Modelling of vibrating machine-tool with improved construction

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S u m m a r y The work presents the mathematical modeling of the motion of the U-shaped container of the vibration of the machine, with the aim of finding the optimum position vibration exciter with respect to the container and an improved design of the machine. Fig.: 6. Bibliogr.: 23 titles.
K e y w o r d s **:** vibration processing circular motion, vibrating machine, optimal design, productivity.

INTRODUCTION

One of major tasks of modern engineer is an improvement of quality, increase of reliability and longevity of the produced machines and wares. Perspective direction in providing of these indexes is mastering of progressive technological processes.

Vibration processing has received wide distribution as a promising method of treatment of parts, especially of complex shapes.It runs on vibration machine tools of different types.[1, 17,18]

The analysis and classification of vibration equipment were repeatedly carried out during the existence of the vibratory processing. The aim of analysis was finding a rational design of vibrating machine, providing for intensification of the process of treatment and improving the quality of the machined surfaces. [15, 21, 22].

THE PURPOSE OF THE WORK

The purpose of the work is a modelling of the relationship between the vibrating equipment parameters, its structural elements and the corresponding characteristics of technological processes. Also a development, through research, the advanced design of the vibrating machine, that provides productivity of vibrating processing.

MATHEMATICAL MODELING

Mathematical modeling of the process of vibrating treatment is a quite difficult task. First of all it is connected with the fact that the working environment is a granular medium, which characteristics vary significantly not only from the properties of its elements, but also from the operation modes and parameters of vibrating machine construction (Fig. 1). [5, 12, 13] Such properties as the ability of a medium to transmit the force impulse into the processing zone, transportation of working environment, the appearance in container zones with varying processing intensity may be changed. [6, 7, 14]

1. The movement of the container vibration machine Input parameters: the parameters of the design and operation of the machine, tool options. Output parameters: the trajectory and frequency movement of the container.

↓↑

2. Power transmission and processing zone Input parameters: the trajectory and frequency of movement of the container, the parameters of the working environment. Output parameters: power momentum transferred in a zone of contact of granules of the working environment and parts, usable horsepower for processing, the settings for the entire download (circulation speed, trajectory). [2, 3, 4]

↓↑

3. Exposure to the elements of the working environment on the workpiece Input parameters: speed of movement of the elements, parameters of elements of the working environment (geometric parameters of granules, weight, hardness) and the workpiece. Output parameters: the metal removal or the degree of hardening. [11, 19]

Fig. 1. Classification of basic processes what be going on at vibrating processing

Modeling of a container movement is an indispensable link between the parameters and design of vibrating machine and the end result - energy of power momentum transferred from container walls to the working environment and to the processing zone, allowance removal or the depth of superficial layer hardening depending on the treatment aim. [20]

Description of the container motion with its loading (media, parts and solution) it is an important task. This is the only way to perform further analysis of movement of the working environment (media and solution).

A mathematical model of movement of the vibrating machine container was developed. It takes into account the influence of the loading mass and changing the rheological parameters of oscillatory systems. Its calculation scheme is shown on Fig. 2 .

For solution of such problems is used Lagrange equation of the second kind:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}}\right)-\frac{\partial T}{\partial q}+\frac{\partial U}{\partial q}=F_q\,, \tag{1}$$

where q – is the generalized coordinate ($q \in \{X, Y, \varphi\}$);

T – is the kinetic energy of the system,

U – is the potential energy of the system,

F_q – external generalized force for the model are defined as:

$$F_q = Q_q - \frac{\partial D}{\partial \dot{q}}\,, \tag{2}$$

where: Q_q – disturbances force,

D – Rayleigh dissipative function.

Change the angle of the φ accepted quite small for the observance of the conditions of $\sin\varphi \approx \varphi$, $\cos\varphi \approx 1$. Shoulders projections of elastic forces are constant.

For this case the kinetic energy of the system can be expressed as:

$$T=\frac{1}{2}\left((M+m_d)\dot{x}^2+(M+m_d)\dot{y}^2+J\dot{\varphi}^2+m_r\dot{x}_r^2+m_r\dot{y}_r^2\right) \tag{3}$$

Potential energy is expressed as the total energy of deformation of elastic elements of the system on the corresponding generalized coordinates and energy associated with the elastic properties of the working environment:

$$U=\frac{1}{2}\left[2C_x(x-L_y\varphi)^2+C_y(y-L_x\varphi)^2+C_y(y+L_x\varphi)^2+C_r(x_{cr}-x)^2+C_r(y_{cr}-y)^2\right] \tag{4}$$

This characteristic is expressed with Rayleigh function:

$$D=\frac{1}{2}\int_F \dot{q}^T B\dot{q}\,dF\,, \tag{5}$$

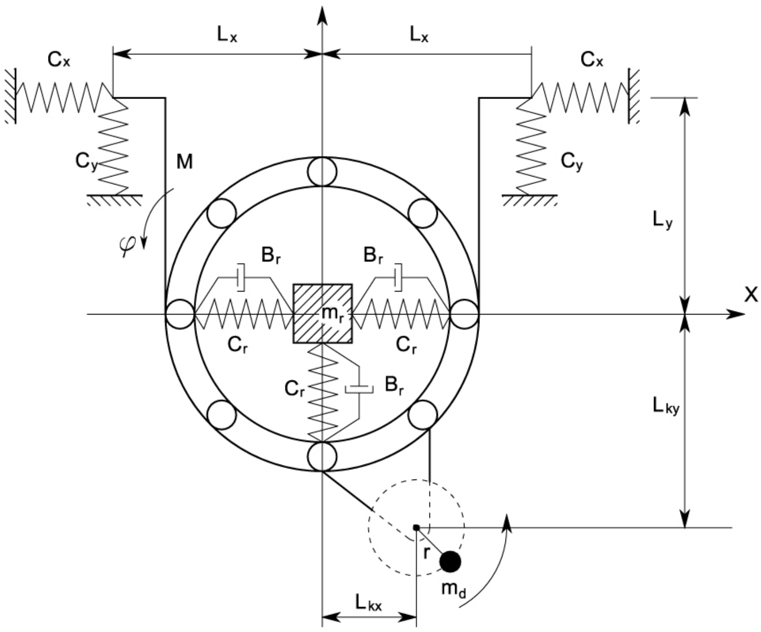

Fig. 2. A calculation scheme of the proposed mathematical model of work of vibrating machine, where: C_x,C_y – the coefficient of elasticity of suspensions, L_x,L_y – distance along the X,Y from the centre of mass of fastening points of left and right suspensions, C_r – coefficient of elasticity of the working environment, B_r – damping factor of the working environment, L_{kx},L_{ky} – distance along the X,Y from the center of mass to the point of application of the disturbing force, M – mass of the container and part of attached loading, m_r – loading weight (according to the scheme located in the center of the container and moving under the influence of the layer that is in contact with the walls), m_d – unbalanced mass of unbalance cargoes; J – is the moment of inertia of the system (total container and debalance) about the center of mass, r – eccentricity of mass debalance relative to its axis of rotation, ω – angular velocity of rotation of unbalanced shaft of vibroexciter, φ – rotation angle of the container about the system center of mass counterclockwise, X,Y – axes are conducted through the center of mass of the container

where: $\dot{q}$ – is the column of the generalized velocities of the friction surfaces,

B – is a nonnegative matrix of the coefficients of viscous friction, and the integration is performed by the internal frame running gear surfaces F.

Physically D function expresses the power of surface friction dissipative forces. For this calculation scheme and the corresponding generalized coordinates D can be written as:

$$D = \frac{1}{2}\left[B_r\left(\dot{x}_r - \dot{x}\right)^2 + B_r\left(\dot{y}_r + \dot{y}\right)^2\right]. \qquad (6)$$

The force exerted Q_q for the corresponding generalized coordinates defined as:

$$\begin{gathered} Q_x = m_d r\omega^2\cos(\omega t), \\ Q_y = m_d r\omega^2\sin(\omega t), \\ Q_\varphi = m_d r\omega^2\left(L_x\sin(\omega t) - L_y\cos(\omega t)\right). \end{gathered} \qquad (7)$$

Substituting D, T, U in equation (1) for the corresponding generalized coordinates, we will receive a system of five ordinary linear differential equations (8):

$$\begin{cases} (M + m_d)\ddot{x} + (2C_x + C_r)x - 2C_xL_y\varphi - C_rx_r + B_r\dot{x} - \\ - B_r\dot{x}_r = \omega^2 r\,cos(\omega t)m_d, \\ (M + m_d)\ddot{y} + (2C_y + C_r)y - C_ry_r + B_r\dot{y} - B_r\dot{y}_r = \\ = \omega^2 r\,sin(\omega t)m_d, \\ J\ddot{\varphi} + \left(2C_xL_y^2 + 2C_yL_x^2\right)\varphi - 2C_xL_yx = \\ = L_{kx}\left(\omega^2 r\,sin(\omega t)m_d\right) - L_{ky}\left(\omega^2 r\,cos(\omega t)m_d\right), \\ m_r\ddot{x}_r + C_rx_r - C_rx + B_r\dot{x}_r - B_r\dot{x} = 0, \\ m_r\ddot{y}_r + C_ry_r - C_ry + B_r\dot{y}_r - B_r\dot{y} = 0. \end{cases}$$

Research of dependence of the productivity of vibrating treatment from the location of vibroexciter. At treatment in identical terms the power expended on a process can simply characterize his productivity, because she is a general parameter for all variety of his technological operations, characterized by different technological end-point which in turn depend on combination of great number of factors also different for every operation [16, 23].

We will define intercommunications between power, expended on the process of treatment, and productivity of this process.

After the decision of equalization (8), coming from the dissipative Rayleigh function, the worked out mathematical model allows to determine middle useful power for period depending on parameters vibrating machine-tool:

$$N = \frac{1}{2T}\int_0^T \left[B_r\left(\dot{x}_r(\omega,r,t) - \dot{x}(\omega,r,t)\right)^2 + B_r\left(\dot{y}_r(\omega,r,t) + \dot{y}(\omega,r,t)\right)^2\right]dt$$

The results of calculations of power that can be transferred into working environment depending on the location of vibroexciter , are presented on a fig. 3.

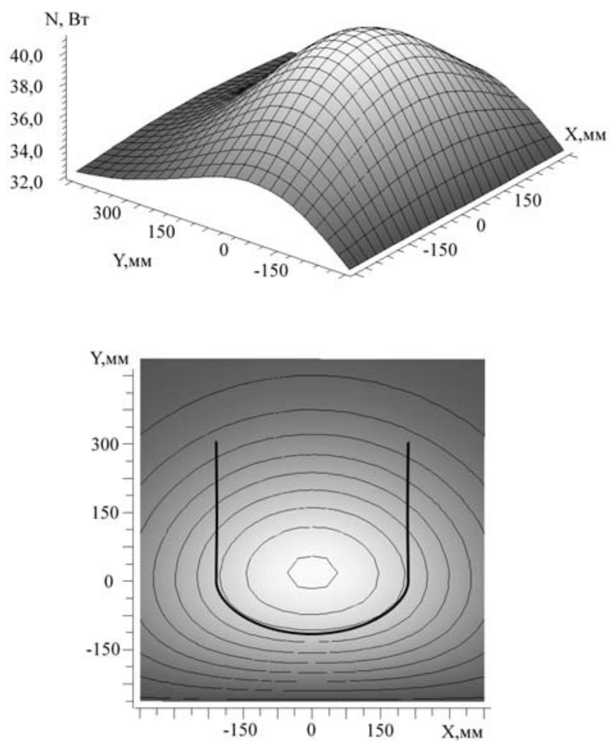

Fig. 3. Calculation of middle useful power, that can be transfered from the walls of container to the working environment for period (a, b image – in the three- and two-dimensional system of co-ordinates accordingly)

The got results are confirmed by works [2, 6].

From charts evidently, that most productive is a location of vibroexciter in the center of container of oscillation machine-tool (co-ordinates – 0;0). Accordingly, with approaching to this point useful power increases. Advantage of application of circular trajectory, and also trajectory, being a prolate on a vertical line ellipse, were resulted in-process [6], that confirms the rightness of the chosen direction.

THE RESULTS OF THEORETICAL RESEARCH

The system (8) has been solved numerically using a modified Runge-Kutta method, which allows to achieve the following aims:

- to study the dependence of trajectory of the vibrating machine container movement from the location of the vibroexciter,

- to assess the circular motion of the loading mass,

-to study the dependence of vibrating processing productivity from the location of the vibroexciter relatively to the U-shaped container.

The proposed model allows to calculate the trajectory of container movement, as well as the power expended on details treatment depending on conditions and place of the vibroexciter relatively to the container of the vibrating machine.

A methodic of precise definition of the working environment circulation speed and a method of determining of the stability of circulation flow motion were suggest based on the developed model.

The developed model allowed to determine the efficiency of vibrating processing depending on the coordinates of vibroexciter location relatively to the longitudinal axis of the container, ensuring the circulation flow and improving the process productivity without introduction of additional energy consumption.

The results of mathematical modeling were confirmed with the experimental studies. They showed that changes in the design of vibrating machine, a choice of location of vibroexciter relatively to the container, namely its location 45º to the vertical axis is perpendicular to the longitudinal axis passing through the center of mass of the container for the machine, with the volume of container to 100 dm^3 provides increase of productivity of vibrating processing 20...30 % upon reaching the necessary technological results.

IMPROVEMENT OF MACHINE-TOOL CONSTRUCTION

Based on the above studies of a modified vibration machine VNU 100 was designed, with the possibility of changing the location of vibroexciter relatively to the container (Fig. 4) intended to perform the following operations: clean the surface of the parts from scale, corrosion, moulding materials; removal of burrs and rounding of sharp edges, waste removal; grinding and polishing of surfaces of details in the preparation of their under protective and decorative galvanic and other coverings; improving the quality of the surface layer, ensuring the required geometrical and physical-mechanical characteristics.

The difference of this machine is in possibility to modify the location of the source of vibrations - the vibroexciter relatively to the container. It can be achieved by attaching a vibroexciter rigidly on a bracket with the possibility of changing in the regulations relatively to the container and attaching to it.

Machine for vibrating processing of the parts contains a U-shaped container 1, vibroexciter 2, rigidly mounted on the bracket 3, attached to the container using washers 4 and 5 bolt, with the ability to change the position of the bracket relatively to the container, defined on a scale of 6 and the subsequent fastening to him bolts 7.

A three-dimensional model of the vibrating machine of modified designs, was developed in the program Compass 3D (Fig. 5), which allowed to conduct computer analisys of the got design of machine. [8, 9, 10]

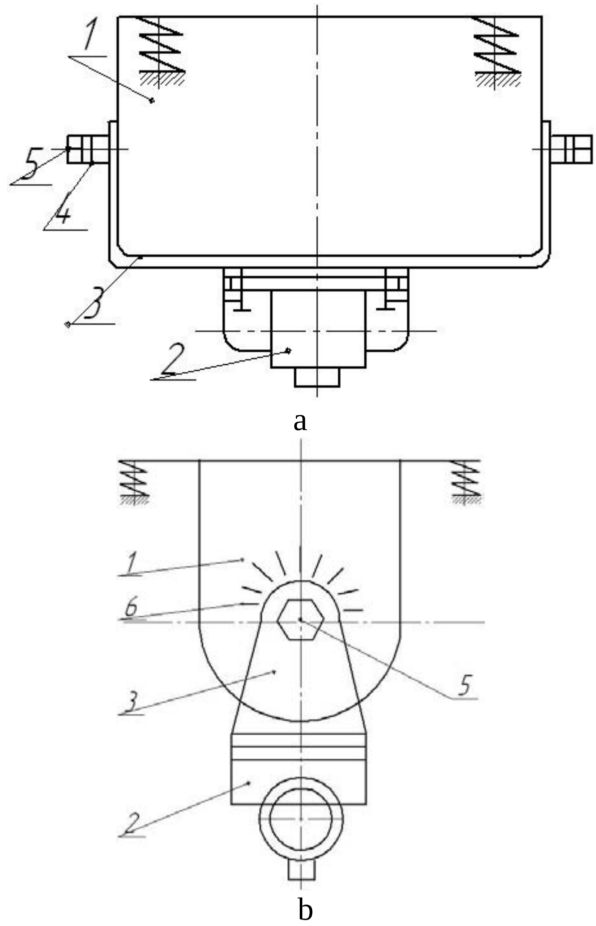

Fig. 4. Schematic diagram of the modified vibrating machine VNU-100: a – a general view; b – side view

Technical characteristics of the machine VNU-100: container volume V – 100 dm^3; the amplitude of oscillation A – 0,2...3,2 mm; oscillation frequency f – 50 Hz, power N – 7,0 kW, weight m – 2400 kg, size – 2100x950x1200 mm

A work of machine for vibrating processing of parts is carried out as follows. Container 1, mounted on resilient suspension and availability to fluctuate in different directions, are reported oscillating motion with the help of the inertial vibroexciter 2. Vibroexciter 2 is set at a certain angle relatively to the container 1, determined on a scale of 6. Depending on the angle brackets 3, which rigidly fixed the vibroexciter, set its position, providing stable circular motion, which promotes the achievement of the quality process. The motion of the vibroexciter shaft is opposite to the movement of the working environment.

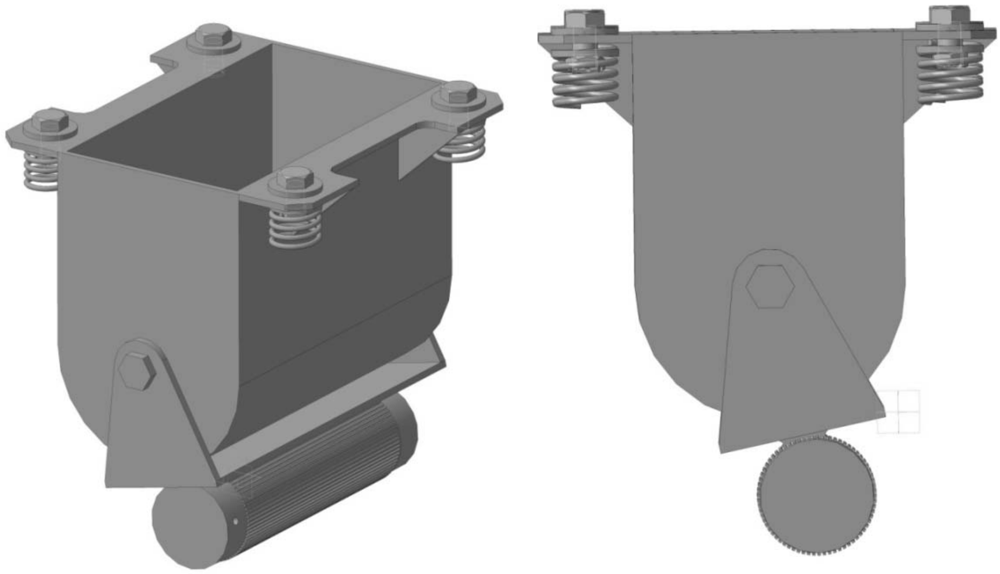

Fig. 5. Three-dimensional model of the vibrating machine modified designs, developed in the program Compass 3D

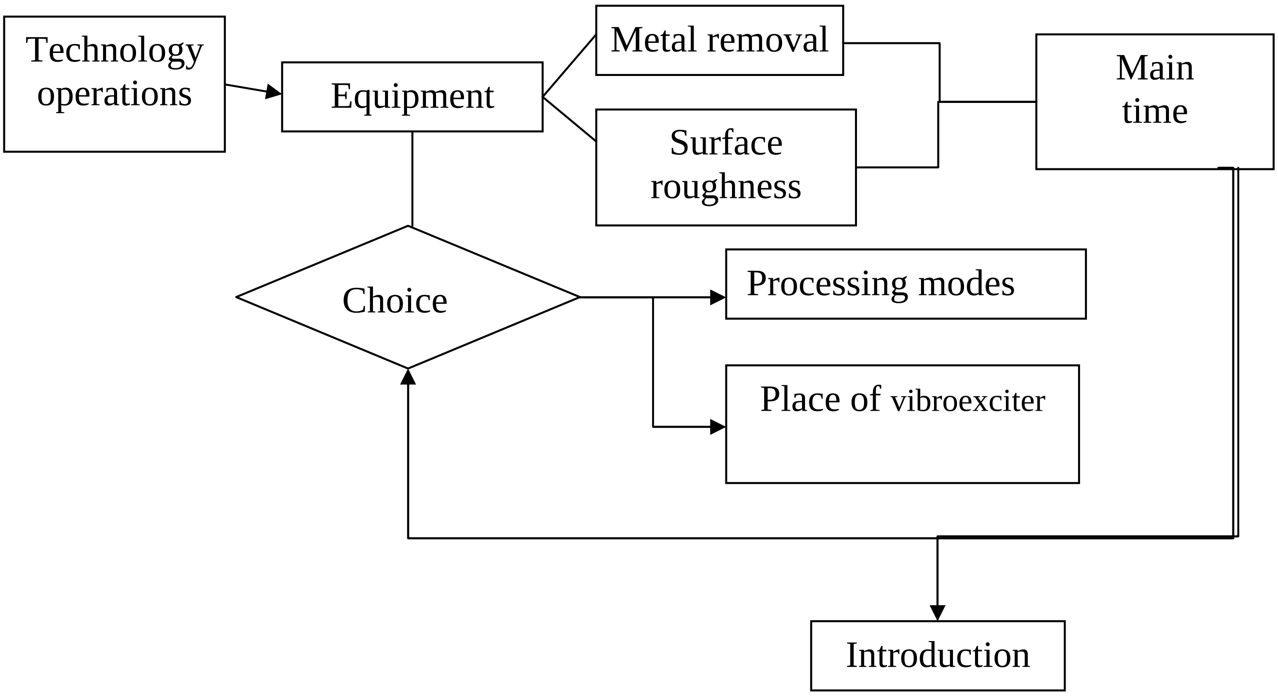

Fig. 6. Scheme of the selection of equipment for the operation of vibrating processing

The choice of the location of vibroexciter was conducted as follows (Fig. 6). On the basis of earlier studies were set initial parameters, namely, the frequency and amplitude, loaded the working environment and the specified amount of fluid. Then an initial coordinate of the location of vibroexciter were installed. After the launch of the machine, measurement of the circulation speed of the working environment flow was carried out, and, if its value matches the required downloaded details. Then the circulation speed of the working environment and loaded into the container parts was re-measurement, if this value was close to the first, that the treatment was carried out at the given position of vibroexciter. So, when moving the bracket with vibroexciter relative to the container, using the scale and measuring the circulation speed of load mass, you can choose an optimal location of vibroexciter.

Due to vibration details and working environment continuously have variables in sign of acceleration and are in an inertial relative movement, making two kinds of motion: oscillatory with a frequency depending on the frequency of oscillations of the container and the rotation of the whole load mass (circulatory).

The direction of the relative movements of the parts and media is changing, resulting in the processing. In the process parts occupy different positions in the working environment that provides a relatively uniform treatment of all surfaces in contact with the working environment.

CONCLUSIONS

1. The developed model allowed to determine the efficiency of vibrating processing depending on the coordinates of vibroexciter location relatively to the longitudinal axis of the container, ensuring the circulation flow and improving the process productivity without introduction of additional energy consumption.
2. With the ability to provide rational location of a vibroexciter relatively to container increases the efficiency of vibrating treatment process, reduces the time required for processing of products without increasing power consumption of the process.

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МОДЕЛИРОВАНИЕ ВИБРАЦИОННОГО СТАНКА УСОВЕРШЕНСТВОВАННОЙ КОНСТРУКЦИИ

Анна Николаенко, Алсаяд Тага Хуссейн

Аннотация: В работе представлено математическая модель движения U-образного контейнера вибрационного станка для определения оптимального положения вибровозбудителя относительно контейнера и создания усовершенствованной конструкции вибрацилонного станка.

Ключевые слова**:** вибрационная обработка, циркуляционное движение, вибрационный станко, совершенствование констуркции, производитель-ность.