The dynamic factor determination of the vibration mechanism with asymmetric vibrations

M Gerasimov¹, N Vorobiov¹, M Romanovich¹*, E Amini²
¹BSTU named after V.G. Shukhov, 46 Kostyukova Street, Belgorod, 308012, Russian Federation
²K. N. Toosi University of Technology, Tehran, Iran

E-mail: bel31rm@yandex.ru

Abstract. A vibration mechanism with asymmetric vibrations is discussed in the article. The mechanism consists of two stages of vibration blocks with directional vibrations. The asymmetric vibrations nature is estimated by the driving force components magnitude acting in opposite directions. The article deals with the obtaining rational parameters issue of a vibration mechanism with asymmetric vibrations, using the vibration mechanism dynamic factor. The vibration mechanism dynamic factor is numerically equal to the driving force largest component magnitude ratio to the smallest acting in the opposite direction. The work solves the following problems:
- obtaining the vibration mechanism dynamic factor maximum value with asymmetric oscillations at the driving force largest component given value;
- the conditions determination for reaching its maximum by the dynamic coefficient;
- the conditions determination for obtaining the total driving force maximum value of the vibration mechanism with asymmetric vibrations, consisting of several stages of vibrators with directional vibrations.

Introduction
Vibration machines are widely used in construction production and road-building materials and works. The vibration machines efficiency used for specific purposes is determined by a combination of design and technological parameters of the vibration mechanism. These parameters include: magnitude, application point, direction and speed of change of direction of the driving force; imbalances gravity center displacement mass and radius; oscillation amplitude and frequency; type of oscillations – circular, directional or asymmetric. The technical and reference literature [1,2,3,4] sufficiently presents the results of studies relating to circular and directional oscillations. Methods of calculation and design of vibration mechanisms with circular and directional vibrations are developed. The research in the development field of vibration mechanisms with asymmetric oscillations is currently conducted quite intensively [5,6,7,8]. The problems of determining the rational number of stages for the use of asymmetric oscillations in specific conditions are of scientific interest [9,10]; what is the driving forces ratio for each stage? How to achieve the highest dynamism coefficient of the mechanism with asymmetric oscillations? Under the dynamic coefficient of the mechanism with asymmetric oscillations we understand the driving force largest component ratio to the smallest, directed in the opposite side relative to the largest component.
The solution of each task separately or in a complex makes it possible to provide not only the process computerization with use of asymmetric fluctuations, but also if necessary, its intellectualization.

The challenge is to achieve the vibration mechanism $K_d$ dynamic coefficient maximum value at a given immersion force $Y_{ra}$ by combining several pairs of vibrators with directional vibrations and varying their parameters.

The main part

We consider the vibration mechanism consisting of the unbalanced vibrators $n$ pairs (Figure 1).

![Figure 1. The vibration mechanism scheme consisting of $n$ pairs of unbalanced vibrators, each pair of which forms a vibration unit, a stage that generates directional vibrations](image)

On the figure $\varphi_k$ – defines an angle deviation of the $k$-th imbalance from the horizontal one. Further the following notation is used for $k$-th vibrator: $m_k$ – imbalance mass, $R_k$ – radius of the guide circle, $\varphi_{k0}$ – the imbalance (the initial phase) deviation initial angle; $\omega_k$ – angular velocity of the imbalance rotation.

We introduce the inertia forces $R_k^i$ applied to the imbalances and the reaction components of the support $X_r$ and $Y_r$. The total horizontal mechanism support reaction component, due to the mirror arrangement of the vibrators, is equal to zero. Neglecting the weight of the guide circles and imbalances, due to their smallness in comparison with the inertia forces (at sufficiently large values of angular velocities $\omega_k$), based on the d’Alembert principle [11,12] we obtain the following equilibrium equation in the projection on the $O_y$ axis [2]:

$$Y_r + 2 \sum_{k=1}^{n} R_k^i \sin \varphi_k = 0,$$

where

$$R_k^i = m_k R_k \omega_k^2, \quad \varphi_k = \omega_k t + \varphi_{k0}.$$
Thus, the support reaction vertical component value can be calculated by the formula:

\[ Y_r = -2 \sum_{k=1}^{n} R_k \sin \varphi_k \]

(3)

or

\[ Y_r = \sum_{k=1}^{n} \left( -2m_k R_k \omega_k^2 \right) \sin(\omega_k t + \varphi_{k0}) \]

(4)

Considering further only the rotation angular velocity vibrators pairs of the imbalances which are related by:

\[ \omega_k = k \omega_1 \]

(5)

where \( \omega_1 \) – is the imbalances first stage pair rotation angular velocity, the formula (4) is written in the following form:

\[ Y_r = \sum_{k=1}^{n} a_k \sin(k \varphi + \varphi_{k0}) \]

(6)

Where:

\[ \varphi = \omega_1 t \]

(7)

and the \( a_k \) parameters can take any values (by selecting the values of the radiiuses of the guide circles \( R_k \) and the masses of the imbalances \( m_k \)).

The minimum value of the \( Y_r \), as a function of the angle \( \varphi \), denote it \( Y_{ri} \), is the immersion dynamic force. The maximum value \( Y_r \) integer \( Y_{ra} \), is power lifting. The ratio of these forces:

\[ K_d = -\frac{Y_{ri}}{Y_{ra}} \]

(8)

is called the vibration mechanism dynamism coefficient (the “minus” sign in the formula (8) is introduced since the \( Y_{ri} \) value is negative).

The problem is that by combining several pairs of planetary vibrators and varying their parameters to achieve the vibration mechanism \( K_d \) dynamism coefficient maximum value at a given force of immersion \( Y_{ra} \), which will be denoted by \( A \).

Solving the problem for five pairs of vibrators, we can get the total amount of reaction supports.

The vibrators all five pairs supports’ reactions sum is shown in the Figure 2. The immersion force in this case is equal to 5, the lifting force is equal to 1.67, and the dynamism coefficient is equal to 2.99.
Solving the components ratio problem of the driving force from the two subsequent stages of the vibrators, the dependence of the total immersion force is obtained:

\[ a_1' = \frac{2}{3} A, \quad a_2 = \frac{1}{3} A \]  \hspace{1cm} (9)

where \( a_1 \) and \( a_2 \) are the plunging force from the first and second stages.

The change in the magnitude of the total driving force \( Y_r(\varphi) \) is presented in Figure 3.

**Summary**

The dynamic factor \( K_{ad} \) magnitude of the vibration mechanisms with asymmetric oscillations is determined by the initial phases’ values of the imbalances \( \varphi_{k0} \) and the generalized characteristics of the imbalances \( a_k \) determined by the formula

\[ a_k = 2m_k R_k \omega_k^2. \]  \hspace{1cm} (10)
For vibration mechanisms with asymmetric vibrations with any number of vibrator stages, the maximum dynamic factor has been proved to achieve the initial phases of stages vibrators satisfying the relation:

\[ \varphi_{k0} = \frac{\pi}{2} (k - 1) \]  \hspace{1cm} (11)

For the two-stage vibrators it is theoretically proved and confirmed by numerical calculations that the maximum possible dynamic factor \( K_d \) is equal to two and is achieved with the values of generalized characteristics of imbalances satisfying the conditions:

\[ a_1 = \frac{2}{3} A, \ a_2 = \frac{1}{3} A \]  \hspace{1cm} (12)

References

[1] Blekhman I I, Dzhanilidze G Yu 1964 Vibrational motion (Nauka, Moscow).
[2] Bauman V A 1970 Vibration machines in the construction and production of construction materials (Mashinostroenie, Moscow).
[3] Maslov A G, Ponomar V M 1985 Vibrating machines and processes in road building (Budivelnik, Kiev).
[4] Brooks R, Kwing-So Choi, Giddings D, Howe A, Hyde T, Jones A, Williams E An Introduction to Mechanical Engineering. University of Nottingham 2 480.
[5] Gerasimov M D, Glagolev S N, Gerasimov D M, Mkrtcheyev O V 2015 Determination of the driving force's asymmetry factor and the vibrostand's work's analysis (International journal of applied engineering research) ISSN 0973-4562. 10 (24) 45392-45398.
[6] Gerasimov M D, Mkrtcheyev O V, Glagolev S N, Gerasimov D M, Latyishev S S 2016 Method of determination of vibrating screens oscillation's amplitude in a characteristic point for plane motion (ARPN Journal of Engineering and Applied Sciences) 11 (20) 12295-12301.
[7] Gerasimov M D, Mkrtcheyev O V, Sevostyanov V S, Stepanischev V A 2014 Calculation of main kinematic characteristics of the single-shaft vibrator with aimed fluctuations (Research journal of applied sciences) 9 855-861.
[8] Bashkarev A Ya, Musiiko D V, Peshkov V S 2013 Oscillatory motion of the plate compactor (Scientific and technical statements SPbGPU) 1 (166) 175-178. (In Russian).
[9] Gerasimov M D 2016 The addition of oscillations in vibration exciters (Bulletin of BSTU named after V.G. Shukhov) 3 116-120.
[10] U.S. Patent 7,804,211. B2 (2010).
[11] Korn G, Korn T 2003 Handbook of Mathematics (for scientists and engineers) (Definitions, theorems, formulas, Lan, Saint-Petersburg).
[12] Targ S M 2002 A short course of theoretical mechanics (studies. for colleges, Higher School, Moscow).

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