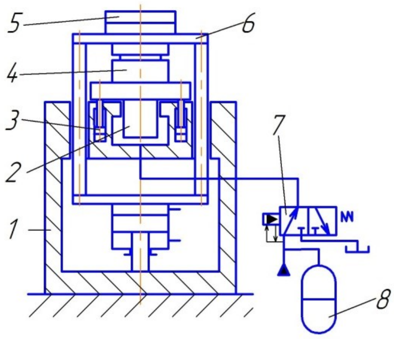


Fig. 4. Inertial vibropress hammer: 1 - bed, 2 - table lower drive, 3 - elastic return elements, 4 - workpiece load modes, 5 - variable inertial mass, 6 - movable crossbar, 7 - pulsator valve, 8 - one-way hydraulic accumulator.

Such a hydraulic impulse drive provides a clear relationship between the energy stored in the hydraulic accumulator for a working stroke of the machine and the pressure in the hydraulic system, and makes it possible to adjust the parameters of the hydraulic impulse depending on the impulse energy. The inertial loading scheme of the IVPH, in combination with an additional static clamping, allows the implementation of the vibration and loading modes of the workpiece 4 when it interacts with the moving crosshead.

The research and industrial operation of the IVPH have demonstrated the versatility of this equipment in pressing workpieces of complex configuration and large dimensions made of carbide-silicon powder materials, as well as its high efficiency, and have shown the need for further work to ensure wide industrial application of the IVPH [4, 5].

The vibropress based on existing electrohydraulic impulse units (EHIU) of the "Udar" type also attracts great interest. However, the operation of vibropresses with an electrohydraulic drive is not practical in our time due to the limited capabilities of the latter. For example, in the case of presses of the "Udar" type, the electric (power) part of the machine reaches 80% of the full volume and ensures the transfer of the estimated energy of the liquid pressure pulse at a frequency of passage of no more than 2-3 pulses per minute. When switching to the vibratory press mode, the energy of a pulse decreases significantly with unchanged drive parameters, which does not provide a solution to the posed technological problems, especially when vibratory pressing products with complex configuration and large dimensions. The technical characteristics of the vibratory press tested under production conditions are listed in Table 2.

Vibratory pressing of blanks from powder products under production conditions has been carried out mainly on two types of vibratory presses — VP and IVPH, respectively - with mechanical and hydraulic drives. Comparison of the characteristics of these two types of vibratory presses shows the advantages of IVPH in terms of the possibility to adjust the loading parameters and thus solve broader production problems. Other known advantages of the hydraulic drive make it possible to consider the IVPH as a more promising equipment, especially when there is a need to increase the power and workload, reduce the metal capacity, solve the problems of increasing the level of mechanization and automation of the technological process, increase the reliability and durability of the machine drive elements [4-6].

When choosing equipment for forming powder materials, the IVPH type vibropress hammer is considered to be the most economically and technologically promising machine. The design of IVPH also allows its automation through the use of software, as modern software and hardware of computer systems has made rapid progress towards production automation compared to previous decades, and by connecting execution organs to the control system allows to reproduce the necessary technological parameters on known equipment. Such automation makes it possible to replace complex and large-scale computer systems, which were located right next to the corresponding equipment, with a control system that includes a control unit, an adaptive part, elements for input and visualization of information, and the modern software used makes it possible to involve simple specialists in the field of vibratory casting without additional computer training and to constantly monitor the technical characteristics of the corresponding equipment by installing sensors of various types [5].

Table. 2. Types of vibrating equipment for forming blanks

Name Characteristics		Maximum working force, kN	Limits of change in the frequency of working strokes, Hz	Limits of adjustment of the stroke of the working link, mm	Type of drive of the working link	Purpose
Type of equipment	VP	200	50	4	M*	Production of refractory products from plastic and semi-dry masses
	HIP	2000	1...10	1...10	H*	Deposition and extraction of metals
	PLP	3150	50	1	H	Calibration and finishing of pipes and profiles
	IVPH	320	1...40	1...10	H	Pressing blanks from powder materials of molding and core mixtures
	EHD	320	1...55	0.1...1	EH*	Pressing blanks from powder materials

* M– mechanic; H – hydraulic; EH – electro hydraulic.

However, considering all the above points, it should be noted that with all the advantages of modern production resulting from the integration of computer technology into control systems, the principles of reproduction of the main movements of the executive elements according to the principle of their action have remained unchanged, and therefore the main elements for disturbing vibrations and vibrating ironing have the same constructive solutions.

Vibratory and vibratory impact devices are used for the implementation of technological vibratory processes, which are manufactured according to a unified design scheme (Fig.5). From the energy source, the drive of the energy carrier and the system of control elements and energy distribution is transferred to the drive of the vibration generator, which is connected to the performing working link, and to the drive of the auxiliary working links, which are exemplarily represented in the form of a punch - an inert mass.

In this sense, the design and nomenclature of vibratory equipment includes the main elements of conventional presses. Most of the works on development of special devices for forming of workpieces by the method of vibratory pressing were often completed at the stage of testing of the experimental or development of the experimental and industrial sample. The main reason for this was the low technological and economic efficiency. Nevertheless, vibratory and vibratory impact equipment found wide application in various industries, especially in powder metallurgy [5].

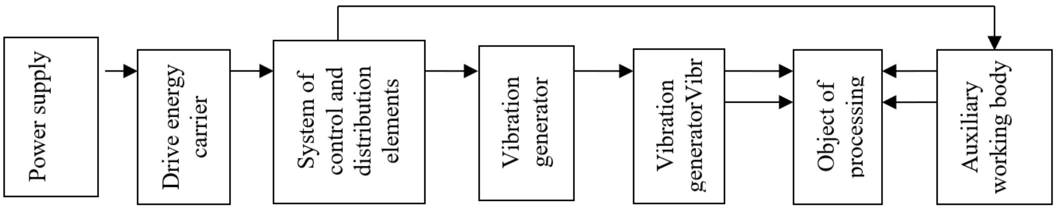


Fig. 5. Structural diagram of a typical VM and VUM.

Narrow- or wide-band stationary random vibration is often used in testing vibrating machines. This is usually done in cases where the conditions of vibration testing of the object must sufficiently approximate the random effects to which the object is subjected under real conditions.

Depending on the requirements of technologies or tests, one can use shock-free shocks or shock-vibration shocks, where the vibration motion of the inertial element is moved by a successive shock. Shocks can be generated in the vibration exciter itself or in the vibration drive, in the sum of the devices for vibration excitation, their transformation and transmission to the executive element of the machine, or in the collision of the executive element of the machine with the processing environment. Therefore, according to the methods of vibration excitation, the following are distinguished: centrifugal, electromagnetic, electrodynamic, kinematic and forced hydraulic and pneumatic vibration exciters. The drives of vibratory machines are divided into mechanical, hydraulic, pneumatic, electric and combined drives according to that [5].

Of all types of vibration exciters used for technological purposes, centrifugal exciters are the most widely used. Their advantages are simple construction, low cost and easy, stepless adjustment of vibration frequency. The disadvantages of centrifugal vibration exciters include a relatively low resource, which depends largely on the quality of materials and products used, the accuracy of manufacture and assembly of parts, the correctness of operation and maintenance, the difficulty of independent regulation of the frequency and amplitude of the forced forces, the relatively long duration of the transition process under deceleration [5-7].

Kinematic vibration exciters are divided into centrifugal drives with elastic connecting rod and with drive damper according to the basic device. There are drives with controlling and non-controlling vibration amplitude. In turn, controlling drives are divided into a drive that is adjusted without the machine being at a standstill and a drive that is adjusted when the machine is at a standstill. According to the type of control, a distinction is made between drives with stepless and stepless control.

With kinematic vibration exciters, both straight-line harmonic and biharmonic vibrations and elliptical vibrations can be excited.

With electromagnetic vibration exciters, the forces that excite the vibrations are generated by the action of a time-varying magnetic field on ferromagnetic bodies.

The main advantages of electromagnetic vibration exciters are [6]:

- the ease of setting the vibration amplitude and the possibility of its adjustment during the operation of the device, which allows the inclusion of electrovibration devices in systems with automatically controlled productivity;
- Reliability and durability due to the absence of friction pairs in the vibration exciter;
- the possibility of using several simultaneously operating vibration exciters in one vibration machine, without special measures to ensure synchronization; this is due to the synchronization of vibration exciters during power supply from the common network and allows the distribution of forces causing vibrations along the length in one or two directions of the elastic body.

With the help of two and more vibration exciters, it is also possible to obtain different vibration trajectories.

Disadvantages compared to other vibration exciters include:

- relatively high weight incurred per unit amplitude of force generated; high cost of electrical material and spring steel;
- significant changes in vibration amplitude with changes in load, which is also due to the resonant operation of devices with electromagnetic exciters;
- the amplitude of deflection is small, its value is limited by the permissible values of the air gap between the armature and the core of the electromagnet.

Electrodynamic vibration exciters are widely used for vibration testing of various kinds. They are used to test samples of materials, parts, and assemblies of machines and equipment; to perform natural tests on aggregates, machines, and vehicles; and to investigate the properties of bulk materials and the handling of biological objects. Relatively rarely, electrodynamic vibration exciters are used to perform technological processes [6].

Depending on the purpose of the vibration exciter, its power, the frequency range of the vibrations and other factors, cooling systems, devices for guiding the vibrations, amplification and attenuation systems can be included in its design.

The parameter range of reproducible vibrations is characterized by a wide breadth. The most important parameters of the vibration exciter are the range and amplitude of the forced force in harmonic vibrations. The most characteristic frequency range for medium-power electrodynamic vibration exciters is 5 – 3000 Hz. In some designs, tests are performed at frequencies up to 15-30 kHz. Special amplification devices allow the use of vibrators at frequencies below 1 Hz. At the same time, the force amplitude ranges from 1 N to 500 kN. Electrodynamic vibratory exciters allow the recording of random vibrations and the performance of vibration studies according to a predetermined program.

Disadvantages of electrodynamic vibration exciters include relative design complexity (for high-power vibration exciters), sensitivity to difficult operating conditions (detrimental influence of external factors), and the presence of significant stray magnetic fields in some designs.

Pneumatic vibration exciters, using the energy of compressed air, belong to the large groups, which is explained by their following advantages: the possibility of working in explosive conditions; the relatively uncomplicated adjustment of the amplitude and frequency of vibrations with the help of a simple throttle; a wide range of possible frequencies from 0 to 500-800 Hz; a wide range of changes in amplitude and strength, including quite large changes.

Pneumatic vibration exciters usually work with standard industrial pneumatic systems with a pressure of 2-7 atm [6, 7].

Disadvantages include: calculation of the main dynamic indicators of motion (frequency, amplitude) is quite difficult; simple technical formulas are practically non-existent; high noise level during operation; pressure loss in the system due to low air density, vibration exciters differ:

- with pulsator, they are used at relatively low frequencies (up to 15 Hz), large amplitudes (up to 20-30 mm) and large developing force;
- self-oscillating, approximate frequency range 15-60 Hz, possibly sufficiently large amplitudes and forces;
- centrifugal, used at frequencies of 20-400 Hz;
- using self-oscillating processes in compressed air flow, reach high frequencies up to 2000 Hz, but amplitudes are small up to 0.2 mm.

Hydraulic vibratory exciters transmit the vibrations to the executive member of the vibrating machine when a pulsating source of working fluid is used, or when the flow of a constant supply of working fluid with the help of coils and other regulating devices [6].

the hydraulic vibrators are divided into pulsating, self-oscillating, trailing and self-controlling.

Vibrostimulators of the first type are based on the principle of excitation of the executing body (hydraulic cylinder) by pulsating pressure generated by a pulsating flow of working fluid.

In self-oscillating and self-controlled hydraulic vibratory exciters, a periodic forced force is generated during feeding from a constant pressure line, in the case of a special system that automatically supplies and discharges the working fluid periodically. The piston of the hydraulic cylinder independently controls the movement of the piston and ensures the continuity of the backward and forward movement.

In the case of self-oscillating and self-propelled vibratory exciters, a periodic force is generated during feeding from a constant pressure line, because the vibratory exciter has a special system that automatically periodically feeds and discharges the working fluid. The piston of the hydraulic cylinder independently controls the movement of the control piston and ensures the continuity of the backward and forward movement [6].

In self-oscillating systems, oscillations are excited by the presence of a nonlinear element in the hydraulic tracking system - a gap in the rigid feedback loop. Self-regulating oscillations are generated in oscillating exciters by the presence of special devices that ensure switching of the regulating piston when the piston of the hydraulic cylinder is in the end position. The frequency of the oscillations is controlled by the applied pressure, and the amplitude is controlled by the size of the gap in the feedback of the self-oscillating vibration exciter.

The pulsating vibration exciters are divided into two groups according to the principle of excitation - with pulsating pumps and with a coil generating pulsations.

The rotational or translational movements of the piston driven by an external motor are used as hydraulic distributors. The frequency of the oscillations of the vibration exciter is controlled by the speed of the rotational or translational movement of the hydraulic distributor. The amplitude is controlled by changing the pressure of the working fluid [6, 7].

One of the major disadvantages of hydraulic machines is the loss of working fluid during operation due to the technological gaps between the piston and cylinder, seals and rod, as well as the heating of the working fluid due to the closed volume. The disadvantages also include the fact that as the amplitude of the vibrations increases, their frequency decreases, as well as the complexity of control and adjustment of the vibration exciters.

The main advantages of pulsating vibration exciters with pumps - pulsators - are the clear implementation of the specified amplitude and frequency of the piston of the execution cylinder. This is a volumetric action drive. The amplitude of the vibrations of the rod of the working cylinder is determined by the volume ejected by the pistons of the pulsator pump and the ratios of the design parameters of the machine, regardless of the working load. The advantages also include the large force generated in comparison with other vibration exciters, considering their dimensions; the simplicity of the connection schemes; the possibility of use in all conditions and environments; a wide range of frequencies of the generated vibrations [7, 8].

One of the types of hydraulic vibration exciters is the hydraulic impulse drive of the HID. The main element of the HID is the pressure pulse generator (PPG), which is also known in the literature as "pulsator valve" and "hydropulse vibration exciter". The main advantages of this actuator are high force generation up to 100 kN, depending on operational and technological requirements, with small dimensions, low working pressure in the hydraulic system up to 10 MPa and the use of small power electric motors up to 5 kW, as well as parametric adjustment [8].

The main elements of the HID are a hydraulic pump, a hydraulic accumulator and a pressure pulse generator. Depending on the connection of the HID to the executive element of the vibrating machine, they are usually divided into "at the input", "at the output" and "combined". Depending on the principle of operation, the nomenclature HID is divided into single-, two- and multi-stage systems, as well as according to the type of closing elements - valve, ball and slide, the schemes of which are given in Table 3. Single- and two-stage HIDs are used for single-component vibratory loading and multistage for multicomponent loading to provide the necessary connection between all movements of the performing element.

A wide nomenclature of HID schemes is embodied in constructive solutions in the following models A1Sh1-B32, A2K1-BK2, P202, A232-B32. If we consider the design scheme of the A2K1-BK2 type vibration exciter (Fig.6), we should note the complexity of its construction. Another disadvantage of these vibration exciters is their regulation, which depends on the adjustment of the elastic elements, which can be carried out only experimentally in the course of adaptation to the required technological parameters. The main regulation of all HITs is the setting of the first cascade, which subsequently determines the function of all other cascades. That is, the first stage is responsible for setting to the specified pressure, and the second stage is a power element that ensures the flow of the required volume of compressed fluid from the injection cavity into the cavity of the execution cylinder [8-10].

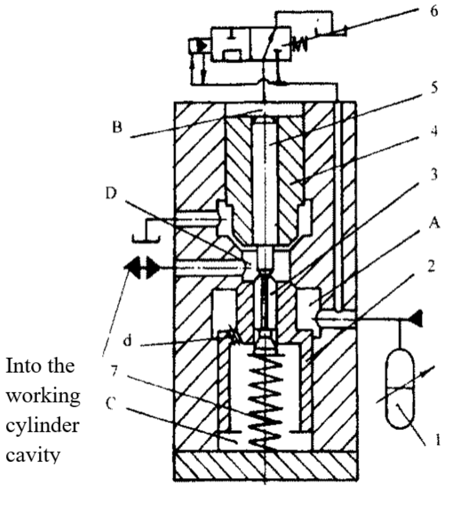
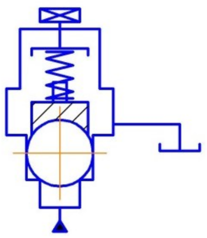
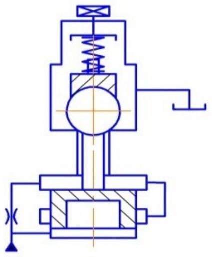
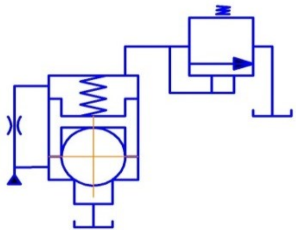
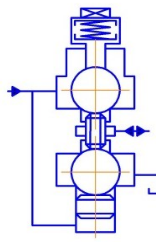
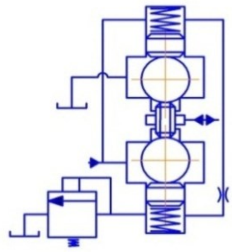
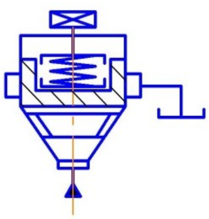
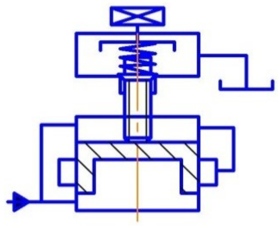
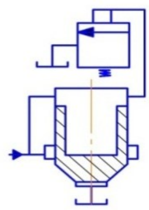
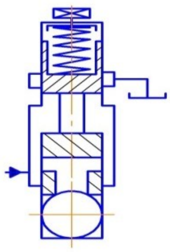
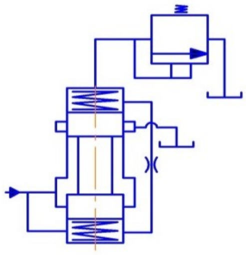
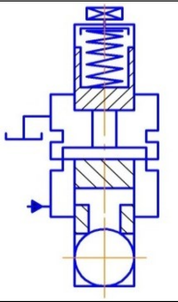
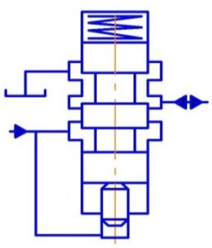
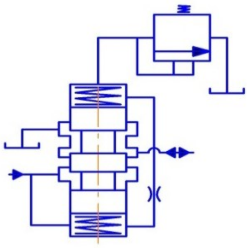


Fig. 6. Structural diagram of the A2K1-BK2 type vibration exciter: A, B, D, C – cavities, d – hole, 1 – battery, 2 – intake valve, 3 – servo valve, 4 – exhaust valve, 5 – pusher, 6 – valve of the 1st stage, 7 – spring.

We proposed to replace the first stage of the HIT with an electromagnet controlled from the control unit, which allows to clearly reproduce the necessary technological parameters, simplify the process of reconfiguration and automate the system. Such a scheme of the vibration exciter refers to combined drives, which are used more and more often with the modern development of the industry, as individual systems cannot perform the tasks assigned to them by modern production systems - automation, computerization, which ensures the intensification of technological processes and reduces the errors of the human factor, which ultimately improves the quality of the product.

Table.3. Schemes of vibration exciters of HIT

In vibrostimulator			Single cascade		Two-stage
			with a pusher	with variable area	
Types of locking elements	Ball valve	2/2			
		3/2			
	Valves	2/2			
	Zolotnikov	2/2			
		3/2			

By using a combined drive, you can take advantage of both drives, which complement each other. In fact, it is known that hydraulic vibration exciters produce large working forces and have much smaller dimensions compared to other vibration exciters. And electromagnetic vibration exciters make it possible to receive vibrations at a higher frequency and reproduce them quite easily according to a given law, which is due to the use of software. Finally, the use of a combined drive allows the vibration exciter to be easily adjusted without losing the required power. By using transition plates [8, 9, 10], such a drive can be mounted on known vibration devices without structural modifications.

As a combined actuator can be used, among others, commercially available electrohydraulic valves, the technical characteristics of which correspond to the parameters of combined electrohydraulic vibration reducers, i.e. the operating frequency is 50 Hz, the fluid flow through the valve is 100 l/min and more, the supply pressure in the system is 10 MPa. After analyzing the relevant electrohydraulic devices (EHD) in the relevant technical manuals, we chose the domestic manufacturer of the model UEG.S and the foreign manufacturer Parker, whose technical characteristics are listed in Table 1.4. The external and structural appearance is shown in Fig.7and Fig.8.

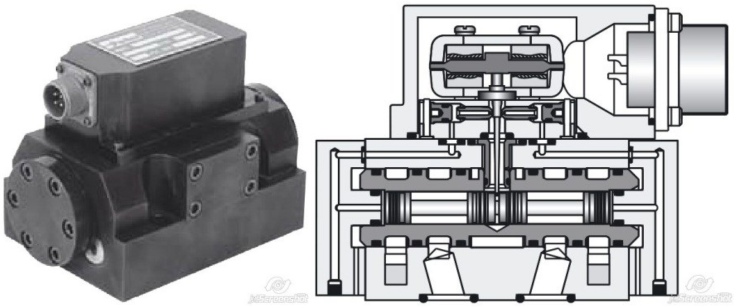


Fig.7. General and structural view of Parker SE 60 [11]

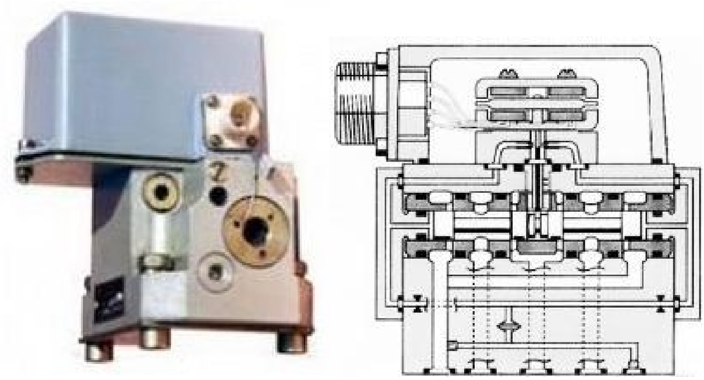


Fig. 8. General and structural view of UEG.S -200 [11]

Table.4. Technical characteristics of electromagnetic valves

Marking	Producer	Supply pressure, MPa	Operating temperature range of lubricants, °C	Oil consumption, l/min	The frequency corresponds to a phase shift of 90°, Hz	D_{in}, mm
UEG.S -500	Heating machine	1.6-32	+20...+70	500	27	23
UEG.S -200	Heating machine	1.6-32	+20...+70	200	70	18
UEG.S -100	Heating machine	1.6-32	+20...+70	100	120	13
SE2N	Parker	1, 0-21	-1 ... +82	95 - 125	>5 0	12.7
SE 60	Parker	1, 0-21	-30...+130	95-230	>100	17.5
In D30	Parker	7-9	-1 ... +82	76-152	40	12.7
72 D	Moog	32	+20...+80	95, 152, 228	70, 55, 35	13-20
SM4-40	Vickers	21	-10...+80	76-151	43	12-18
4WSE3E32-2X	Rexton	32	+10...+90	500, 700, 1000	60	21-32

The control of these valves is carried out by means of ordinary hardware, which makes it possible to reproduce different types of movements of the executing elements of the valves, depending on the technological requirements. The unit from which the electromagnetic valves are controlled is integrated into the control system, which includes an analog-digital converter ADC, to which pressure and displacement sensors are connected, as well as computer equipment for visualization and correction of changes in the technological parameters of the execution device, the block diagram of which is shown in Figure 9. Such a system allows simultaneous control of several electromagnets, which depends on the number of channels that the control system and the hardware part can perceive. The control unit, taking into account the wide range and capabilities of modern control systems, makes it possible to provide output signals with the desired power, frequency and shape [12].

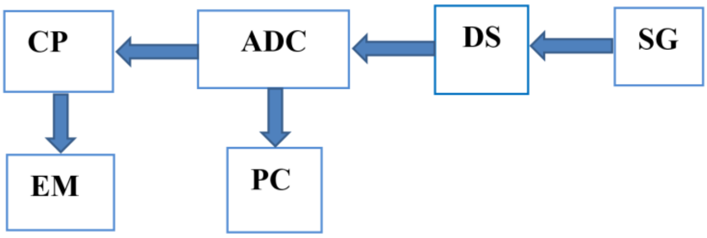


Fig.9. Control system where: CP – Control panel; SG – hydraulic system; D – sensors; ADC – analog-digital converter; PC – personal computer; EM – electromagnet.

The software (software) for the management of this system contains programs intended for a wide range of users and designed to organize the computing process and solve the most common data processing problems. Such programs allow to expand the functionality of computers, automate the planning of the computer queue, control and management of the data processing process, and also automate the work of programmers [12].

Special software is the set of programs developed for a specific control system. It contains packages of applied programs, which perform organization data and their processing in solving functional tasks.

4. Conclusions

Vibration devices for shaping blanks have a different structure, but they function according to the same principles of replicating the movements of executing elements. One of the main elements of vibratory equipment are vibrators, which can be divided into electric, pneumatic, mechanical, hydraulic and combined vibrators. The most widely used drive in powder metallurgy is the hydraulic one, which, compared to other drives, allows for large outputs with small dimensions. The main vibration exciter in the hydraulic impulse drive is the HIT, which the authors of this work intend to replace with a conventional electrohydraulic valve controlled from the control unit.

References

[1] Paladijchuk Yu.B., Telyatnik I.A. (2022). [Tipi i konstrukciyi vibrozbudzhuvachiv suchasnogo mashinobuduvannya]. Vibraciyi v tehnici ta tehnologiyi. Vol. 4, no. 107, pp. 26-35. [in Ukrainian].

[2] Veselovska N.R., Paladijchuk Yu.B., Telyatnik I.A. (2022). [Doslidzhennya mikrotverdosti poverhni cilindrichnoyi detali pri deformacijnomu protyaguvanni]. Tehnika, energetika, transport APK. vol. 3 no. 118. pp. 31-42. [in Ukrainian].

[3] Iskovich-Lotockij R. D., Ivanchuk Ya. V. (2008). [Pidvishennya efektivnosti rozvantazhennya materialiv pid diyeyu periodichnih udarnih impulsive]. Vibraciyi v tehnici i tehnologiyah. vol. 2, no. 51, pp. 8-11. [in Ukrainian].

[4] Iskovich-Lotockij R. D., Ivanchuk Ya. V. (2007). [Doslidzhennya dinamiki procesu roboti universalnogo gidravlichnogo vibroudranogo privodu dlya rozvantazhennya transportnih zasobiv]. Naukovi notatki. Mizhvuzivskij zbirnik (za napryamom «Inzhenerna mehanika»). no. 20, pp. 184-187. [in Ukrainian].

[5] Miskov V. P. (2015). [Inercijnij vibropres-molot z elektrogidravlichnoyu sistemoyu keruvannya gidroimpulsnogo privoda dlya formoutvorennya zagotovok z poroshkovih materialiv] : avtoref. dis. na

zdobuttya nauk. stupenya kand. tehn. nauk : spec. 05.03.05 / Miskov Vadim Petrovich. pp. 22. Vinnicya, [in Ukrainian].
[6] Iskovych-Lototsky R., Veselovska N. (2018). [Automatic system for modeling vibro-impact unloading bulk cargo on vehicles]. Proc. SPIE 10808, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments. 1080860 (1 October 2018): veb-sajt. URL: https://doi.org/10.1117/12.2501526. (data zvernennya 30.09.2022) [in English].
[7] Rostislav Iskovych-Lototsky, Yaroslav Ivanchuk, Yaroslav Veselovsky, Konrad Gromaszek, and Ayaulym Oralbekova. (2018). [Automatic system for modeling of working processes in pressure generators of hydraulic vibrating and vibro-impact machine]. Proc. SPIE 10808, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 1080850 (1 October 2018): veb-sajt. URL: https://doi.org/ 10.1117/12.2501532. (data zvernennya 30.09.2022).) [in English].
[8] Iskovich-Lotockij R. D., Ivanchuk Ya. V., Veselovskij Ya. P. (2014). Osnovi rezonansno-strukturnoyi teoriyi vibroudarnogo rozvantazhennya transportnih zasobiv. Nauka ta progres transportu. Visnik Dnipropetrovskogo nacionalnogo universitetu zaliznichnogo transportu im. akademika V. Lazaryana..vol. 5, no. 53, pp. 109-118. [in Ukrainian].
[9] S. Matysiak, and P. Pusz. (1985). [Axisummetric bousinesg problem for a granular hal]. Bulletin of Polish Academie of Scienes, Technical Sciences.. vol. 33, no. 7/8, pp. 351-358. [in English].
[10] D. I. Zolotarevskaya (2011). [Mathematical simulation and calculation of the soil compaction under dynamic loads]. Eurasian Soil Science. Vol. 44, no. 4, pp. 407-416. [in English].
[11] A. Li, F. Dai, N. Xu, G. Gu, and Z. Hu. Analysis of a Complex Flexural Toppling Failure of Large Underground Caverns in Layered Rock Masses. Rock Mechanics and Rock Engineering: veb-sajt. URL: https://doi.org/10.1007/s00603-019-01760-5. (data zvernennya 01.10.2022). [in English].
[12] C. Debeleac, S. Nastac. (2014). [Stochastic Approaches of Nonlinear Model-Based Simulations for Vibratory Compaction Process]. PAMM. 2014. vol. 14, no. 1, pp. 749-750. [in English].

Authors contacts:

Yury Paladiychuk

Candidate of Science (Engineering),
Associate Professor of the Department
of Agroengineering and Technical Service
Vinnytsia National Agrarian University,
Faculty of Engineering and Technology,
Sonyachna str., 3, Vinnytsia, 21008, Ukraine

e-mail: rewet@vsau.vin.ua

Inna Telyatnik

second-year post-graduate student,
specialty Materials Science,
Department of Agricultural Engineering and Technical Service
Vinnytsia National Agrarian University,
Faculty of Engineering and Technology,
Sonyachna str., 3, Vinnytsia, 21008, Ukraine

e-mail: inna201098@gmail.com