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# MULTI-STAGE VIBROIMPACT DEWATERING OF WET DISPERSED MATERIALS USING HYDRAULIC IMPULSE EQUIPMENT

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*The paper presents a comprehensive multi-stage technology and original hydraulic impulse equipment (HID) for vibroimpact dewatering of wet dispersed food production waste. Conventional single-stage mechanical dewatering equipment typically achieves insufficient moisture reduction and requires costly thermal post-treatment. The proposed technological line resolves these limitations by dividing the dewatering process into four sequential stages, each employing a dedicated unit of equipment with progressively increasing vibroimpact loading intensity applied to the wet dispersed material. At the first stage, preliminary dewatering is performed on a hydraulic impulse vibroimpact screen, reducing concentrate moisture content to 85%. The screen incorporates a rubber-fabric conveyor belt with riveted U-shaped steel plates, fine filter mesh, and four HID hydraulic cylinders that impart high-frequency vertical oscillations to the belt, forcing liquid through the mesh and holes. At the second stage, the concentrate undergoes further dewatering in a screw press to a moisture content of 75%; the expelled filtrate is collected for subsequent microfiltration. At the third stage, an inertial vibroimpact press-hammer (IVPM) with HID applies simultaneous static, inertial, and vibroimpact loading from above and below, reducing moisture content to 70%. The fourth and final stage employs a roll press with HID, where the concentrate passes in a thin layer between driven and passive rolls subjected to combined static and vibroimpact compression, achieving a final moisture content of approximately 25% without thermal treatment. The filtrate from each stage is directed to microfiltration, ultrafiltration, and nanofiltration installations equipped with HID. The structural designs of all four units of equipment are described in detail. Six principal design requirements for the equipment complex are formulated, covering multi-stage organisation, progressive loading intensification, stepless HID parameter adjustment, use of proven machine bases, vibration isolation, noise control, sensor-based monitoring, and computer-aided remote control of the process.*

***Keywords:*** *hydraulic impulse drive, multi-stage vibroimpact dewatering, wet dispersed materials, food production waste, screw press, roll press, inertial vibroimpact press-hammer, moisture content, microfiltration.*
***Fig. 4. Ref. 16.***

## 1. Problem formulation

Dewatering of wet dispersed materials generated during food production is an important technological process that significantly affects energy consumption, transportation efficiency, storage conditions, and the possibility of further utilisation of food industry waste. Conventional mechanical dewatering methods based on screw and roll presses often provide insufficient moisture reduction and require additional thermal drying, which increases operational costs and energy demand [1].

Wet dispersed materials are characterised by complex rheological and filtration properties that continuously change during compression and liquid removal. As the material structure becomes denser, filtration resistance increases and the efficiency of static pressing decreases. Under such conditions, the application of vibroimpact and hydraulic impulse loading is considered a promising method for intensifying moisture removal processes and improving dewatering efficiency.

Modern research confirms that multi-stage dewatering with progressively increasing vibroimpact loading intensity allows significant reduction of residual moisture content without thermal treatment. However, the development of integrated technological systems and hydraulic impulse equipment for multi-stage vibroimpact dewatering remains insufficiently investigated. Therefore, the development of efficient hydraulic impulse equipment for dewatering wet dispersed materials is an important scientific and practical task [3].

## 2. Analysis of recent research and publications

A growing body of research confirms the high efficiency of vibroimpact and impulse-based methods for dewatering of wet dispersed materials. Li et al. [3] demonstrated that dynamic loading significantly reduces


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residual moisture in food by-products compared to static pressing alone. Mocňak et al. [4] reviewed mechanical separation technologies for food industry waste and highlighted the advantages of combined compression-vibration systems. Selvam et al. [5] investigated screw press performance for vegetable pomace dewatering and reported the strong dependence of exit moisture on applied pressure and speed. Toscano et al. [6] confirmed that multi-pass pressing at incrementally higher pressures improves overall separation yield. Krokida and Maroulis [7] provided a systematic comparison of drying and mechanical dewatering efficiency for food materials. Sevostianov [1] established the theoretical and experimental basis for hydraulic impulse drive technology and demonstrated its advantages for vibroimpact dewatering of food production waste. Slabkyi et al. [8] developed and tested a two-component vibroimpact dewatering installation, reporting moisture reduction to 28–30%. Ochoa-Martinez et al. [9] studied the effect of pressure pulse frequency on solid–liquid separation in filter presses. Barba et al. [10] reviewed emerging non-thermal technologies for liquid-food processing and noted the potential of pulsed mechanical forces. It has been established that progressive, multi-stage application of vibroimpact loading with increasing intensity at each stage is the most effective strategy for achieving the lowest possible final moisture contents [1, 2, 11].

## 3. The purpose of the article

The objective of the present work is to develop and describe a multi-stage technology and the corresponding hydraulic impulse equipment for vibroimpact dewatering of wet dispersed food production waste, to define the structural design of each equipment unit, and to formulate the principal design requirements for the complete technological complex.

## 4. Results and discussion

The proposed general sequence of phase-separation processes for wet dispersed materials is presented in Figure 1 and comprises four sequential dewatering stages with progressively increasing loading intensity [1, 2].

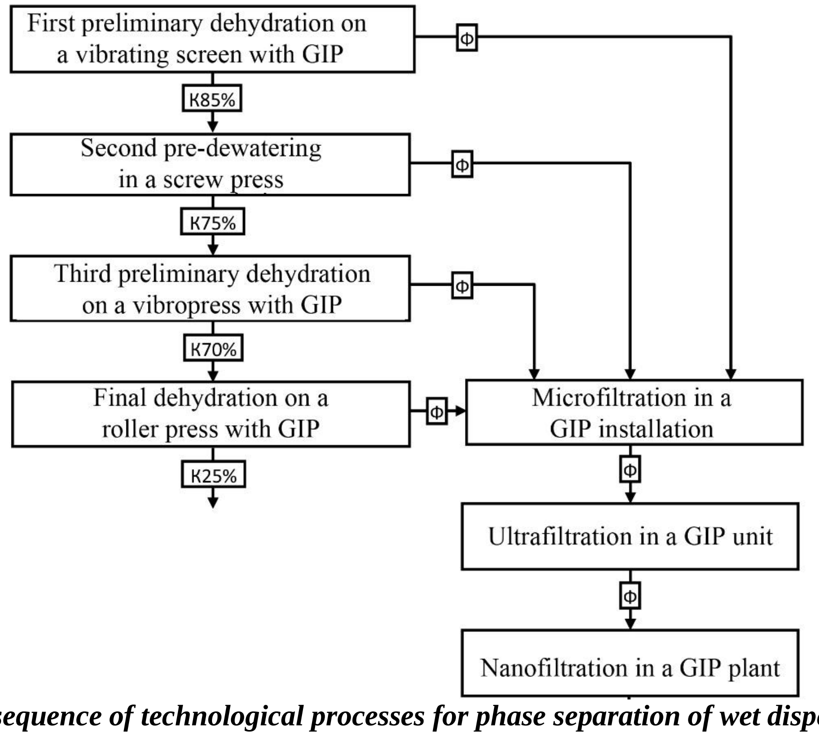


***Fig. 1. General sequence of technological processes for phase separation of wet dispersed materials***

Figure 1 presents the general sequence of implementation of the considered technological processes [5].

1. First preliminary dewatering on a hydraulic impulse (HID) vibroimpact screen – concentrate moisture content reduced to $K_1$ = 85%;
2. Second preliminary dewatering on a screw press – concentrate moisture content reduced to $K_2$ = 75%;
3. Third preliminary dewatering on a vibroimpact press with HID – concentrate moisture content reduced to $K_3$ = 70%;
4. Final dewatering on a roll press with HID – final concentrate moisture content $K_4$ = 25%.

The filtrate collected at each stage is directed to subsequent microfiltration, ultrafiltration, and nanofiltration stages using HID-based installations [12, 13].

The hydraulic impulse vibroimpact screen (Figure 2) is employed at the first preliminary dewatering stage [14]. It comprises a load-bearing conveyor belt passing around supporting and drive rollers. The receiving pan is mounted on the frame beneath the upper run of the belt, which is inclined at an angle of 10–20° to the horizontal. The belt is fabricated on a rubber-fabric base to which steel U-shaped plates of 30–50 mm width are fastened by rivets. Fine through-holes covered with filter mesh are provided in each plate and in the rubber-fabric base. Four HID hydraulic cylinders are mounted vertically on the frame; their piston rods are connected in pairs via articulated joints to two crossbeams supporting the upper run of the belt. Fans for belt drying and a brush for filter mesh cleaning are also mounted on the frame. Additional belt conveyors are installed on both sides beneath the lower belt run for discharge of the solid phase.

During operation, the wet dispersed material is loaded into the hopper and discharged uniformly onto the moving upper belt run. The HID pistons perform vertical reciprocating motions, imparting vibrations via the crossbeams. The liquid phase passes intensively through the filter mesh and the holes in the belt, collecting in the receiving pan. The solid phase is retained by the mesh and discharged onto the lateral conveyors [15].

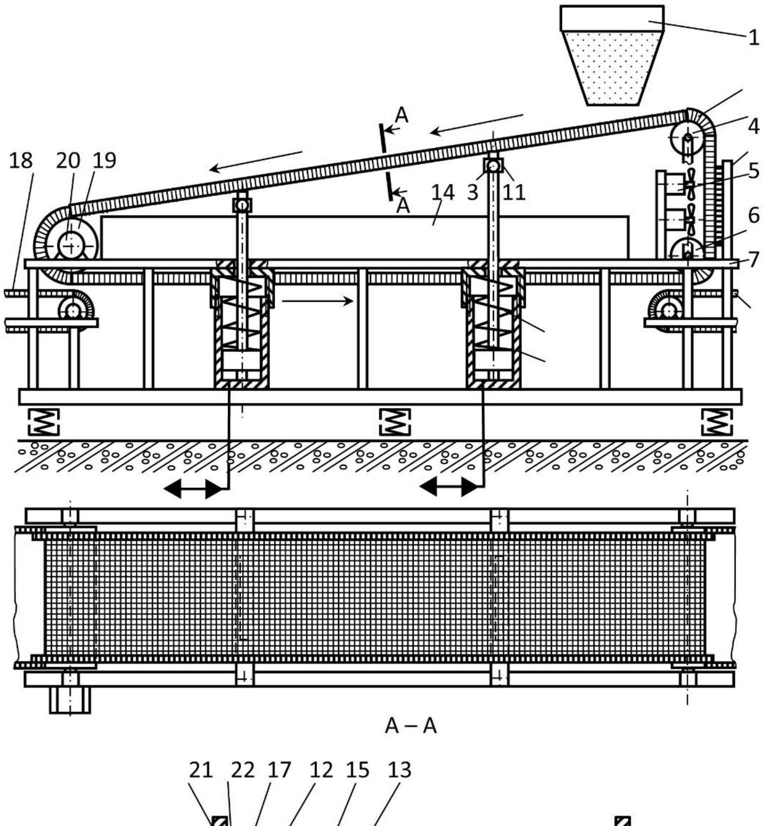


***Fig. 2. Structural diagram of a hydropulse vibrating screen for preliminary flow dehydration of wet dispersed materials***

Figure 2 shows a diagram of a hydropulse vibro-impact sieve [16] used at the stage of the first preliminary dehydration of the material (see Figure 1). The sieve (see Figure 2) contains a carrier conveyor belt 4, which passes around the supporting rollers 5, 8 and the driving roller 19, which is connected to the shaft of the electric motor 20. The receiving tank 14 is mounted on the frame 9 under the upper branch of the belt 4, which, in turn, is located at an angle of 10…20° to the horizontal surface. The belt 4 is made on a rubber-fabric base 22, to which steel U-shaped plates 21 with a width of 30…50 mm are attached by rivets 17. Each plate and rubber-fabric base has through-hole small holes 15, closed by a filter mesh 13. The rivets 17 of the belt 4 have conical heads 12 at the bottom, which enter the holes on the surface of the driving roller 19 to ensure its necessary traction capacity [16]. The hopper 1 for the material to be dewatered is installed above the belt 4. Four hydraulic cylinders 2 of the GIP are also vertically fixed on the frame 9, in the rod cavities of which springs 16 are installed. In this case, the rods of the hydraulic cylinders 2 are connected in pairs by means of hinges 3 with two crossbars 11, on which the upper branch of the belt 4 rests. On the side of the vertical branch of the belt, on the frame 9, fans 7 are installed for its blowing and drying, as well as a brush 6 for cleaning the filter mesh. On both sides of the belt 4, under its lower branch, additional belt conveyors 10, 18 are installed for removing the solid phase of materials.

The complex for second and third preliminary dewatering (Figure 3) is based on a screw press and an inertial vibroimpact press-hammer (IVPM), such as the IVPM-16 model [16]. The concentrate is fed through an inlet nozzle into the screw press cylinder. During compression, the expelled filtrate drains through fine filter-mesh-covered holes into the outer cylinder and is directed to microfiltration. The dewatered concentrate passes through a flexible hose into the mould of the IVPM [16].

Once the mould is filled, the screw press is stopped and the IVPM drives are activated. The vibrating table, linked to the HID cylinder, performs vertical reciprocating motions, applying vibroimpact loading from below. From above, the concentrate is loaded by the inertial force of the punch and moving traverse with inertia weights, together with static force from the auxiliary hydraulic cylinder. The expelled liquid is discharged through filter mesh-covered holes in the mould, collected in a trough, and directed to a collection tank for subsequent microfiltration. After dewatering to the specified moisture content, the HID is deactivated, the traverse is raised, and the mould is refilled for the next cycle [1, 16].

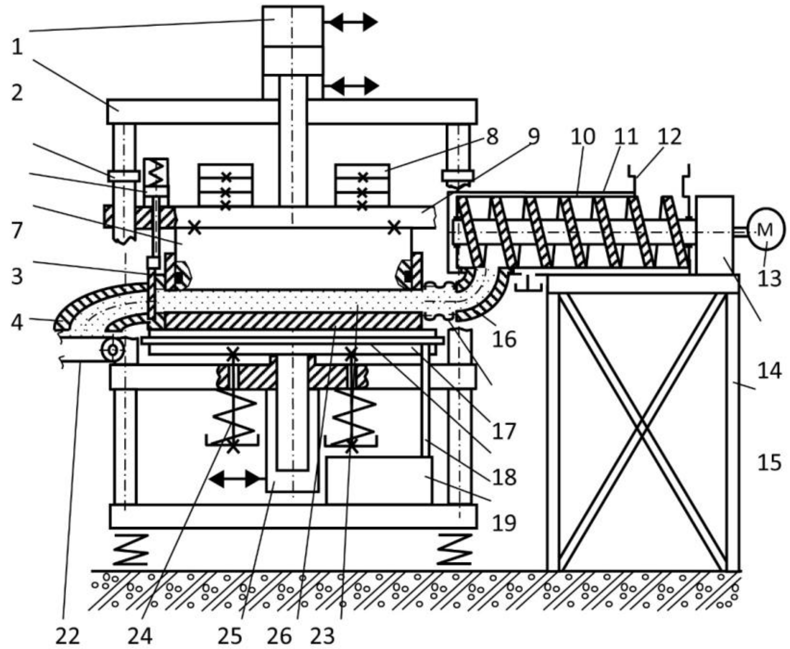


***Fig. 3. Structural diagram of a technological complex based on a screw press and a vibropress with GIP for preliminary dehydration of wet dispersed materials***

Next, Figure 3 shows a diagram of the complex for the second and third dehydration of wet dispersed material (see Figure 1). The complex can be created on the basis of a screw press [4] and an IVPM, for example, the IVPM-16 model [6]. The concentrate flow is fed through the pipe 12 into the cylinder 10 (see Figure 3) of the screw press, which is driven by an electric motor 13 through a gearbox 14. During the movement and compression of the concentrate in the cylinder 10, the filtrate removed from it flows through small holes in the cylinder 10, closed from the inside by a filter mesh, into the outer cylinder 11, from where it goes to microfiltration. The dehydrated concentrate through the pipe 16 and the rubber-fabric sleeve 17 enters the IVPM mold 26, after which the screw press stops. The main and auxiliary drives of the IVPM are turned on, the vibrating table 18 of which, connected to the hydraulic cylinder 25 of the GIP, performs reciprocating vertical movements, creating a vibration-shock load on a portion of materials from below. From above, the concentrate in the mold 26 is loaded with inertial force created by the punch 4, the movable crossbar 9 with inertial loads 8, as well as the static force provided by the auxiliary hydraulic cylinder 1 [6]. The liquid squeezed out as a result of this is discharged through the holes of the mold 26 closed by a filter mesh (not shown in the diagram), flows into the chute 19 around the vibrating table, and then through the elastic tube 20 into the tank 21, from which it goes to microfiltration [5]. After dewatering portion 23 to a given final moisture content (see Figure 1), the GIP is turned off, and the traverse 9 with the punch 4 are raised up to the traverse stop in the limiter 7. At the same time, the damper 5, which covers the pipe 6 during dehydration, is also raised. The screw press is turned on, which ensures the squeezing of the dehydrated portion through the pipe 6 onto the conveyor 22 and filling the mold 26 with the next portion of material. Then the screw press is turned off, the traverse 8 is lowered and the GIP is turned on; the dehydration cycle of the wet dispersed material on the

IVPM is repeated. From the conveyor 22, the concentrate dehydrated on the IVPM is fed to the roller press with the GIP (Figure 4) for final dehydration [7].

For final dewatering, a roll press with HID (Figure 4) is employed [16]. The concentrate passes through the gap between the driven and passive rolls, which rotate slowly. The passive roll is periodically pressed towards the driven roll at a defined frequency and amplitude controlled by the HID settings. These loads are transmitted through a yoke as the working fluid pressure in the HID cylinder piston cavity increases and the cylinder body is displaced relative to the stationary piston and rod. During pressure reduction phases, the cylinder body and passive roll return to their initial position under the action of a compressed spring in the rod cavity. As a result, the concentrate is drawn into the roll gap and subjected to combined static and vibroimpact loading [1].

Liquid expelled from the concentrate passes through fine filter-mesh-covered holes in the rolls and is directed to a microfiltration installation. The dewatered concentrate is scraped from the roll surfaces by knives pressed against the rolls by weights, and is discharged onto a belt conveyor. Since the IVPM with HID operates in batch mode, a sufficiently large buffer hopper between the IVPM and the roll press is recommended to ensure reliable rhythmic operation of the complete complex [1, 11].

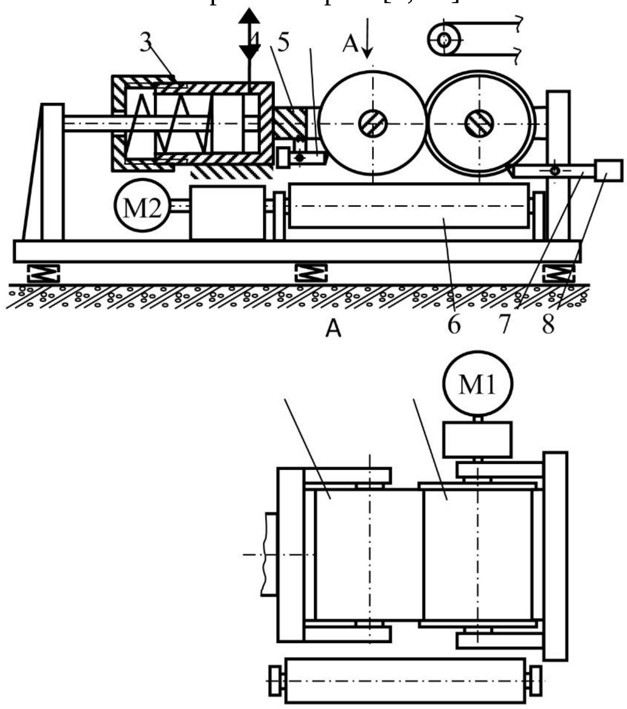


***Fig. 4. Structural diagram of a roller press with GIP for final dehydration of wet dispersed materials***

In a roller press [16], the concentrate passes into the gap between the driving 10 and driven 9 rollers, which rotate slowly. In addition, the roller 9 is periodically pressed against the roller 10 with a given frequency and amplitude, which are determined by the settings of the hydraulic press. The specified loads are transmitted through the fork 4, with an increase in the pressure of the working fluid in the piston cavity of the hydraulic cylinder 3 of the hydraulic press and the displacement of its housing relative to the stationary piston with the rod to the right according to the diagram. At the stages of pressure drop in the hydraulic system of the hydraulic press, the housing 3, and with it the roller 9 under the action of a compressed spring in the rod cavity of the hydraulic cylinder, return to the original left position. As a result, the concentrate of materials is drawn into the gap between the rollers where it is subjected to static and vibration-shock loading. The liquid squeezed out of the concentrate passes through small holes in the rollers, closed with a metal filter mesh. Then from the cavities of the rollers it flows through the tubes into the collection container and is pumped to the hydropulse installation for microfiltration. The squeezed concentrate is cut from the surfaces of the rollers by knives 5, 7 of the appropriate width, which are pressed against the rollers by means of weights 8. The concentrate separated in this way is discharged onto the belt conveyor 6, on which it is transported to the container.

Based on the process and equipment configurations described above, the following principal design requirements for hydraulic impulse equipment for vibroimpact dewatering of wet dispersed materials have been formulated [1, 2]:

1. The complete sequence of vibroimpact dewatering processes shall be divided into several stages, with a separate unit of equipment employed at each stage.

2. As dewatering progresses from the first to the final stage, the volume of separated liquid decreases due to reduction in free liquid content. Accordingly, the intensity of vibroimpact loading shall be progressively increased and the thickness of the material layer decreased, to maintain sufficiently high process efficiency.

3. The HID shall provide stepless, independent, and precise adjustment of the principal loading parameters (pressure in the HID cylinder cavity, oscillation frequency and amplitude of the executive elements), as well as stable maintenance of their set values after adjustment.

4. The equipment of the technological complex shall preferably be developed on the basis of known static, vibratory, and vibroimpact machines: screw and roll presses, vibratory screens with unbalanced drives, and inertial vibroimpact press-hammers (IVPM) with HID.

5. Equipment components that are sources of elevated noise shall be enclosed in sound-absorbing covers. Reliable vibration isolation of the machine frames, as well as a computer-based remote control and monitoring system, are mandatory.

6. The equipment shall be fitted with a sensor system for monitoring the principal process loading parameters and for diagnosing its technical condition.

## 5. Conclusion

1. A multi-stage technology for vibroimpact dewatering of wet dispersed food production waste has been developed, comprising four sequential stages with progressively increasing loading intensity, enabling reduction of the final concentrate moisture content to approximately 25% without thermal post-treatment.

2. The developed hydraulic impulse equipment provides progressive multi-stage dewatering of wet dispersed materials with gradual intensification of vibroimpact loading at each technological stage. The proposed structural solutions for the HID vibroimpact screen, screw press and IVPM complex, and roll press with HID ensure effective moisture removal, reduction of specific energy consumption, and improvement of the overall efficiency of the dewatering process.

3. Six principal design requirements for the equipment complex have been formulated, encompassing multi-stage organisation, progressive loading intensification, stepless HID parameter adjustment, use of proven machine bases, vibration isolation, noise control, and sensor-based condition monitoring.

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## БАГАТОСТАДІЙНЕ ВІБРОУДАРНЕ ЗНЕВОДНЕННЯ ВОЛОГИХ ДИСПЕРСНИХ МАТЕРІАЛІВ ІЗ ЗАСТОСУВАННЯМ ГІДРОІМПУЛЬСНОГО ОБЛАДНАННЯ

*У статті представлено комплексну багатоступеневу технологію та оригінальне гідравлічно-імпульсне обладнання (ГІО) для віброударного зневоднення вологих диспергованих відходів харчового виробництва. Традиційне одноступеневе механічне зневоднювальне обладнання зазвичай досягає недостатнього зниження вологості та вимагає дорогої термічної дообробки. Запропонована технологічна лінія усуває ці обмеження, розділяючи процес зневоднення на чотири послідовні етапи, кожен з яких використовує спеціалізований блок обладнання з поступово зростаючою інтенсивністю віброударного навантаження, що прикладається до вологого диспергованого матеріалу. На першому етапі попереднє зневоднення проводиться на гідравлічно-імпульсному віброударному грохоті, що знижує вміст вологи в концентраті до 85%. Грохот включає гумотканинну конвеєрну стрічку із заклепками U-подібних сталевих пластин, дрібну фільтрувальну сітку та чотири гідравлічні циліндри ГІО, які надають стрічці високочастотні вертикальні коливання, проштовхуючи рідину через сітку та отвори. На другому етапі концентрат піддається подальшому зневодненню у шнековому пресі до вмісту вологи 75%; фільтрат, що виходить, збирається для подальшої мікрофільтрації. На третьому етапі інерційний віброударний прес-молот (ІВПМ) з ГРІ застосовує одночасне статичне, інерційне та віброударне навантаження зверху та знизу, зменшуючи вміст вологи до 70%. Четвертий і останній етап використовує валковий прес з ГРІ, де концентрат проходить тонким шаром між веденими та пасивними валками, що піддаються комбінованому статичному та віброударному стисканню, досягаючи кінцевої вологості приблизно 25% без термічної обробки. Фільтрат з кожного етапу спрямовується на установки мікрофільтрації, ультрафільтрації та нанофільтрації, оснащені ГРІ. Детально описано конструктивні рішення всіх чотирьох одиниць обладнання. Сформульовано шість основних вимог до проектування комплексу обладнання, що охоплюють багатоступеневу організацію, поступову інтенсифікацію навантаження, безступінчасте регулювання параметрів ГРІ, використання перевірених машинних баз, віброізоляцію, контроль шуму, моніторинг на основі датчиків та дистанційне керування процесом за допомогою комп'ютера.*

***Ключові слова:*** *гідроімпульсний привід, багатостадійне віброударне зневоднення, вологі дисперсні матеріали, відходи харчових виробництв, шнековий прес, вальцьовий прес, вологість.*

***Рис. 4. Літ. 16.***

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