The influence of the ratio of the vibration device’s two stages’ imbalances’ static moments with asymmetric oscillations on the system amplification factor

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Abstract. Vibration devices with asymmetric oscillations can consist of two or more stages of vibrators with directed vibrations. Component stages of a vibration device with asymmetric oscillations have multiple frequencies of rotation of the imbalanced shafts. The multiplicity of rotation frequencies of the imbalanced shafts of the vibrator’s stages with directed vibrators in a vibration device with asymmetric oscillations is imperative. In this case, the parameters of the total asymmetric oscillation depend entirely on the ratio of the static moments of the imbalances of the stages included in the vibratory device. The simplest vibration device with asymmetric oscillations is a device consisting of two stages of vibrators with directed vibrations. The article is devoted to the question of the influence of the ratio of the vibration device’s two stages’ imbalances’ static moments with asymmetric oscillations on the system amplification factor.

1. Introduction

A vibration device with asymmetric oscillations, formed on the basis of two or more successively installed imbalance vibrators with directed vibrations [1,2,3,4], as a rule, has a multiple value of the rotation frequency of the imbalance shafts of individual stages’ vibrators:

$$\omega_1; \omega_2; \omega_3; \ldots; \omega_n = 1: 2: 3: \ldots: n.$$

where \(\omega_1, \omega_2, \omega_3, \ldots, \omega_n\) – the angular velocity of the successively installed imbalance shafts of a vibration device with asymmetric oscillations, consisting of \(n\) stages [c⁻¹].

A vibration device with asymmetric oscillations generates driving force \(F\), where the components magnitudes \(F_p\) and \(F_x\) act in opposite directions and obey the relation [5,6,7,8]:

$$F_p = k_d \cdot F_x$$

where \(F_p\) - component of the driving force acting in the direction of useful work;
\(F_x\) - component of the driving force acting in the direction of the idle;
$k_d$ - the amplification factor of the vibration system, which characterizes the ratio of the components of the driving force acting in opposite directions: in the direction of useful work and in the direction of idle, respectively.

Let’s set the values of the static moments of the first and second stages imbalances as $(M_1=m_1r_1)$ and $(M_2=m_2r_2)$, respectively. The ratio $F_p/F_x$, and the value of the amplification factor $k_d$ will depend on the ratio $(m_1r_1)/(m_2r_2)$. Let’s set the value of each stage imbalance’s the center of gravity offset as equal to one, $r_1=r_2=1$. Then we have an opportunity to obtain the dependence of the change in the amplification factor of a vibration system with asymmetric oscillations on the ratio of the static moments of the first and second stage imbalances, by changing only the mass ratio $(m_1/m_2)$ of the first and second stage imbalances:

$$k_d = f\left(\frac{M_1}{M_2}\right)$$ (3)

where $M_1=m_1r_1$ - static moments of imbalance of the first stage of the vibration device with asymmetric oscillations;

$M_2=m_2r_2$ - static moments of imbalance of the second stage of the vibration device with asymmetric oscillations.

2. Methods

We developed a program for addition of the harmonic oscillations, which is being used to study the influence of the static moments ratio of the vibration device’s two stages’ imbalances with asymmetric oscillations on the system amplification factor [9,10,11].

3. The main part

The output parameters of the total asymmetric oscillation are controlled by the frequency of the forced oscillations, the mass and the radius of the center of gravity offset of the imbalances. An example of sampling the initial parameters are given in Table 1.

| Adopted Initial Parameters | Examples of initial parameters sample $(m_1:m_2)$ |
|----------------------------|--------------------------------------------------|
| № of vibrator              | 6:1, 7,175:1, 10:1                                |
| Mass (kg)                  | 6, 1, 7.175                                      |
| Radius(cm)                 | 1, 1, 1                                         |
| Initial phase (degrees)    | 0, 0, 0                                         |
| Speed (turn/min)           | 500, 1000, 500, 1000                             |
| R (m)                      | 0.01, 0.01, 0.01                                |
| $\varphi_0$ (rad)          | 0.00, 0.00, 0.00                                |
| $\omega$ (1/sec)           | 52.36, 104.72, 52.36, 104.72                     |

As a result of the calculation, for each adopted mass ratio of imbalances $(m_1:m_2)$, we plot the change in the driving force of each stage and the total driving force of asymmetric oscillations. Figure 1 shows the result for the ratio of the masses of the imbalances of the first and second stages $(m_1:m_2)$ equal to (6: 1).
Figure 1. The change in the value of the driving force within the period of 0.12 sec.

The calculation clearly shows that the minimum value of the amplification factor $k_0$ is present at any ratio of the masses of the imbalances of the first and second stages. However, for each ratio of the masses of the first and second stage vibrators, the minimum value of the amplification factor is reached at a certain moment of the oscillation period. This dependence can be represented by the equation or graphically (Figure 2).
Figure 2. The change in the minimum value of the system amplification factor (y) with asymmetric oscillations from the mass ratio of the imbalances \( m_1 : m_2 \) of first and second stages (x).

The equation will be:

\[
k_d = -9E - 05x^4 + 0.0049x^3 - 0.0965x^2 + 0.7781x - 0.1611
\]

where \( x \) – mass ratio of first and second stage imbalances, \( m_1 : m_2 \).

Similarly, we can get the equation for the dependence of the average value of the amplification factor on the value of the mass ratio of the imbalances \( m_1 : m_2 \) of first and second stage.

\[
k_{d,cp} = 0.001 \cdot x^4 - 0.057 \cdot x^3 + 1.004 \cdot x^2 - 7.525 \cdot x + 23.05
\]

Thus, we got the equations describing the influence of the ratio of the vibration device’s two stages’ imbalances’ static moments with asymmetric oscillations on the system amplification factor.

4. Conclusion

The obtained equations (4) and (5) can be used in the design of a vibration device with asymmetric oscillations, consisting of two stages of imbalanced vibrators with directed vibrations. With a given mass ratio of imbalance vibrators of the first and second stages, we can determine the project value of the amplification factor. Conversely, given the value of the amplification factor of a vibration system with asymmetric oscillations, it is possible to determine the rational mass ratio of the first and second stage imbalances.

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