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Determination of Dynamic Characteristics of the Frame Bearing Structures of the Vibrating Separating Machines

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Abstract. Within the vibrating separating machines the vibration displacement of the members is transferred to a frame bearing structure, and over it the movement is transferred again to the suspension brackets of the sieve separating surfaces and to the foundation, on which the machine is fixed. The forced oscillations of the sieve separating surfaces ensure the separation process, and the vibration, transferred from the frame structure, disturbs this process. It is necessary to ensure the vibration displacement of the separating surfaces within the fixed limitations by means of optimal design of the frame bearing surfaces. The aim of the work is to decrease adverse vibrations towards the technological separation process. The calculated and graphical relations, acquired according to the presented methods, enable to estimate the influence of various structure solutions on vibration displacements of the structure elements at the stage of design.

1. Introduction

The vibrating machines are widely used in the industry for physical and chemical processes intensification, transportation, mixing, compaction, and dozing of bulk materials, as well as during their division into fractions [1, 2]. Numerous researches have established a distinctive relation of the quality of performance of vibration technological process from the rational operating modes and parameters of the vibration equipment [3, 4, 5]. The most challenging and demanding task is separation of bulk granular materials in postharvest grain. This is because the active material is a foodstuff and requires a high quality of separation [3, 6]. The main working members of vibrating separating machines are flat sieves, making vibration displacements. The sieves are connected to the frame bearing structure through elastic elements (Fig. 1).

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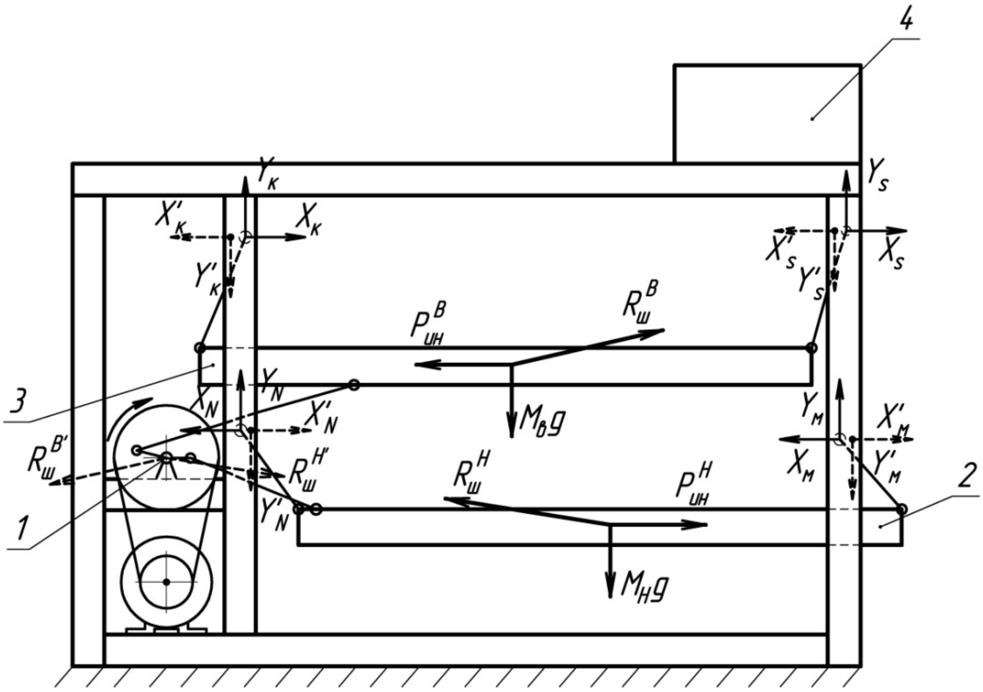

Figure 1. Structural scheme of vibrating separating machine's structure (the forces, acting towards the bearing construction from the drive mechanism parts, are shown with dotted lines): 1. Drive mechanism 2. Lower sieve case 3. Upper sieve case 4. Aspiration system.

The vibration displacement of the working members is transferred to the framework bearing construction. Then, over the bearing structure vibration is transferred to a closing of the structure building, where the machines of this type are fixed [7]. Vibration enables the technological process implementation, but its maximum values are limited by ergonomic requirements. Besides, the vibration displacement in the surface, perpendicular to the separating surface, may lead to a decrease of technological process quality.

In order to choose the optimal structure parameters for vibrating machines design it is necessary to investigate all the vibration characteristics of these machines' elements [7, 8, 9, 10]. One of the most important dynamic characteristics of the frame bearing structure is eigenfrequencies of oscillations of the mechanical system.

2. Materials and Method.

To assess the impact of the design features on the vibratory displacement of the frame structure is a necessity to determine the natural eigenfrequencies of the structure. We perform these calculations by the example of an elementary design with two weights of m1 and m2 (Fig. 2). The frame structure taken into consideration may be presented as an asymmetric frame with sealed poles, loaded with two concentrated masses.

Disregarding the proper mass of the system, we apply the inertia forces to the points of the frame structure taken into consideration may be presented as an asymmetric frame with sealed poles, loaded with two concentrated masses location of the masses m_1 and m_2. For the system with two degrees of freedom the formulae for calculating the eigenfrequencies will be as follows [11]:

$$\lambda_1 \cdot (m_1 \delta_{11} \omega^2 - 1) + \lambda_2 m_2 \delta_{12} \omega^2 = 0;$$
$$\lambda_1 m_1 \delta_{21} \omega^2 + \lambda_2 \cdot (m_2 \delta_{22} \omega^2 - 1) = 0, \tag{1}$$

where λ - amplitude of oscillations, m; δ_{ik} – shift towards *i*, caused by the single force, acting towards *k*, m; ω - oscillations' eigenfrequencies, rad/sec.

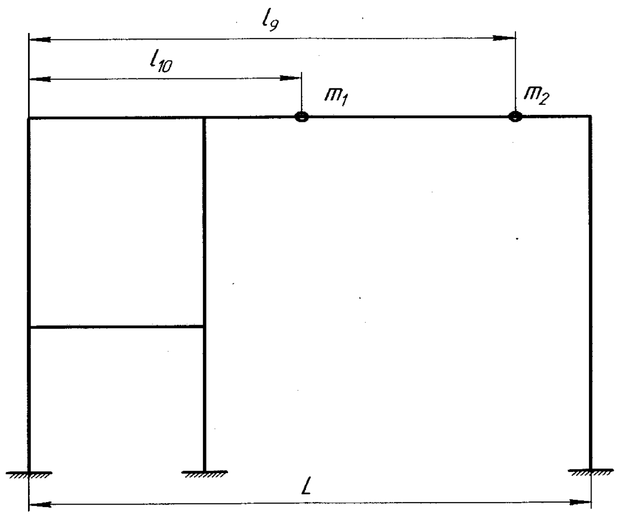

Figure 2. Diagram for calculating eigenfrequencies of oscillations of a framework construction in a vertical direction.

Taking into consideration that the amplitude, in case of oscillation doesn't vanish (does not turn to zero), the determiner, made up from coefficients of the system of equations, is equal to zero. The expanded determiner may be presented with the following equation:

$$\omega^4 \cdot (\delta_{11}\delta_{22} - \delta_{12}^2) \cdot m_1 m_2 - \omega^2 \cdot (\delta_{11} m_1 + \delta_{22} m_2) + 1 = 0 \,. \tag{2}$$

In order to determine the shifts from the single loads it is necessary to draw distribution diagrams of bending moments under the single forces $P_1 = 1$ and $P_2 = 1$, applied at the points of location of the loads with the masses m_1 and m_2 the values of the shifts δ_{ik} are determined with the help of the Vereschagin's rule and the shifts reciprocity theorem (Maxwell's theorem) [11].

3. Results and Discussion.

The solution of the equation (2) was carried out in the "MATHCAD" program. There were the first and second eigenfrequencies of the frame bearing structure's oscillations obtained, which were equal to 110 rad/sec and 185 rad/sec correspondingly.

In order to pick up the optimal construction of the frame it is necessary to have a look at the influence of various factors on the vibration displacements of the frame. The value of the vibration displacements of the bearing structure depends on the value of eigenfrequencies of the structure. According to the equation (2), the influence on the eigenfrequencies value is made by the value of concentrated masses and the shift of the beam under the influence of the loads with the masses m_1 and m_2 (Fig. 2), as well as the deviation of direction of the gravitation force from the m_1 mass under the influence of the m_2 mass. The values of the given shifts depend on these masses location points. If the masses are shifted towards the center, the deflections increase and the non-dimensional dynamic factor, i.e. the relation of dynamic shift to the static, determined by the formula [12], is growing:

$$K_{\partial} = 1 / |(1 - p^2/\omega^2)| , \tag{3}$$

where p – frequency of the exciting force, rad/sec.

The relation between the dynamic factor and the point of application of the load with the m_1 mass, in case the value of l_9 is constant, is presented in the figure 3 (curve 1). The relation between the dynamic factor from the point of

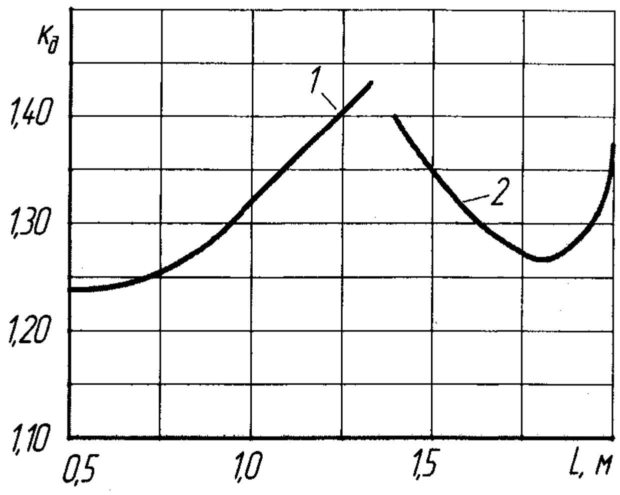

Figure 3. Relation of the dynamic factor *(k∂)* from the masses location points: 1.For the load with the m_1 mass 2. For the load with the m_2 mass.

location of the load with the m_2 mass, in case the value of l_{10} is constant, is described with the curve 2. The value of dynamic factor is maximal, if the masses are simultaneously applied to the center of the construction. In this case the dynamic factor takes the value of 1.78, in case of the initial diagram it is equal to 1.26 and its increase in this case is 40%. In case of the maximal remoteness of the given loads from one another, the dynamic factor decreases for 10%.

Let us investigate the relation of the dynamic factor from the values of the masses, applied to the given structure. As either of the masses grows, all the eigenfrequencies decrease, which leads to the grow of the dynamic factor. The relations of the dynamic factor from the values of the loads' masses are presented in the figure 4. The increase of the m_1 mass for 40% causes the growth of the dynamic factor for 8% (curve 1).

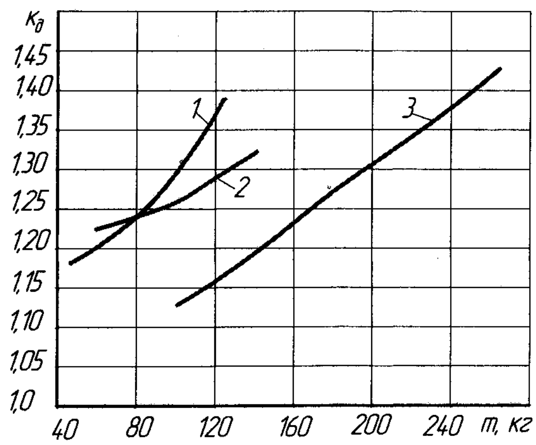

Figure 4. Relation of the dynamic factor *(k∂)* from the value of masses *(m_1, m_2)*: 1. For the load with the m_1 mass
2. For the load with the m_2 mass 3. For the both loads with the sum of masses $m_1 + m_2$.

As the m_2 mass grows for 47%, the value of the dynamic factor grows for 9.5% (curve 2). The simultaneous growth of the masses causes the maximal growth of the dynamic factor. In case of increasing the sum of the masses for 43% the dynamic factor grows for 13.2% (curve 3).

The data presented indicate that the value and position of concentrated masses make a considerable influence on vibration displacements of the separation machine's bearing structure. The most significant factor is location of the masses. If the masses are positioned in the middle of the upper horizontal beam, the value of its vibration displacement in a vertical direction increases for 40%. If the mass of the system is increased due to the increase of concentrated masses, the values of eigenfrequencies decrease, and the vibration displacements increase (for the case when the forced frequencies of oscillations are less then the eigenfrequencies).

In order to determine the influence of additional stiffeners on the vibration displacements of the bearing structure there were calculations made for the maximal values of the vibration displacements of changed structures (Fig. 5 – 6). The additional stiffeners are marked with dotted lines. The values of axial inertia torques of additional stiffeners sections are equal.

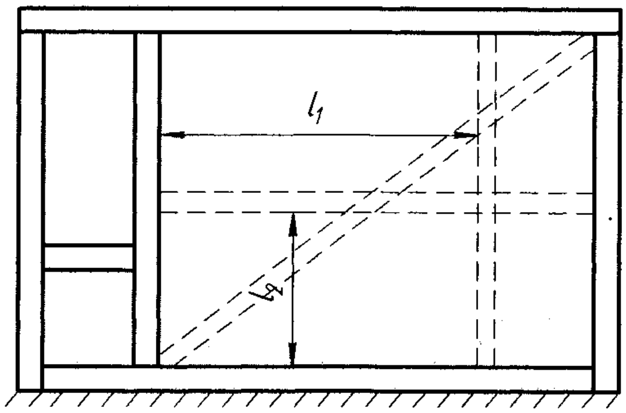

Figure 5. The framework structure diagram with the elements, implementing its stiffness (the length of the construction L= 2.27 m; height H= 1.59 m).

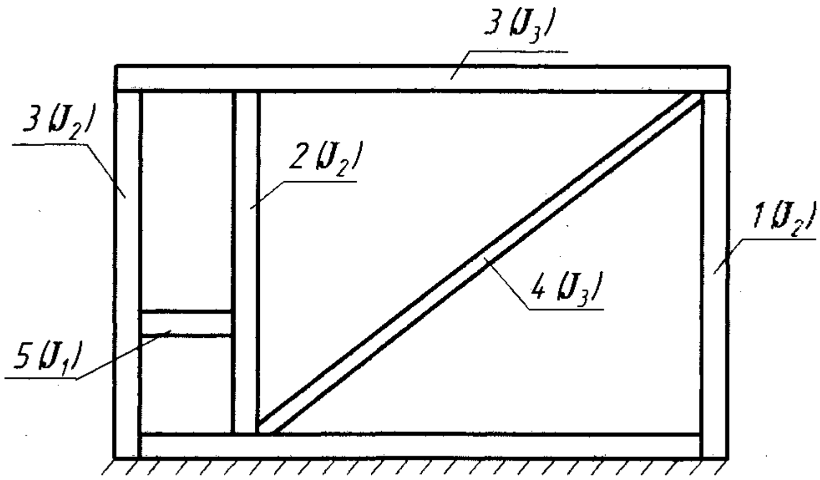

Figure 6. Example of the bearing structure diagram with an indication of axial inertia torques of the section *(J)* and numbers of beams constituents: J_1= 88.35·10^{-8} m^4 (length of the beam with inertia moment of the section J_1 – 0.4 m) ,

J_2= 87.88·10^{-8} m^4, J_3= 29.96·10^{-8} m^4.

The calculations of maximal vibration displacements were carried out with the help of the "MATCAD" program, adding the introduced internal force factors to the initial diagram. The statistical indeterminateness of the changed structure was found. The determination of shifts in the bars was carried out by the initial parameters method, taking into consideration, that the bars have the same section. The obtained values approximation was carried out with the help of the "MAPLE" program.

The values obtained were decomposed into the first, second, and third degree polynomials, and the function with the least error was taken. Secondary members of rigidity of the frame structure have different effects on the vibration displacement of the frame structure. Examine the impact of changes in the value of l2 vibration characteristics for horizontal stiffener (see Fig. 5).

We will investigate the influence of the l_2 value change on the vibration characteristics. The dependence of the dynamic fac tor from the l_2 value is presented in the figure 7.

If a horizontal element is added, the dynamic factor decreases with the minimal value in the middle of the vertical pole's height. The dynamic factor's decrease, compared to the initial diagram, is 15%.

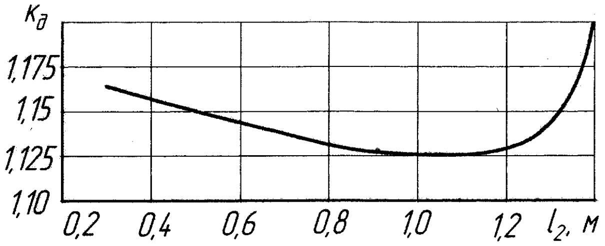

Figure 7. Relation of the *($k_д$)* dynamic factor from the l_2 value.

If a horizontal element is added, the dynamic factor decreases with the minimal value in the middle of the vertical pole's height. The dynamic factor's decrease, compared to the initial diagram, is 15%.

At change of the size l2 there is a change of magnitude of the maximum vibration displacement of the top horizontal beam in the vertical direction. It is expressed by the relation, presented in the Fig. 8 (curve 2).

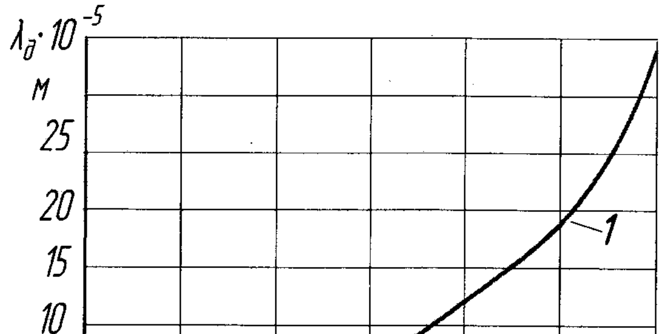

Figure 8. Relation of the vibration displacement *($\lambda_д$)* from the l_2 value: 1. For the right vertical pole in the horizontal direction 2. For the upper horizontal beam in the vertical direction.

The vibration displacement's decrease of the horizontal beam, compared to the initial diagram is 30%. For the operation of the machine with the presented structure diagram the most important issue is the vibration displacement of the vertical pole, on which the sieve frame's suspension brackets are fixed. This vibration displacement makes a considerable influence on the technological process. The influence of the l_2 value change on the vibration displacement of the right vertical pole in the horizontal direction is shown in the Fig. 8 (curve 1).

The additional horizontal stiffener increases the vertical shift of the vertical pole for 70%. Thus, installation of the given additional stiffening element is not efficient for the presented structure.

Let us change the initial diagram, placing an additional vertical stiffening element into it (see Fig. 5). Let us have a look at the influence of the given element on the vibration displacements of the same vertical and horizontal beams. The space location of the additional bar is determined by the l_1 variable quantity. In the Fig. 9 the relation of the dynamic factor from the l_1 value is presented. Placement of the additional vertical bar increases the construction's dynamic factor within a certain range. The maximal increase of the dynamic factor, compared to the initial diagram is 70%.

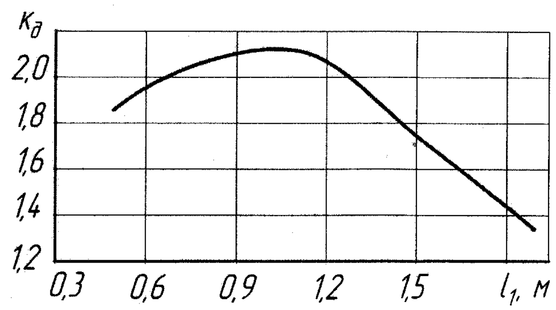

Figure 9. Relation of the dynamic factor *($k_∂$)* from the l_1 value.

The dependence of the maximal vibration displacement of the upper horizontal beam from the l_1 value is shown in the Fig. 10 (curve 2). The dependence of the vibration displacement of the vertical pole from the l_1 value is presented in the Fig 10 (curve 1).

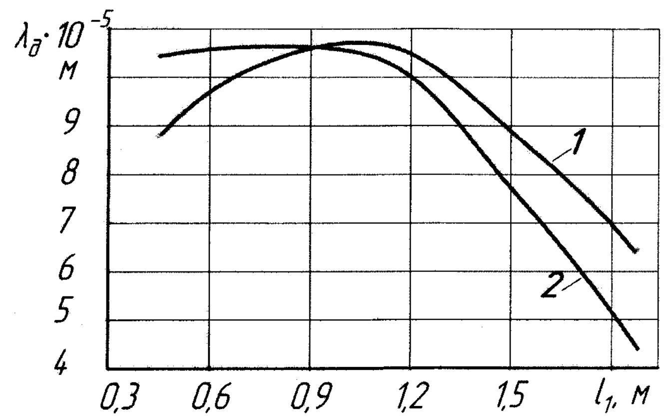

Figure 10. Relation of the vibration displacement *(λ_d)* from the l_1 value: 1. For the right vertical pole in the horizontal direction 2. For the upper horizontal beam in the vertical direction.

The maximal value of the horizontal beam's vibration displacement, if the location of the stiffening element is within the range of l_1= 0.6 – 1.2 m is 80% and the vertical beam – 44%.

The efficiency of application of any stiffening elements in statically undetermined frame structures should be identified by means of improving the structure in terms of a number of necessary parameters.

The introduction of additional inclined stiffener (see Fig. 5) causes a reduction of vibration displacement of horizontal beam by 11% and the vertical one by 89%. Thus, the given diagram proves to be the most efficient.

By the similar method we analyze the vibration displacements of the frame structure members with various methods of connecting the elements between each other (for example, in case of a joined connection). In this case, disclosing the static indeterminateness of the construction, it is necessary to make the corresponding internal force factors to be equal to zero.

4. Conclusion.

As a result of the conducted research, there is established the influence of capacity of the concentrated masses and a place of their location on the coefficient of dynamism of a frame bearing structure of the vibrating separating machines. There are obtained dependences describing influence on vibration displacements of a frame structure of various elements of rigidity. The results of the research are recommended to be used at design of bearing structures of vibrating separating machines for decrease of adverse vibrations.

Further researches in the field should be directed on studying of the influence of vibration displacement of the basis on which the separating machine is installed. Accountability of all the presented factors enables one to provide a more qualitative description of a process of moving of a separated component on a perforated separating surface and to estimate a possible technological separation effect more precisely.

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