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The analysis of theoretical and experimental research results of infrared vibrowave conveyer dryer main parameters

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Summary. The description, scheme and general view of designed infrared vibrowave conveyer dryer for seeds of oil crops drying, the comparative analysis of theoretical and experimental researches of energy and kinematic model's parameters have been done in this article. The main theoretical dependences and curves of results are presented. The mentioned above characteristics have been determined for two types of infrared products drying in the moving layer of products such as moving of treated raw materials by conveyer belt and products transporting by wave movement due to vibrating flat motion of conveyer supporting rollers. The schemes of infrared drying in moving layer of products are presented. The transporting method of raw materials during the technological drying process has been proved. All the researches have been conducted on conditions that products should be treated to necessary humidity by one pass through the working zone; it is possible due to the combined influence of infrared radiation and vibration action on the raw materials.

The conducted researches have given the opportunity to evaluate the conformity of created mathematical model to the gained experimental data and choose the optimal working parameters of infrared vibrowave conveyer dryer for this technological conditions.

Key words: dryer, raw materials, vibration, treatment, wave, heat.

INTRODUCTION

The creation of new highly technological equipment for drying agricultural raw materials means proving of its working rational parameters, their determination is done by theoretical and experimental researches, they are based on scientific drying technological foundation, designed by known scientists of this branch [1-4].

Short term intensive action of infrared field on the surface layer causes its overheating and irregularity of layers treatment. That is why the using of conveyor vibrational and wave technologies in treatment zone is promising; it lets to create favorable conditions for production process intensification and to use the effective methods of action on the object; to carry out technological movement in continuous mode; reduce and eliminate the use of unproductive labor for auxiliary operations; to design the common control of system dynamic mill where the technological action takes place; to minimize mechanical object damage. The combination of vibrational and current technologies for conveyer vibrational machines causes the realization of the highest form of continuity, that is automation of the production process, harmonic ratio of its main structural components, implementation of effective actions on volume production corresponding to higher forms of perfection of process equipment.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The expediency and efficiency of vibration machines for agricultural raw materials drying are grounded in such works as [4-7]; their works define the role of vibration as an intensification factor. The processes of heat and mass exchange can be intensified by infrared (IR) rays influence [10-13]. The greatest effect is obtained by combination of IR-heat and vibration influence on the product [14].

OBJECTIVE

The objective of the work is to obtain rational parameters of working mode of designed infrared vibrowave conveyer dryer and to check the adequacy of the mathematical model analyzing theoretical and experimental research results.

THE MAIN RESULTS OF THE RESEARCH

When checking the deviation between theoretical and experimental research as evaluation criteria we choose the power and kinematic characteristics of the researched processes. We suggest speed of processed products among kinematic characteristics; it is directly proportional to the mass performance of the dryer. We use force consumption of infrared drying in a moving layer of raw material as an energy parameter of assessment. The given assessment criteria determine the technical and economic efficiency of the studied processes and equipment.

These characteristics are defined for two ways infrared drying in a moving layer of products [15, 16]:
- when you move the weight of the treated material due to conveyor belt motion (Fig. 1, a);
- when transporting of products is done by vibrating circular motion of conveyer supporting rollers (Fig. 1, b);

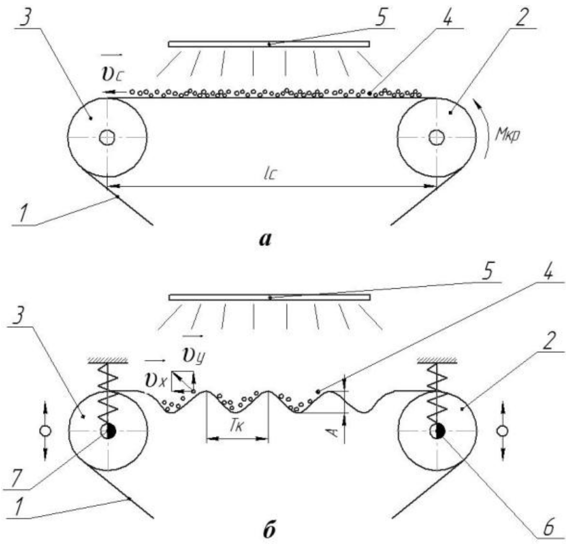

Fig. 1. Scheme of infrared drying in a moving layer of products: a – raw material is transported by conveyor belt motion; b – raw material is transported by belt wave motion; 1 – conveyor belt; 2, 3 – supporting rollers; 4 – products to be processed; 5 – the radiator; 6, 7 – debalance vibrodrives; A – amplitude; $T_к$ – period fluctuations; l_c – the length of the tape; υ_x, υ_y – vibration speed components.

The speed of treated products or the transporting speed $\upsilon_{тр}$ can be taken from the interval of 10…50 sm/s as for conveyer belt for transporting loose components for the first working conditions [17]. Taking into consideration the fact that products should be treated to the appropriate humidity by one pass through the working zone and using the appropriate experimental data, we accept the following:

$$\upsilon_{пр} = \upsilon_{тр} = \upsilon_c = 13 \text{ см/с}. \quad (1)$$

When mixing products in terms of the fluidized bed due to fluctuations of supporting rollers and creation of running or standing wave (fig. 1, b) the rate of the products treatment can be identified with the part of vibration speed υ_x that we determine such as:

$$\upsilon_{пр} = \upsilon_x = A_x \omega_к \quad (2)$$

$$A_x = A_{x1} + A_{x2} \quad (3)$$

$$\omega_к = \frac{2\pi}{T_к} \quad (4)$$

where: A_{x1}, A_{x2} – amplitude component of vibrodrive, $\omega_к$ – wave oscillation of frequency conveyor.

Power loss during infrared drying in a moving layer of products is:

$$N_0 = N_{оп} + N_{пр}.$$

Gear power $N_{прс}$ for the first way of researched treatment type is power for conveyer moving with a load on the straight part.

When moving is done by wave conveyer gear power can be determined as [18, 19]:

$$N_{прх} = \frac{2k_3 N_к}{\eta_{пр}} \quad (5)$$

where: $N_к$ – technological capacity for creating oscillatory motion of supporting roller, $\eta_{пр}$ – the drive mechanism efficiency .

Taking into consideration the fact that two symmetrically located from the center of dryer vibrodrives of debalance type are used for working movement of wave conveyer, the transportation speed depends on vibration speeds that are provided for machines vibrodrives. That's why:

$$\upsilon_{тр.x} = \upsilon_{x1} + \upsilon_{x2} = A_{x1}\omega_1 + A_{x2}\omega_2. \quad (6)$$

According to the results of experimental research the following ratio of amplitude and frequency vibrodrives parameters are necessary for receiving stable moving of loose raw materials by wave conveyer [18-20]:

$$\begin{aligned} A_{x2} &= 1,68 A_{x1}. \\ \omega_2 &= 1,22\omega_1 \end{aligned} \quad (7)$$

So, searched speed of wave conveyer or transporting speed is:

$$\upsilon_{тр.x} = 3,05 A_{x1}\omega_1 \quad (8)$$

We analyze the main kinematic and power characteristics of oscillating system using the designed experimental model of infrared vibrowave conveyer dryer (fig. 2). The parameters assessment is done under the different angles of debalances location relative to each other. It is obvious that inertia force of unbalanced elements decreases from a maximum value to zero by changing the angle from 0 to π. The variation of debalances` position allowed to obtain graphical dependences of vibrational parameters at the figures 3-7. The positions variations of unbalanced elements by the vertical axis of the machine allowed getting versions of power, torque and combined unequilibrium of the researched oscillating system.

Fig. 2. The general view of the researched model of infrared vibrovawe conveyer dryer.

The presented amplitude and frequency system characteristics (Fig. 3) indicate shift to lower frequency resonant mode and more dynamic fluctuation extinction for the estimated resonant mode.

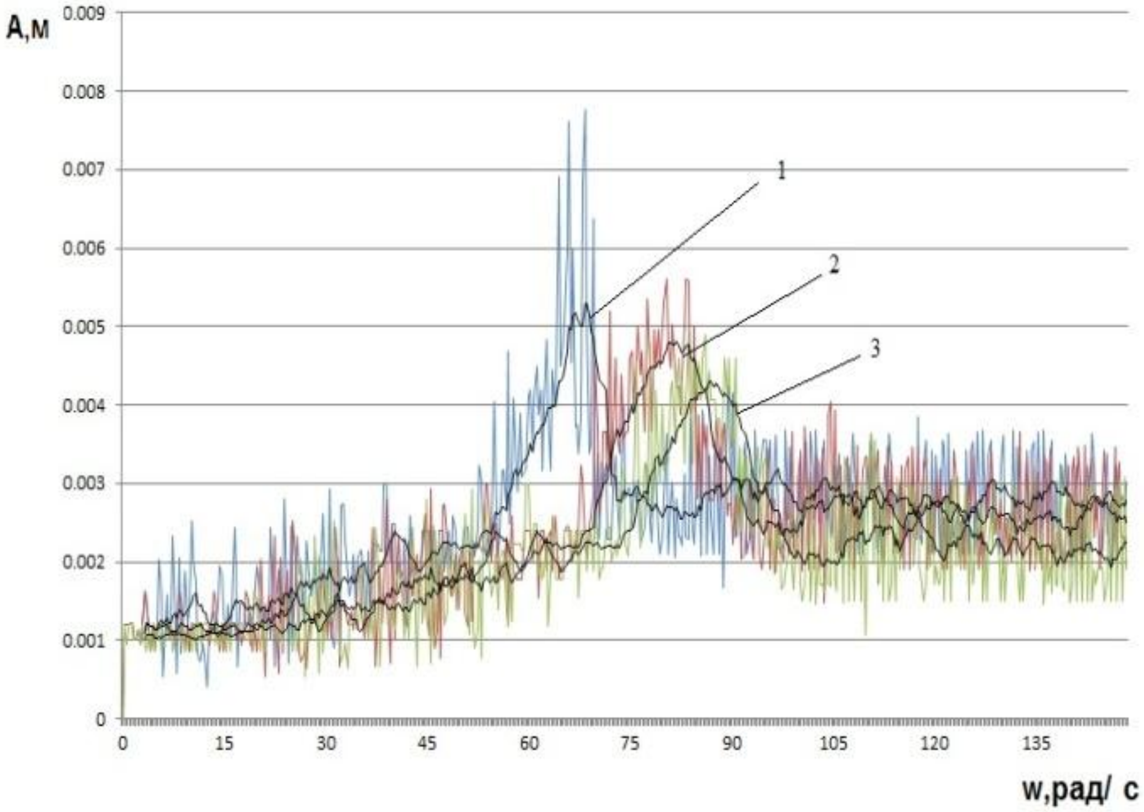

Fig. 3. The amplitude and frequency characteristics of the researched machine depending on angular velocity drive shaft and the swinging open of debalances: 1 – at 0 degree, 2 – at 45 degrees, 3 – at 90 degrees.

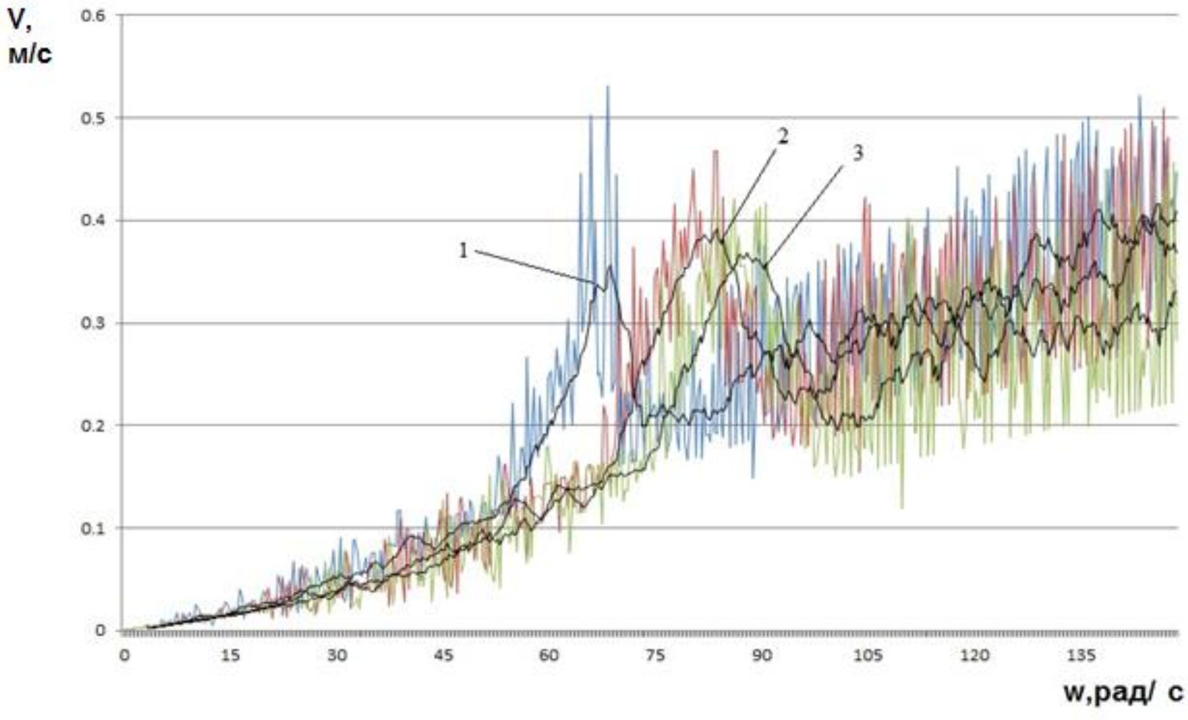

Fig. 4. The vibrational speed of the researched machine depending on angular velocity drive shaft and the swinging open of debalances: 1 – at 0 degree, 2 – at 45 degrees, 3 – at 90 degrees.

More rapid increase of power and energy vibration characteristics is observed when debalances are consolidated, i.e. when inertial force is maximum (Fig. 4).

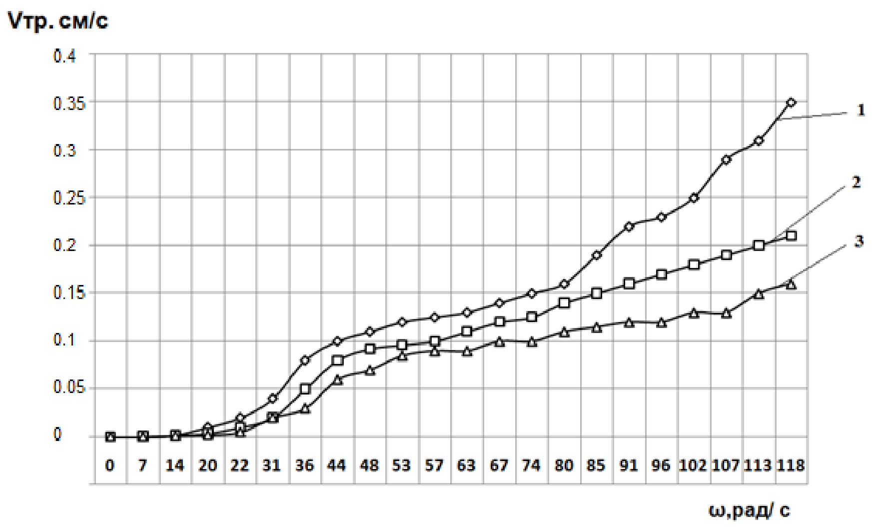

Fig. 5. The transporting speed of treated products depending on angular velocity drive shaft, the swinging open of debalances and debalances relative position at vibrodrive rollers: 1 – under power unequilibrium, 2 – under torque unequilibrium, 3 – under combined unequilibrium.

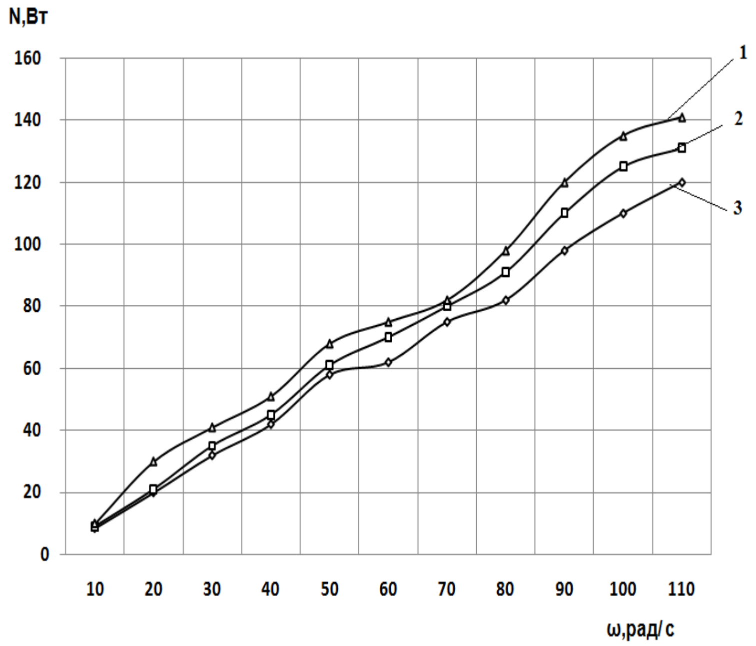

Fig. 6. The power characteristics of of the researched machine depending on angular velocity drive shaft, the swinging open of debalances and debalances relative position at vibrodrive rollers: 1 – under power unequilibrium, 2 – under torque unequilibrium, 3 – under combined unequilibrium.

While analyzing the graphical and kinematical characteristics of the researched model of infrared vibrowave conveyer dryer we should mention that operating modes under the set amplitude and moderate energy consumption is equal to the drive shaft angular velocity of ω=100 rad/s and A=3 mm.

The research of vibrational parameters influence uder the various types of oscillating system unequilibriums demonstrates the dynamic similarity of speed changes, starting with ω=0…85 rad/s (fig. 5.). Then we observe more rapid increase in speed of product flow under the conditions of combined system unequilibrium.

The realization of combined unequilibrium of oscillating system allows to increase both the products transporting speed on the surface of wave conveyer starting with the drive shaft angular velocity of 90 rad/s and the drive energy consumption starting with 70 rad/s (Fig. 6) [18].

The results of comparative analysis on kinematic characteristics received on the basis of formula (8) and amplitude and frequency characteristics (Fig. 7) are presented as Figure 8.

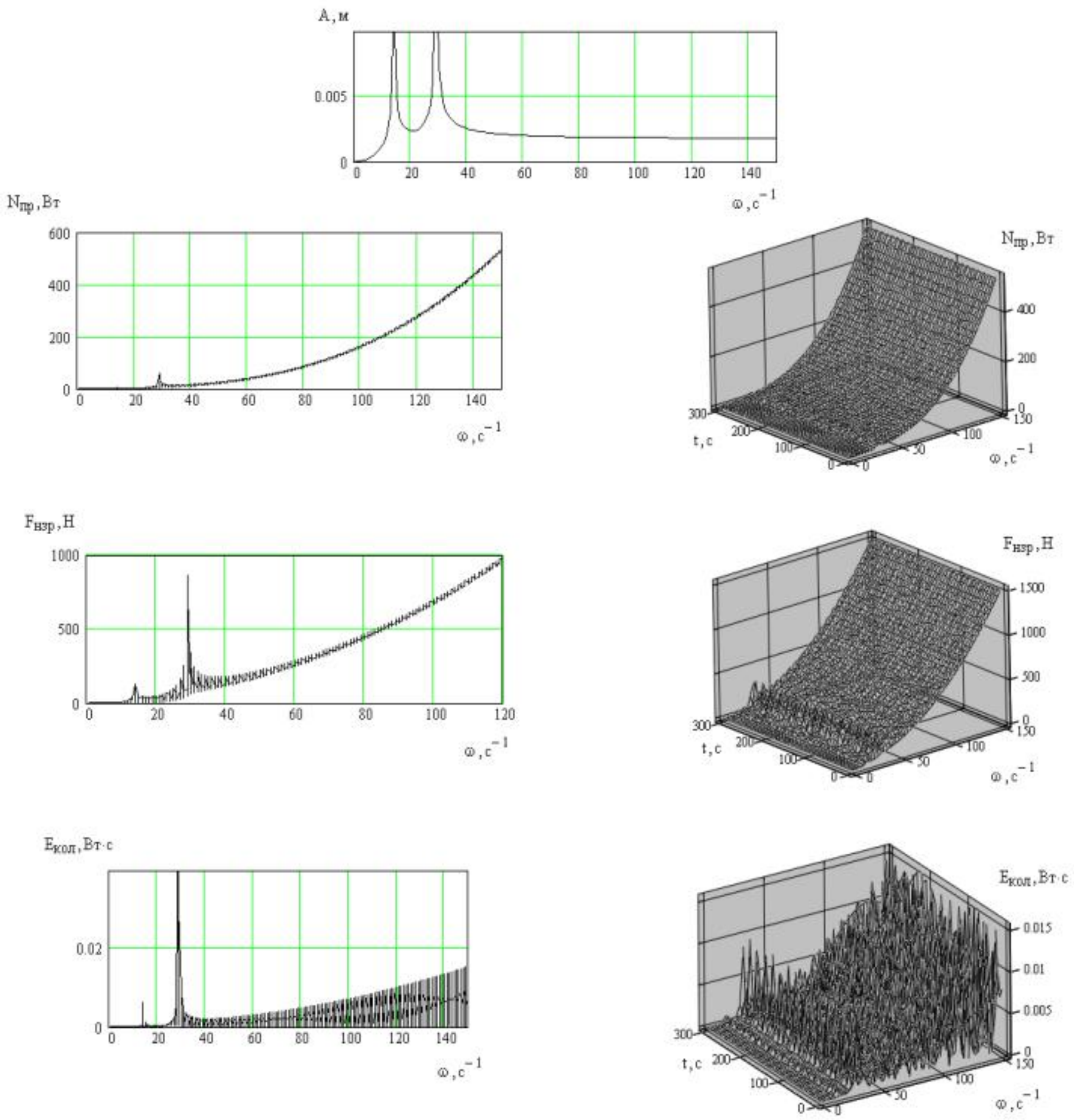

Fig. 7. Amplitude and frequency (f = A(ω)), power (f = $F_{нзр}$ (ω, t)) and energy (f = $N_{пр}$ (ω, t)), $E_{кол}$ (ω, t) characteristics of debalance dynamic vibrodrive of machines with flexible or deformed transporting part:
A – amplitude of working container fluctuation, $N_{пр}$ – drive power, $F_{нзр}$ – unbalanced efforts load bearing components, $E_{кол}$ – the vibrational energy of the masses.

When determining the energetic characteristics of researched schemes of infrared drying at conveyer machines we take into account that mixing power N_F using the presented above experimental recommendations is:

$$N_F = m_\partial a_x \cdot \upsilon_{mp.x} = m_\partial (a_{x1} + a_{x2}) \cdot \upsilon_{mp.x} = \\ = m_\partial (A_{x1}\omega_1^2 + A_{x2}\omega_2^2) \cdot 3{,}05 A_{x1}\omega_1 = 10{,}68 m_\partial A_{x1}^2 \omega_1^3 \quad (9)$$

where: m_∂ – is a debalance weight.

We present the comparative analysis results at figure 9 using the received formula (9), the presented above methods of receiving drive energy loss.

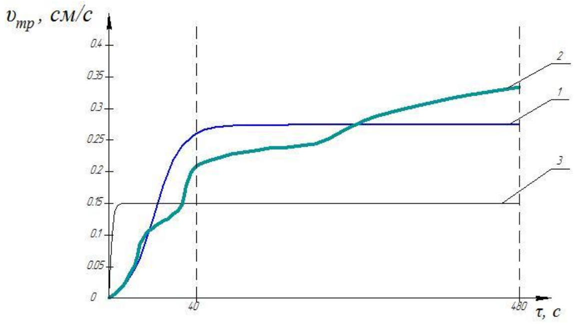

Fig. 8. Comparative analysis of theoretical and experimental research on kinematic characteristics evaluation: 1 – results of theoretical research, 2 – results of experimental studies, 3 – speed traffic transportation by product conveyor belt.

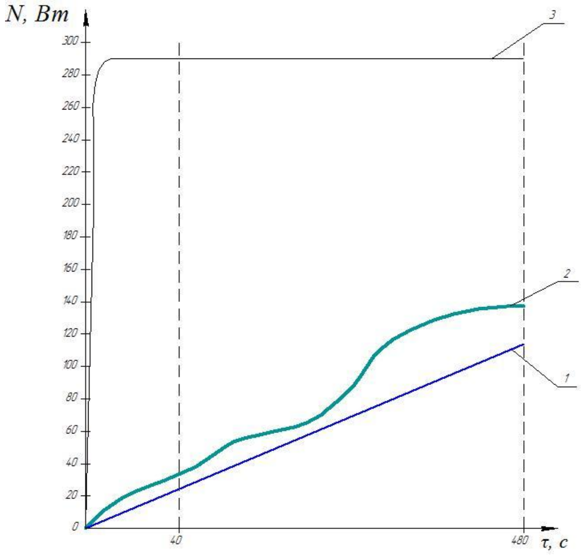

Fig. 9. Comparative analysis of theoretical and experimental research on the energy characteristics of the process: 1 – results of theoretical research, 2 – results of experimental research, 3 – theoretically received power value over the conveyor belt.

CONCLUSIONS

1. The research of the power forcing factors allows modeling of power, torque and combined unequilibrium of the researched oscillating system. The realization of combined unequilibrium allow to increase the products transporting system by 29 % compared with torque unequilibrium and by 46% compared with power unequilibrium; the drive energy consumption is higher by 8% and 19 % respectively in comparison with torque and power unequllibriums of the oscillating system

2. The difference between theoretical and experimental research for grounded parameters of working condition of designed vibrowave dryer is 14 % by kinematic characteristics and 15 % by energetic characteristics.

3. The comparative analysis of transporting ways by belt and wave conveyer has presented more dynamic characteristics ($\upsilon_{тр.с}$= 1,87$\upsilon_{тр.х}$) and less power drive loss ($N_{пр.с}$= 2,54$N_{пр.х}$) for the wave conveyer.

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