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Research Article

Technical and Economic Assessment of the Process of Vibrating Thermal Radiation Drying of Bulk Products

Igor P Palamarchuk[1]* and Vladyslav I Palamarchuk[2]

[1]*Doctor of Technical Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine*

[2]*Associate Professor, Vinnytsia Trade and Economic Institute of the State Trade and Economic University, Ukraine*

***Corresponding Author:** Igor P Palamarchuk, Doctor of Technical Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine.

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Abstract

High technical and economic results were obtained by the use of infrared radiation of bulk agricultural products. The development of this process is observed when using the developed vibration dryer. Low -frequency vibrations provided to the executive bodies of the machine from the mechanical vibrations built in the supporting nodes of the conveyor tape can be considered as a tool for influencing the guide organ to create a running wave tape on the surface. As a scientific hypothesis in this scientific article, it was accepted that the vibration of the supporting nodes of a lifetime flexible tape allows you to create a running or standing wave on its surface, the energy of which is sufficient to move products in the conditions of a pseudo -wore layer and to ensure a constant updating of the surface layer. Such a wave conveyor provides promotion of products at a given speed, intensifies the heat exchange processes of moisture removal and prevents burning of products while processing infrared rays. Such drying conditions are characterized by a high coefficient of heat transfer, which may exceed typical convective processes by several orders of orders; There is an increase in the active surface of heat exchange up to 100%; The contact surface with energy increases in proportion, which leads to a decrease in the active temperature difference; There is a decrease in 2-3 times of internal friction in the mass of production and accordingly reduces the technological resistance in the mass of loading, which is the potential for improving the technical and economic characteristics of the studied process. In the technical and economic assessment of the developed process of infrared drying, the cost of power for its sale and possible speeds of providing vibration-wave transportation of products, which theoretically and experimentally proved to increase the speed of transportation of raw materials by 1.2-2.1 times with a decrease in energy costs in 1, 4 - 2 times compared to typical schemes of machines.

Keywords: Technical and Economic Assessment of the Process of Vibrating Thermal Radiation Drying of Bulk Products

Introduction

The process of drying, along with its main function, which is to reduce the moisture content in the weight of products, accelerates it post -harvesting, equalizes the technological mass by the degree of maturity and humidity, improves the appearance of products. In addition, there is a positive impact on the quality of processing products; inhibits the functioning of pests and pathogenic microflora in the mass of production; which allows to some extent improve the technological properties of even defective material, bring it to a more stable state for storage and further use.

The intensity of the drying process depends primarily on the amount of heat transferred, which is determined by its potential. In this case, the maximum increase in the temperature of the coolant, provided that the required structure of the material is stored, is determined by such deepening into the evaporation zone, which is numerically equal to the second critical moisture. The use of infrared technological action allows to create an energy potential that exceeds the convective heat transfer by almost 30 - 40 times [1-3]. Drying with infrared rays is due to the transfer of the heat of the product from the source of radiation energy, in the process of heat exchange the radiant flow penetrates partially inside the capillary-porous bodies to a depth of 0.1... 2 mm and is almost completely absorbed as a result of a number of reflections from the walls. The removal of moisture from the surface of the product occurs by convective heat exchange, which allows to reduce energy consumption by almost 3 times [4,5].

Other methods of intensification of the drying process, which have become widespread recently, can be noted an increase in the surface of contact of the material with a drying agent by creating a pseudo -thinned or loose layer of production. This state of production in conveyor systems is achieved by the barbounding of the coolant flow through perforation of the cargo organ and, accordingly, through a layer of technological loading, when the surface of the conveyor is switched when the conveyor is moved or a combination of these methods.

Low -frequency fluctuations in the support surface of the transport organ lead to the fact that the clutch between the parts of the working environment is weakened, the loose body receives mobility or pseudotecurity and a state of pseudo -thinning occurs. With the further increase in the intensity of oscillations, the filler particles begin to lose contact with the vibrating working body, increases the number of equilibrium positions of loose lobes, decrease and periodically disturb the relationship between them, reaching the state of vibration. In this case, there is a loosening of the bulk body and increasing the circulation of particles, which creates the most favorable conditions for the realization of transportation of bulk mass of production. This condition significantly improves the conditions of mixing and, as a consequence, increases the surface of heat and mass exchange; Reduces the forces of internal friction and, accordingly, energy costs for the implementation of technological movement. In addition, given the sufficiently high thermal intensity of the surface layer under the conditions of infrared rays, it is the mobility of the product layer that balances thermal load and accordingly prevents the surface of the material.

Performing the drying process of continuous action devices is the necessary prerequisite for the automation of the operation of technological equipment. When creating effective automatic lines, it is important to establish conditions that determine economic sufficiency or feasibility to move to a higher level of continuity. For the process under study, this level is ensured by the fact that the processing process occurs in the process of transportation, that is, the contradiction between transport and technological traffic is excluded. This achieves the main function of transport action, namely, ensuring the minimum time of passing the object of processing through the work area, that is, achieving the maximum speed of flow of products. Thus, the optimum for transportation will always be the position of processing items, which at a given speed provides the maximum throughput of the flow, which corresponds to the maximum productivity of the equipment. Koskkin LN and later Serg GV [6,7] As the main criterion for the efficiency of working machines, the ratio of the most general and contradictory parties to any production process was assigned: the ratio of transport and technological action. Thus, the most effective design scheme of the infrared dryer is a conveyor machine, on the surface of the loading organ of which low -frequency vibrations are created.

Literature Review and Problem Statement

Infrared dryers have significant advantages over traditional drying methods, in particular, convective heat transfer. For thermal radiation heat exchange, the radiation heats directly objects, not air; Because infrared; Due to the high energy saturation of the process, the intensity of evaporation of moisture from the product increases and accordingly reduces the heating time, accelerates the whole process of thermophysical treatment of the material. Therefore, enterprises that use this technological equipment significantly reduce production costs. In particular, when processing thin layers of products, the intensification of drying increases 1.5-2.0 times with a decrease in energy consumption by 1.5 times [8,9]. Thermal rays penetrate into the thickness of the product by 10-20 mm, while heating the product and moisture contained in it, which is much more efficient than when covering the flow of particles of loose particles. The second technological effect of the use of infrared drying, in particular, fruit and vegetable products is the long -term preservation of their beneficial properties and taste. Finally, the destruction or suppression of different types of bacteria, in turn, improves the quality of the product, but also improves the conditions of functioning of the surrounding biocenosis.

The efficiency of implementation, high potential and prospects for the improvement of the processes of vibration thermal radiation drying is observed from the creative combination of directions of vibration processing and transportation systems, as evidenced by the work as known vibrotechnologists and designers A.P. Babichev, P.S. Bernik, I.I. Blekhman, I.F. Goncharevich, V.P. Nadulyu, V.N. Poturaev, O.O. Spivakovsky, A.G. Chervonenko; and recognized founders of technologies and equipment of food and processing agricultural production industries O.G. Burdo, G.E. Lemonov, V.D. Popov, P.O. Rebinder, Z.A. Rogov, V.M. Stabnikov, A.I. Sokolenko and other prominent scientists [4,6,8,9].

As a scientific hypothesis of this scientific work it is that the use of a vibromechanical source to create a running and standing wave of a flexible carrier body allows you to create the movement of products in the area of processing due to the energy of the created wave.

The aim and objective of research

The purpose of the conducted research is to justify the structural and technological scheme of the conveyor infrared dryer; Assessment of the technical and economic efficiency of the developed equipment for the implementation of the drying process by determining and analyzing the patterns of change of its energy and speed parameters. To fulfill this goal, the following tasks were provided.

- Development of constructive sale of infrared drying with a pseudo -thinned layer of products.
- Determination of basic technical and economic parameters and choice of criteria for evaluating the effectiveness of the investigated process of infrared drying.
- Evaluation of the efficiency of the oscillatory system for vibrating wave transportation of bulk products by energy and kinematic parameters.

Materials and Methods of Research

To determine and evaluate the impact of technological, energy and kinematic parameters of the dryer for infrared irradiation on the efficiency of moisture removal from the product, an experimental vibrating wave unit was created (Figure 1). The mechanical viburnum provides the formation of a wave on the surface of the tape, the energy of which provides the promotion of products at a speed regulated by a laboratory motor vehicle and was fixed by an accelerometer pointer. During the movement of the tape under infrared emitters, the product perceives the effect of radiation of a certain power, the value of which was fixed by a wattmeter. The temperature of the layer of products was determined by means of a pyrometer through the window in the casing of the installations, which are located after each of the emitters during the movement of the tape. To determine the humidity of the product we use moisture meter for Aqua-15 grain.

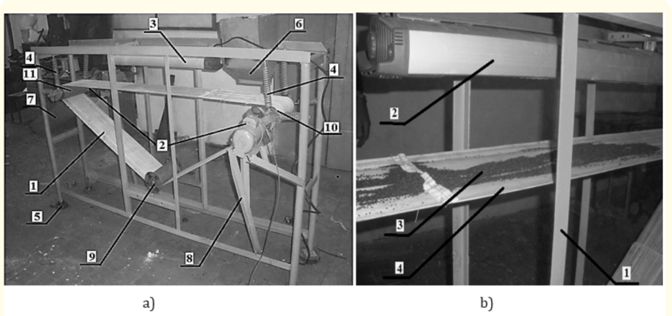

Figure 1: Experimental vibration wave infrared dryer: a - general appearance of the dryer: 1 - flexible lingering tape; 2 - mechanical vibrations; 3 - the emitter block; 4 - elastic suspension; 5 - vibropora; 6 - nutrient pipe of products; 7 - receiving pipe; 8 - installation frame, 9 - stretch roller; 10, 11 - working rollers; B - promotion of products in the radiation zone: 1 - frame; 2 - the radiator panel; 3 - processed products; 4 - ribaning.

Research results and their discussion

The developed experimental vibration -bearing thermal radiation or infrared dryer [9,10] is a combination of tape conveyor and vibrating technological machine. Mechanical vibration actuations or vibrations, which are mounted inside the rollers 3 and 2 (Figure 2), provide the generation of spatial oscillations, creating conditions for continuous movement of products on a given spiral trajectory, ensuring its weighted state. Volt 7 provides the necessary tension of the flexible tape. The fluctuations in working rollers with given amplitude and frequency characteristics create a mechanical wave on the surface of a flexible element, which provides the moving of bulk products along the processing area in infrared irradiation. The loosening of the mass of products under the action of variable loads leads to a decrease in internal friction and viscosity in the technological environment, as well as to layered mixing and ensuring uniform contact with the cold.

In this case, the transport wave is created by vibration of the support cat of the tape. In such a vibrating transport and technological infrared machine, the vibration not only reduces the forces of internal friction during transportation, but also forms a dynamic wave to ensure the forced movement of the material along the flexible loading organ in the conditions of continuous updating of the layers of products during their mixing.

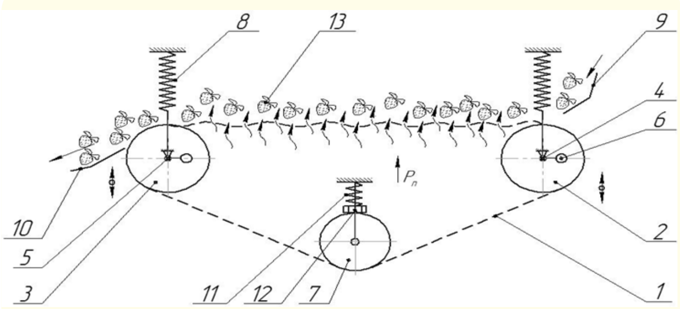

Figure 2: Vibration infrared dryer with vibrating wave transportation: 1 - conveyor tape; 2, 3 - support cats; 4, 5 - actuators of vibrations; 6 - debalanhea; 7 - tension roller; 8 - elastic elements of the vibration unit; 9 - a tray for supply of products; 10 - tray for unloading products; 11 - an elastic element of a tension roller; 12 - adjusting nut; 13 - processed products; RP - the pressure of the coolant flow.

Energy costs for the implementation of the infrared drying process according to the presented schemes can be represented through energy costs for the overcome of the NTR friction forces and the maximum driving force of low -frequency vibrations N_FMAX. The first component is not significant in view of the economy of modern infrared energy. The definition of the second component was carried out as a calculation of the power for the creation of the vibration mode of processing.

The required engine power can be determined by the formula [11]

$$N_{пр} = \frac{1}{\eta}[N_{Fmax} + N_{TP}] \qquad \text{--------- (1)}$$

N_{Fmax} – the maximum power that develops forced force: $N_{F\max} = m_{\partial} \cdot A\omega^2$; η – KKD transfers; N_{mp} - the power of friction forces that can be determined from the equation

$$N_{mp} = M_{mp}\omega_1 = \frac{1}{2}Ffd_y\omega_1$$

We finally get: $$N_{np} = \frac{1}{\eta}m_{\partial}A\omega^2(1+0,5\cdot d_y \cdot \omega f) \qquad \text{--------- (2)}$$

According to the conditions of providing the minimum size (or mass) of the engine as well as the minimum load on the allowance [12]

$N_{пр}=D^2L_я w\, C_m^{-1}$, ---------- (3)

D - the outer diameter of the casing of the engine; $L_я$ - the length of the anchor or rotor; C_m - a permanent machine depends on the magnitude of the magnetic flux and the current of the current.

In determining the energy characteristics of the investigated schemes of implementation of infrared drying on conveyor machines, we take into account that the value of the power of forced force N_F When using the above experimental recommendations is [13].

$$N_F = m_{\partial}a_x \cdot \upsilon_{mp.x} = m_{\partial}(a_{x1}+a_{x2})\cdot\upsilon_{mp.x} = \qquad \text{--------- (4)}$$
$$= m_{\partial}(A_{x1}\omega_1^2 + A_{x2}\omega_2^2)\cdot 3,05A_{x1}\omega_1 = 10,68m_{\partial}A_{x1}^2\omega_1^3$$

$m_д$ - mass of debalas.

As an energy evaluation parameter, power was used in the sale of infrared drying in the moving layer of raw materials (Figure 3). The presented evaluation criteria directly determine the technical and economic efficiency of the studied processes and equipment. Among the kinematic characteristics for the evaluation of the developed dryer used the speed of movement of the workpiece, which is a direct proportional mass productivity of the dryer (Figure 4).

These characteristics were determined for two ways of realization of infrared drying in the moving layer of products

- when moving the mass of the raw material treated with the movement of the conveyor tape, which is inherent in the typical schemes of infrared dryers.
- when transporting products by wave motion of the tape, which is achieved in the vibrating circular movement of the support rollers of the tape for three states of the studied oscillatory system: with power, instant and combined unbalance.

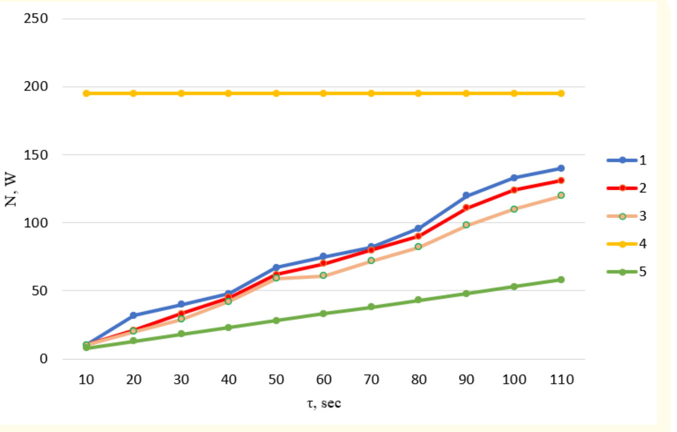

Figure 3: The energy characteristics of the investigated process of infrared drying: 1, 2, 3 - experimentally determined power costs for the creation of a combined, momentary and power inability of the studied oscillatory system; 4 - power consumption when moving the products by the movement of the tractor tape, which is theoretically determined; 5 - Power consumption when moving products due to the energy of the wave on the surface of the tape determined theoretically.

Using the necessary measuring equipment, an analysis of the main kinematic and energy characteristics of the oscillatory system was carried out, which were determined theoretically and experimentally. The evaluation of these parameters was performed at different angles of debalanuts relative to each other. When this angle is changed from 0 to π the force of inertia, the unbalanced elements decreased from maximum value to zero. Variations of such provisions of debalanuts allowed the graphic dependencies of vibration parameters presented in figures 3 and 4. Changing the provisions of unbalanced elements relative to the vertical axis of the machine made it possible to obtain variants Figure 3, 4).

Using the developed experimental model of infrared dryer with vibration -wave transportation of products, an evaluation of energy parameters of the process under study was carried out (Figure 3). The experiments were conducted in the processing of rapeseed and soybean masses. Line 4 (Figure 3) reflects the theoretical dependence of energy costs for the creation of forced force, which generates low -frequency fluctuations in the mass supporting nodes. Line 4 corresponds to energy consumption to ensure the movement of a typical conveyor conveyor with structural parameters that are close to the developed dryer. In the writings [9,10], effective working modes of the developed infrared dryer are substantiated by frequency within 90 - 110 councils/s. For this working interval, energy costs for the moisture removal process during the implementation of the developed dryer are less than 1.4 - 2 times (Figure 3).

When moving products by the motion of the lifetime tape (line 5 in Figure 4) the speed of the workpiece or the speed of its transportation υr is recommended within 10... 50 cm/s as for the tape conveyor when moving the bulk masses. Considering that the products should be processed to a given humidity for one passage of the work area and using appropriate experimental data, we accept. $\upsilon_{пр} = \upsilon_{тр} = \upsilon_c = 13$ cm/sec

When stirring the products in the conditions of the pseudo -wore layer due to the oscillations of the support rollers of the tape and the creation of the last running or standing wave (line 4 in Fig. 4) the theoretical speed of the processed products can be identified with the component of vibration speed υx, which is determined as follows.

$$\upsilon_{пр} = \upsilon_x = A_x \omega_к, \; A_x = A_{x1} + A_{x2}, \; \omega_к = \frac{2\pi}{T_к},$$

A_{x1}, A_{x2} - components of oscillation amplitude from the drive vibrations; ω_k - the frequency of oscillation of the wave conveyor.

For justified frequency intervals 90 - 110 rad/s theoretically calculated the speed of movement of products under the action of a dynamic wave on the surface of the tape developed vibration dryer is 1.8 times higher than the speed developed with a typical transportation body (respectively .4). The speed of movement of products with the help of a developed dryer, which is experimentally defined, exceeds a similar parameter for a typical infrared dryer on average for different schemes of unbalanced system of 1.2 - 2, 07 times (respectively line 1, 2, 3 and 5 in Figure 4).

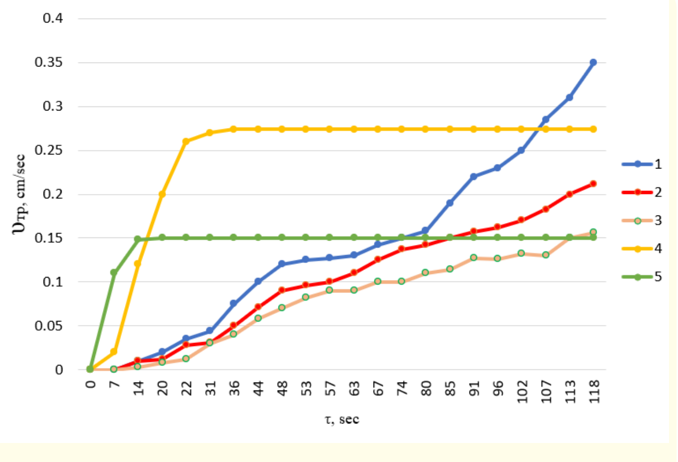

Figure 4: The speed characteristics of the investigated process of infrared drying: 1, 2, 3 - experimentally determined velocities of product mass under the conditions of the combined, momentary and power inability of the studied oscillating system; 4 - the speed of the wave of products due to the energy of the wave on the surface of the tape, which are theoretically determined; 5 - the speed of transportation of a typical tape conveyor together with the products determined theoretically.

Thus, the use of the developed vibrating wave infrared dryer compared to the typical schemes by energy parameters is much less costly, if possible to increase the mass productivity of the process due to increasing the speed of transportation of products in the work area.

Conclusions

- The developed constructive-technological scheme of the vibration-wave dryer allows to increase the intensification of heat-mass exchange by using a pseudo-wore layer of products, the use of vibration and wave effects and the current scheme of implementation of the process of moisture removal.
- The use of a deformed cargo body, two debalanal vibrations, which are connected by flexible communication allowed to implement the transport and technological function of moisture removal and movement of products in the work area under the action of the jogging or standing wave-rented.
- Comparative analysis of the kinematic and energy parameters of the implementation of the processes of transportation of products in the work area when using the developed vibration -wave conveyor infrared dryer and the classic tape conveyor found an increase of 1.2 - 2.07 times the speed of transportation processing of the process of removal of motion; Reduction of 1.4 - 2 times the energy consumption for the process with the help of the projected dryer scheme.

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