DEVELOPMENT OF THE VIBROCENTRIC MACHINE FOR THE PRODUCTION OF A BASIC MIXTURE OF HOMEOPATHIC PREPARATIONS

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On the basis of the analysis of patterns of complex processes of preparing of compound pharmaceutical mixtures and equipment for their realization, was grounded technological and constructive scheme of vibrocentrifugal machine of drum-sieve type. The proposed construction implements the idea of combined interaction of vibration and rotational motion in two planes of container, gives way to complex technological activity and intensive energetic saturation of the processing environment.

As a result of experimental studies, it was first established that the use of a combined vibrocentric method of processing of phyto-raw materials increases the productivity of preparation of pharmaceutical mixtures up to 142-152 kg h^{-1}, which is 2.5 it is on 3 times higher than the existing technology, with a decrease energy consumption in 2,7-3,2 times.

Keywords: homeopathic preparations, vibrocentric machine, phyto-raw materials, grind, mixing, rational modes of work.

1. Introduction

At present an active development and issue of homeopathic preparations on the basis of phyto-raw materials for the production of different medical forms continues in the world. These preparations combine both prophylactic and regulatory functions and can have a variety of therapeutic effects on the human body. The market share of this segment of products in Ukraine is estimated at 1.5 to 3%, while in European countries, similar products make up 15% of the total volume of medicinal products. This tendency is determined not only by the economic factors of the industry, but also by the constructive and technological progress of the pharmaceutical industry.

One of the most important stages of the technological process of producing of homeopathic preparations is the grinding of dried phyto-raw materials and their screening. After that, the resulting mixture is mixed with additional pharmaceutical ingredients to a homogeneous consistency of 97-98% [1, 2].

Thanks to the grinding, the specific surface of the treated material increases from 270-520 cm^2 g^{-1} to 4100-4300 cm^2 g^{-1}, which allows to accelerate

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significantly the dissolution, chemical interaction and the separation of biologically active substances from the raw material [3, 4].

Sifting is used as an auxiliary operation for preliminary preparation of the material for grinding, as well as an independent stage for obtaining a finished product with a particle size of 0.1-0.07 mm [5].

The technological scheme of the production of pharmaceutical mixtures, which exists today, has a number of shortcomings, in particular energy-cost gradual implementation of technological operations of grinding, separation and alternate mixing of phytocomponents with pharmaceutical ingredients in the form of certain powdery masses (talc, lactose).

Obviously, solving the problem of increasing the efficiency of the processes of preparing pharmaceutical homeopathic mixtures is possible by developing and creating equipment that combines the implementation of the above mentioned technological operations into a single system.

It is proposed to solve the mentioned problem by developing of a vibrocentric machine, which allows to carry out the processes of vibration grinding and mixing of plant material simultaneously.

When implementing the process of fine grinding, the vibration force gives the opportunity to increase significantly the shock-abrade effect. On the one hand, it raises the fatigued destruction of material particles under the action of cyclic loads, and on the other hand - as a result of dynamic interaction between them ensures their ability to actively erase. Also, the significant influence of wave phenomena is observed in the process of mixing, where the uniform distribution of particles with different physical and mechanical properties is realized as a result of increasing the porosity of the dispersed medium and reducing its density. This feature provides complex circulation flows of processed raw materials.

For this reason, the development of a new vibrocentric machine, which combines in itself the processes of vibrating grinding and mixing, is actual in technological and constructive aspects in the production of basic mixtures for homeopathic preparations [6-8].

2. Equipments and methods

A series of experimental studies were conducted to establish the rational operating modes of the developed machine and the technological parameters of the proposed technology for the complex processing of raw materials.

Based on the analysis of technological processes and design schemes of existing equipment for the production of pharmaceutical mixtures, a vibrocentric machine was developed (Fig. 1).

This design works as follows. First, we load the necessary amount of raw material in the appropriate proportion to the chambers for grinding and mixing. Then we turn on the electric engine 2. The torque from the electric engine 2 through the system of clutch gears 5 and the conical gear 4 creates the rotation of the rim 14, the unbalance 12 and the carrier 18 relative to the perpendicular axes. The rotation of the unbalance 12 leads to spatial variation of the spring-loaded three-chamber drum 6 together with the loaded raw material and grinding bodies 8 in the form of ceramic balls, which results in the grinding of the processed mass.

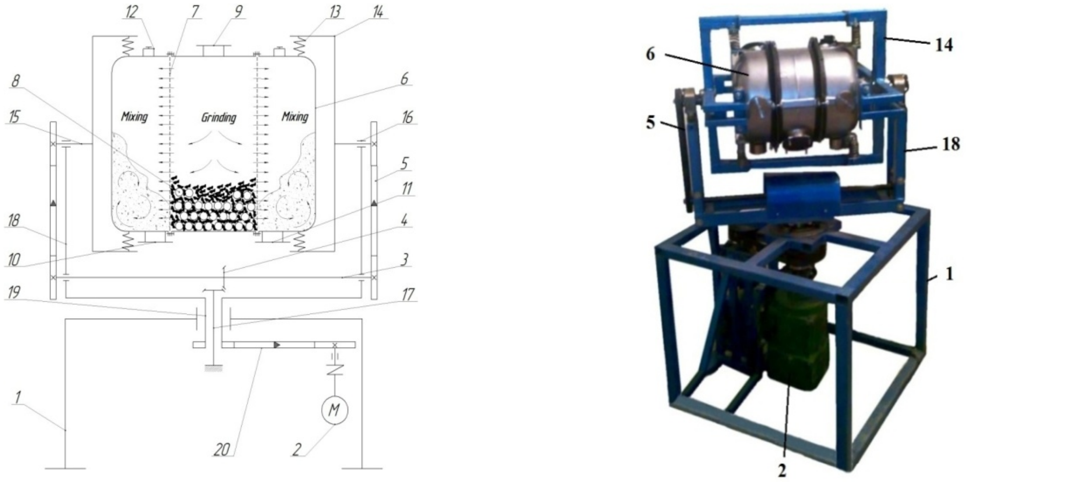


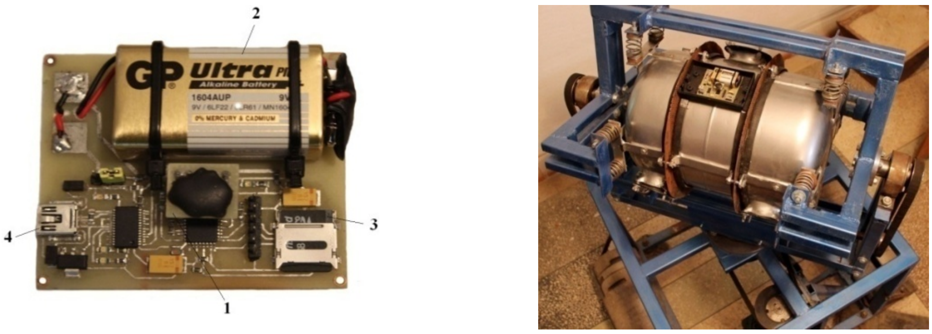
Fig. 1. Vibrocentric machine for the production of a base mixture of homeopathic preparations: a) principal scheme; b) a pilot sample of machine; 1 – carcass; 2 – electric engine; 3, 15, 19 – drive shafts; 4 - conic gear; 5, 20 – clutch gears; 6 – a three-chamber container; 7 – sieve elements; 8 – technological filler; 9, 10, 11 - branch pipes; 12 – unbalanced masses; 13 – elastic elements; 14 – rim; 16 – bearings; 17 – axle; 18 – carrier

During the rotation of the container, together with the loaded raw materials and ceramic balls, the disintegration of the phyto-raw material is taking place. With the size of the particles reduced, the crushed material under the influence of centrifugal forces and alternating loads through the sieve surface undergoes a distribution: particles equal to or smaller than the diameter of the holes of the sieve fall into the mixing compartment with the additional components, the rest - for re-grinding. Such a combination of technological and constructive factors can significantly increase the degree of disintegration of particles, followed by mixing them with additional components, making a comprehensive impact on the treated environment.

The executive body of the vibrocentric machine carries simultaneously oscillating and complex rotating motion around two mutually perpendicular axes. This feature makes it impossible to connect standard piezoceramic accelerometers directly to the insulator. Therefore, for the evaluation of the amplitude-frequency characteristics of the developed machine, a wireless sensor of registration with independent power was developed. This device is based on LIS3DH accelerometer of the STMicroelectronic’s company (Fig. 2 a), which has the following characteristics: power consumption - 2 μA; consumption voltage from 1.71 - 3.6V; range of acceleration measurement: ± 4g; ± 8 g; ± 16g; SPI / I2C interface for reading data; built-in self-testing module; weight 1,5 g.

The principle of operation of the developed sensor is as follows: after connecting the sensor to the surface of the container (Fig. 2 b) the drive mechanism that creates alternating fluctuations of machine’s working body which initiates the activation of the build-in accelerometer, that begins registration of amplitude-frequency characteristics on the microcard of memory of MicroSD type. After stopping the equipment with the help of software and the adaptive cord, the received AFCs are interpreted as graphic dependencies and digital data matrix.

The software developed allows you to analyze vibration acceleration, vibration velocity, vibrational displacement and frequency of created oscillations.



a) b)

Fig. 2. Joining the accelerometer to the surface of the container: a) developed autonomous accelerometer; 1 – accelerometer; 2 – battery; 3 – memory card; 4 – adaptive microport for reading data; b) accelerometer on the container

The UNI-T UT372 wireless tachometer was used to register the drive shaft's rotational speed. To determine the power characteristics of the machine under study, an electronic wattmeter EMF-1 was used, which is designed to measure the network of power consumption of 220V, 16A with the connection through a household socket. With the help of this instrument the measurements of the following parameters were made: network voltage, frequency and AC power, power consumption, power factor, operating time of the equipment and total power consumption over the entire period of machine operation in kWh.

The most rapid and convenient method for determining the degree of grinding of the processed material is sieve analysis. The essence of this analysis lies in the fact that 25-100 g of the researched powder is sifted through a set of sieves with hole sizes of 0.2-2 mm. Weighty material we put on the largest sieve and the whole set of sieves shake together on a vibrating screen Analysette 3 pro for 5 minutes, and then we find the mass of each fraction and its percentage content.

The dispersion of parts smaller than 50 microns was determined by installing a specific surface of the newly formed particles on the PSH-10 device. The action of this device is based on the measurement of the air permeability of the layer material, through which the air is leaked at a pressure close to atmospheric. Among the main technical characteristics of the device it should be noted: the range of measurement of the surface area of the material, which is 300 - 50000 cm^2g^{-1}, which is equivalent to 5 mm and 50 microns, respectively.

A photoanalytical method was developed for evaluation of the formed mixture of finely dispersed materials with dimensions from 0,8-0,05 mm, based on pixel analysis of photoperiod of the obtained mixtures from selected samples.

The essence of the method is as follows. First, the basic components of the mixture, in our case, powder from the roots of valerian, leaves of peppermint, talc are selected. After that, in the given proportions, a series of indicator mixtures with a previously known degree of homogeneity, the range of which is from 16 to 100% are mixed. The suppositories of the submitted mixtures of 50 g are poured into a container with a transparent bottom, which we place on the canvas of the scanner, thus forming a digital profile of the material with a given ratio of pixels 600 × 600. After that, using the MathCad software environment, the resulting images are expanded into a two-dimensional matrix the array of which contains 36 × 104 cells, assigning a color identification to each pixel from 0- "black" to 255- "white" color. That is, each cell contains the identification value of the color of the corresponding pixel on the photos of the resulting mixture. After this analysis we obtain the average values of the identification values of the obtained mixtures with an error of 1.2% (Fig. 3). On the basis of the identified color values of a number of cross sections of mixtures with a previously known degree of mixing, we perform regression-interpolation data analysis and construct a polynomial equation of the 4 degree (1).

$$F_{regres} = 704.46 \cdot x^4 - 1.72 \cdot 10^3 \cdot x^3 + 1.5 \cdot 10^3 \cdot x^2 - 598.7 \cdot x + 282.6 \qquad (1)$$

The mentioned methodology and the obtained polynomial equation make it possible to determine the degree of homogeneity of the mixing of finely dispersed materials depending on the generalized identification value of the photoresist of the treated material. The main advantage of this technique is the speed and high accuracy of the results.

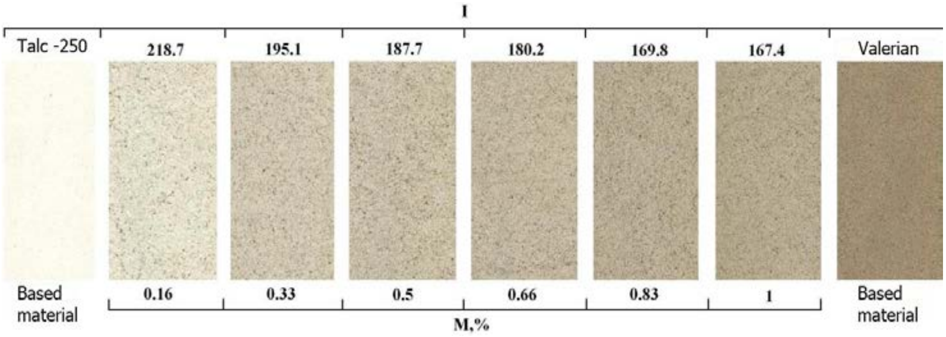


Fig. 3. Color distribution map: I – identification value of color; M – degree of homogeneity of the mixture according to color, %

3. Results and discussion

Figure 4 shows the experimental dependence of the oscillation amplitude on the angular frequency of a container an applied force F = 3.6 kN, where it is evident that as the magnitude of the angular velocity ω increases, the analytical curve of the amplitude of the fluctuations of the container A is divided into three zones: the pre-resonance, in which the amplitude A = 3 mm gradually increases in the range of values of the angular frequency ω = 0-36 rad s^{-1}; resonance, where the maximum value of the amplitude A = 7.8 is observed at ω = 36-60 rad s^{-1}; post-resonance, where the stabilization of the amplitude of oscillations in the range A = 2.0-2.2 mm. With the increase of the load capacity of the total volume of the working chamber of the vibrocentric machine, the peak values of the amplitude of oscillations, namely in the resonant period, decrease as a result of the growth of the dissipative forces of the technological environment.

Figure 5 shows the experimental dependence of the vibration velocity of the executive body of the vibrocentric machine on the angular frequency of the drive shaft rotation. The analysis of this figure showed a peak value of 350 mm/s, occurring as a consequence of the resonance phenomenon at 45 rad s^{-1}, after which the dependence becomes linear in growth with a value of 220 mm/s for the operational mode of operation.

In the general case, the main energy vibration parameters can include the work of compelling forces or moments, and the internal forces of the resistance of the vibrational system. The work of external forces is created by unbalanced masses and is spent on overcoming the forces of the resistance of the system and ensuring the oscillatory motion of the executive bodies of the vibrating technological machine with the given parameters. The internal forces of the resistance of the oscillatory system are the forces of reactive and dissipative resistance.

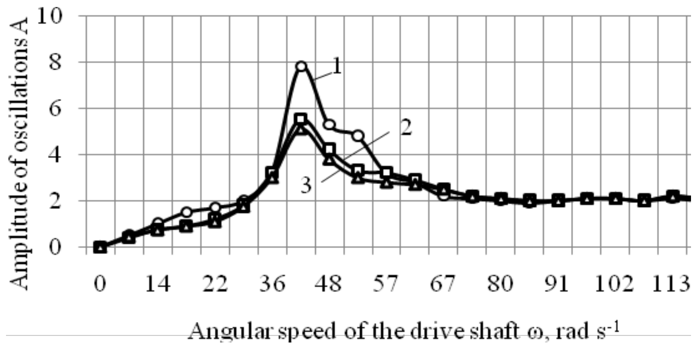


Fig. 4. Dependence of the amplitude of oscillation from the angular frequency of the container: 1 – in the absence of technological load; 2 – when loading ½ of the total volume of the container; 3 – when loading ¾ of the total volume of the container

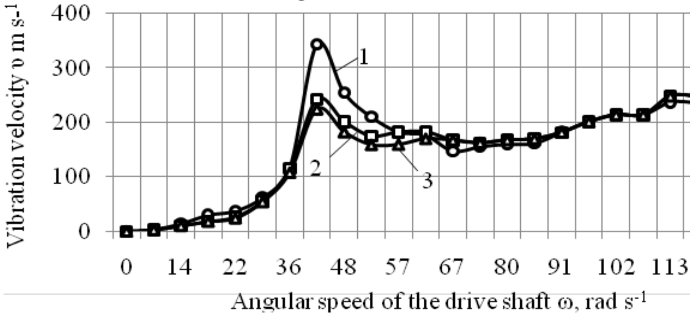


Fig. 5. Dependence of vibration velocity on the angular frequency of rotation of the drive shaft: 1 – in the absence of technological loading; 2 – when loading ½ of the total volume of the container; 3 – when loading ¾ of the total volume of the container

Fig. 6 shows the experimental dependence of energy consumption when changing the force of unbalance.

From the given dependence it is seen that with the increase of compelling forces F the amplitude A of the container fluctuations of the vibrocentric machine and the power consumption N increase practically proportionally. When there is an increase in the working chamber load, the amplitude of the fluctuations in the container decreases, while the power consumption increases.

At the same time, as it is shown in Figure 7, the growth of the amplitude A of the vibration of the container of the vibrocentric machine is accompanied by an almost quadratic increase in the N power, consumed by the electric engine from the network, and hence, more and more energy is dissipated in the technological environment in the form of heat.

At the same time, as it is shown in Figure 8, the increase in the frequency of the vibration of the container of the vibrocentric machine is accompanied by an almost quadratic increase in the power N, consumed by the electric drive from the network, which is caused by energy scattering in the processed medium.

Also, during the analysis of the energy characteristics of the machine under investigation, an increase in energy consumption was detected depending on the total volume of loading of the chambers of vibrocentric machine, which at the operating frequency of the machine ω = 100 rad s^{-1} are: N = 1000 W, when ½ loading; N = 1100 W, when loading ¾; N = 1200 W, when full loading.

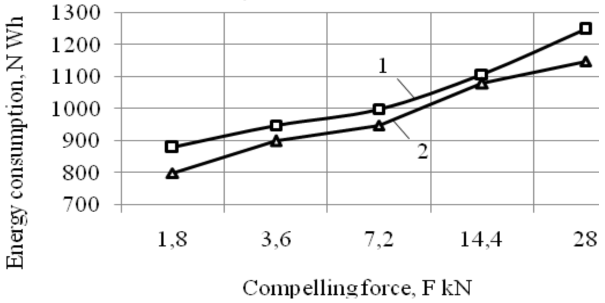


Fig. 6. Dependence of the energy parameters of vibration on the amount of the compelling force: 1 – when the container is loaded on ½ of its full volume; 2 – when the container is loaded by ¾ of its full volume

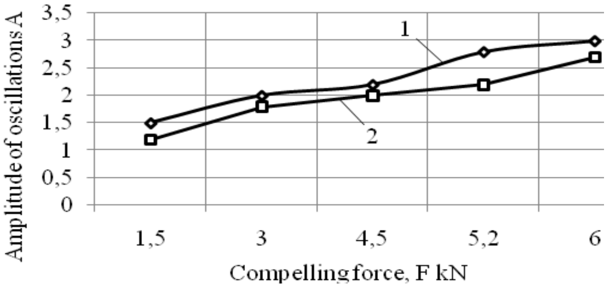


Fig. 7. Dependence of the amplitude of vibration on the amount of the compelling force: 1 – when the container is loaded on ½ of its full volume; 2 – when the container is loaded by ¾ of its full volume.

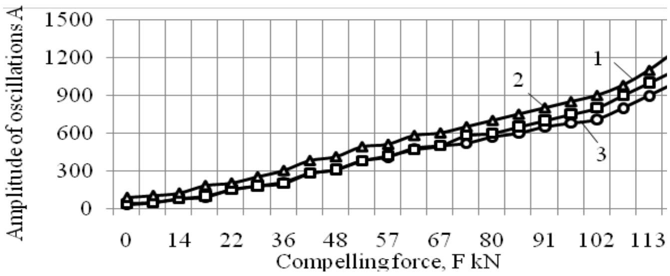


Fig. 8. Energy characteristic of the equipment under investigation: 1 – in the absence of technological loading; 2 – when loading ½ of the total volume of the container; 3 – when loading ¾ of the full volume of the container

To study the kinetics of the process of vibrocentric grinding, realized in the developed machine, a number of experiments were conducted under the influence of vibration-centric impact. Fig. 9 shows a grinding chamber of a vibrocentric machine with crushing balls. Figure 10 shows phyto-raw materials before and after grinding.

a) b)

Fig. 9. Investigation of the process of vibrocentric grinding: a – crushing chamber; b – the location of crushing elements and treated material in the crushing chamber

a) b) c) d)

Fig. 10. Material before and after grinding: a, b – roots of valerianum before and after crushing; c, d – collecting herbs before and after grinding

Initially, a number of experiments were carried out to determine the effect of the vibration frequency of the crushing chamber of the vibrocentric machine on the qualitative characteristics of the investigated process.

Fig. 11 shows the change in the physical and mechanical properties of the processed medium, depending on the frequency of the vibrations of the container of the developed machine. While analyzing the obtained dependence it can be concluded that the growth of the specific surface of the processed material increases with the increase of frequency of oscillations and has a linear character at the initial stages of the kinetic curve. This tendency is due to an increase in the magnitude of the impact pulse of the technological environment. At the same time, there is a decrease in the area of the particles of the treated material, as well as the processing time for 20 seconds, depending on the physical and mechanical parameters of the raw material.

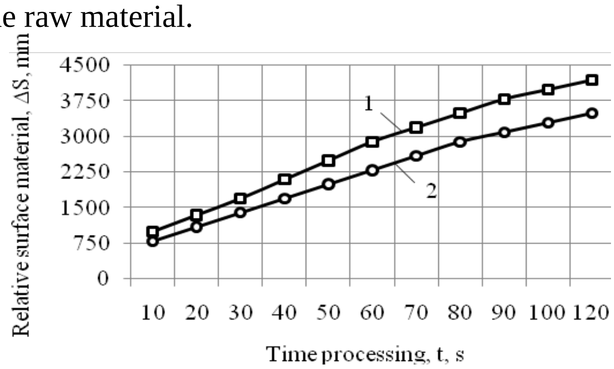


Fig. 11. Dependence of relative surface of the material on the frequency of the oscillation and time processing: 1 – oscillation frequency ω = 9 Hz; 2 – the oscillation frequency ω = 11 Hz

Based on the received data of the kinetics of the grinding process of the treated material depending on the size of the grinding bodies, it can be concluded that the change in the geometrical parameters of the technological loading has no clearly expressed influence on the process, compared with the amplitude-frequency parameters of the equipment.

However, analyzing the graphical dependence on Fig. 12, it can be noted that the technological loading in the form of balls with a diameter of 12-18 mm is better to use for rough grinding, and with its increase in tonnage and for highly dispersed materials it is better to use with a small diameter of 6-9 mm, which causes an increase in the number of collisions with the material and reduces the probability of its aggregation.

Analyzing Fig. 13, we can conclude that the highest productivity is when 75-80% loaded. However, the results of the received experimental data indicate that when the loading of the technological medium reaches 50% of the total volume of the chamber, the power consumed remains constant, and when it increases to 75-80%, the energy costs increase.

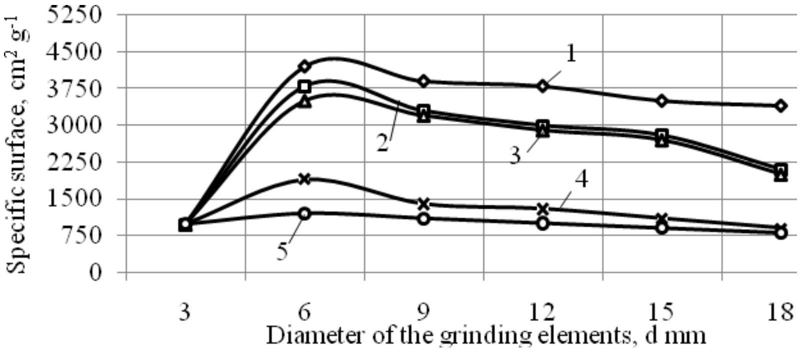


Fig. 12. Dependence of the specific surface of material on the time and diameter of the grinding elements: 1 – t=120 s; 2 – t=90 s; 3 – t=60 s; 4 – t=30 s; 5 – t=10 s

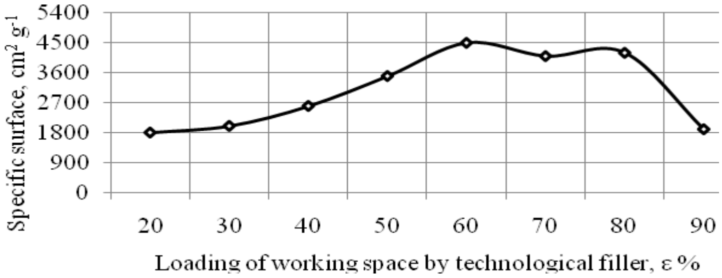


Fig. 13. Dependence of specific surface of material on the degree of loading of working space by technological filler.

This is due to the fact that the camera, which is filled up to 50% of the technological load, operates in a "free-kick mode", however, when a large download occurs, a "compressed" kick takes place, while the resistance forces that arise due to the internal and external friction of the technological download create significant energy costs. A dense loading of 95-100% of grinding elements causes their simultaneous movement with the chamber, which leads to a slippage effect and, as a result, to a significant reduction in the grinding process.

The structure of the basic mixture of pharmaceutical homeopathic medicines includes 6 or more components, which causes some difficulties for most researchers, because it is difficult to get closer to such a structural composition due to material and time limits. In this case, in our experiment, the structural composition of the mixture according to the physico-mechanical similarity of the material was divided into two groups: the first group contained rape and millet; the second group - powder of herbal collection and crushed roots of valerian. In addition, these imitation components are of different color. The accuracy of the implementation of a series of experiments was censured by the equivalent in weight gains and the use of the necessary control and measuring equipment. In the process of the experiment, the mixing chambers, equal in volume and configuration of the working surface, which are in the form of a semi-sphere, closed from the inside by a transparent glass were applied. Before the experiment in the mixing chambers of the proposed design of the machine in given proportions (V1 = V2), through the feed nozzles, the imitation material alternately was sipping, depending on the color of the imitator, and also the control component of the mixture was selected (Fig. 14).

Fig. 14. Distribution of parts of treated material when loading: 1 – milet; 2 – rape

Henceforth, for each group of output components, M,% – the degree of homogeneity depending on the time of technological processing was determined.

After loading the imitation material into the mixing chambers of the developed vibrocentric machine, the electronic timer EMF-1 and the electric drive of the machine were simultaneously activated, with a possible range of measuring the mixing time of 60-240 s.

During the planetary motion of the mixing capacities of the vibrocentric machine, the loose material gradually begins to split, while the vibration field is applied, which leads to the pseudo-liquefied state of the loose material, intensifying the process of interpenetration of the particles between adjacent layers.

By evaluating the profile structure of the samples, one can find the quality of mixing of the components in different operating modes of the proposed design of the machine, that is, to determine the optimal amplitude-frequency and energy characteristics of the investigated process.

Fig. 15 shows the dependence of the homogeneity of the simulation mixture on the centrifugal and vibrocentric movements of the container for 210 seconds, with loading ¾ of the camera's working volume. The analysis of the obtained graphic dependence showed that the homogeneity of the resulting mixture during the centrifugal movement of the container with the increase in the speed of rotation is much smaller than the combined technological effect. This tendency is explained by pushing the mixture to the inner walls of the container by centrifugal forces, which is leveled when oscillating motion is applied, contributing to the interpenetration of the material of the adjacent layers with each other.

Fig. 16 shows the experimental dependences of the degree of homogeneity M, % from time t, s during mixing of the two-component mixture. While analyzing the obtained kinetic curves, we conclude that there is a positive tendency of the investigated process, the essence of which is that the increase in the processing time of the material contributes to an increase in the degree of homogeneity up to 98%.

Thus, from the reduced kinetic curves of the investigated process, it can be seen that the main mixing phase occurs in the first period, the duration of which depends on the technological parameters of the developed vibrocentric machine. In the second period, the degree of uniformity practically does not change in all the regime parameters of the machine, which characterizes the onset of dynamic equilibrium, after which the further mixing process is ineffective.

Also, in fig. 17, experimental dependencies of the energy consumption on the degree of filling of the working volume of the chambers and the angular frequency of the container are obtained.

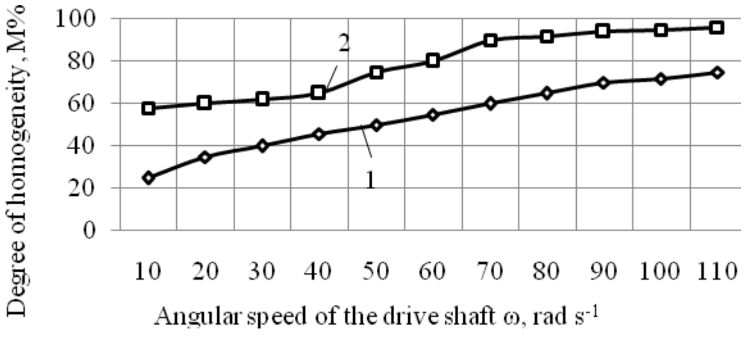


Fig. 15. Dependence of the degree of homogeneity of the imitation mixture on the frequency of rotation of the executive body: 1 – centrifugal movement of the container; 2 – vibration and centrifugal movement of the container

The analysis of the given graphical dependency showed that an increase in the filling capacity of the camera's working volume leads to an increase in average energy consumption by 5%, and with an increase in the rotation speed of the container, they increase to 1.0 kW when loading ½ of the container, up to 1.1 kW when loading ¾ of the container, and up to 1.2 kW at full loading of the container.

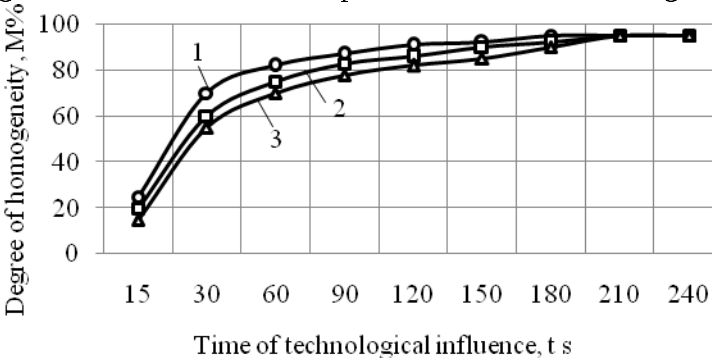


Fig. 16. Dependence of the degree of homogeneity of the imitation mixture from the time of technological influence: 1 – when loading ½ of the total volume of the container; 2 – when loading ¾ of the total volume of the container; 3 – at full load of mixing containers

A number of additional experiments were performed to obtain more accurate values of the measurement parameters, providing the exclusion of results that differ significantly from the average values by the criterion of maximum deviation of the measurement results, which does not exceed 0.05%.

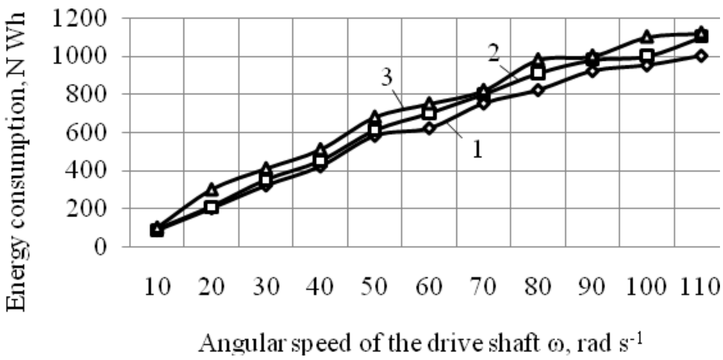


Fig. 17. Energy characteristic of the investigated process: 1 – when loading ½ of the total volume of the container; 2 – when loading ¾ of the total volume of the container; 3 – at full load of mixing containers

4. Conclusions

As a result of the analysis of technological and design features of machines for the realization of the processes of grinding and mixing of pharmaceutical ingredients, a research model of a vibrocentric machine was developed. This machine allows to realize simultaneously the processes of fine grinding and high-level mixing of components to produce homeopathic mixtures.

As a result of the conducted experimental research, the operational characteristics of the developed vibrocentric machine were established. Thus, the operating frequency of the oscillations of the executive body of the machine is ω = 90-100 rad s^{-1}, the amplitude of the oscillations within the limits of A = 2.0-2.2 mm, the vibration acceleration a = 24-28 m s^{-2}. In this case, the power consumption reaches N = 1.1-1.2 W.

Application of the obtained operating characteristics of the machine allowed to establish its technological parameters for the preparation of a basic mixture of homeopathic preparations. Namely: the diameter of crushing balls d = 4-6 mm; the degree of loading of the working volume by technological filler 50-60% and the degree of loading of mixing components 70-80%. According to operational and technological parameters, the total processing time is 380-420 minutes. In this case, the value of the specific surface of the newly formed particles is S = 4080-4190 cm^2 g^{-1}. Then, as the degree of homogeneity of the initial mixture is 97-98%. At the same time the productivity of the machine is 156 kg h^{-1}.

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