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Abstract

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MECHANICS

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EXPERIMENTAL STUDIES OF THE EFFECT OF VIBRATION ON RESISTANCE TO TRANSPORTATION

In many machines, vibration is used as a means of reducing resistance to transportation. On hoppers and chutes, vibratory exciters are installed to prevent hang-ups and to ensure uniform discharge. In loading machines, oscillations are imparted to the working member to facilitate its penetration into a pile and to reduce the forces during loading. Combined means of transport are being developed in which oscillations are imparted to the load-carrying member only in order to reduce resistance to transportation, while motion is produced by other means (for example, gravity transport along vibrating troughs and vibro-pneumatic transport, based on combining the vibrational and pneumatic principles of transportation).

To investigate resistances to transportation under the action of vibration, an experimental stand and measuring apparatus were developed. The stand is a vibrating table with an eccentric drive, producing vertical oscillations. The amplitude and frequency of oscillations of the vibrating table can be adjusted within the ranges 0–25 mm and 0–1500 oscillations/min. The displacement of individual test specimens is carried out in a tube, fixed to the moving part of the vibrating table, by the dynamic pressure of an air jet. Bulk loads are moved over a vibrating surface in a frame by a special traction mechanism, i.e., by a mechanical method. In both cases the velocity of displacement can be varied over wide limits. In studying the displacement of an individual load, in addition to the vibration parameters, the velocity and acceleration of its motion are recorded by means of an optical system with photoresistances, as well as the dynamic and static pressure of the air jet. The coefficient of resistance to transportation is then determined, on the basis of the formula for the coefficient of resistance to transportation,

$$w = \frac{F}{G} - \frac{a}{g},$$

Fig. 1. Dependence of the ratio of the coefficients of resistance w_v/w on the oscillation frequency n

Figure 1: Fig. 1. Dependence of the ratio of the coefficients of resistance w_v/w on the oscillation frequency n

from the expression

$$w \ = \frac{(v - v\ )^2}{v^2} - \frac{a}{g},$$

where F is the tractive force; G is the weight of the specimen; v and v are the velocities of motion of the air and of the load; v is the hovering velocity of the test load specimen, and a and g are the acceleration of the load and the acceleration due to gravity.

In studying bulk loads, the resistances to transportation are recorded directly by means of a strain-gauge dynamometer.

Experimental studies of the interaction of vibration and resistance to transportation of bulk loads (crushed stone of 20–30 mm size) were carried out at oscillation amplitudes A of 2.0, 2.5, and 4.5 mm and frequency n

300; 350; 400; 450; 500; 550; 600; 650; 700; 750; 800; 850, and 900 oscillations/min. In this case the magnitude of the accelerations of the vibratory motion of the vibration stand ranges from 2 to 22 m/sec^2.

The dependence of the ratio w_v/w of the coefficient of resistance to transportation under vibration w_v to the coefficient of resistance to transportation without vibration w on the oscillation frequency for various oscillation amplitudes is shown in Fig. 1. Analyzing the graph of the dependence $w_v/w = f(n)$ at $A =$ const, we see that in a certain frequency range (in this graph, 200–400 oscillations/min) vibrations do not affect the magnitude of the resistance to transportation. This frequency range decreases as the oscillation amplitude increases. Thus, for example, if at an oscillation amplitude of 2.0 mm it is 0–400 oscillations/min, then at an amplitude of 4.5 mm it does not exceed 200 oscillations/min. With a further increase in the oscillation frequency, the resistance to transportation begins to decrease sharply. This decrease, for all values of the oscillation amplitude, is approximately linear in character. After a certain oscillation frequency is reached (at $A = 4.5$ mm –500 oscillations/min; at $A = 2.5$ mm –700 oscillations/min; at $A = 2.0$ mm –800 oscillations/min), a break occurs in the curves, and with further increase in oscillation frequency they decrease less intensively.

Fig. 1. Dependence of the ratio of the coefficients of resistance w_v/w on the oscillation frequency n

At a frequency of 900 oscillations/min, the resistances to transportation under

Fig. 2. Dependence of the ratio of the coefficients of resistance w_{v}/w on the oscillation acceleration $A(2\pi n)^2$

Figure 2: Fig. 2. Dependence of the ratio of the coefficients of resistance w_{v}/w on the oscillation acceleration $A(2\pi n)^2$

the action of vibration do not exceed 1-5% of the resistances to transportation in the absence of vibration.

It also follows from the graph that at high oscillation frequencies (900-1000 oscillations/min) the magnitude of the resistances to transportation depends very little on the oscillation amplitude.

Fig. 2. Dependence of the ratio of the coefficients of resistance w_{v}/w on the oscillation acceleration $A(2\pi n)^2$

Thus, with the aid of the graph in Fig. 1, it is possible to determine rational oscillation frequencies and amplitudes that ensure an effective reduction in the resistances to transportation. At amplitudes of 4.5-2.0 mm it is advisable to limit oneself to frequencies of 500-800 oscillations/min, and only when it is necessary to obtain very low resistances to transportation should frequencies of 900-1000 oscillations/min be used.

Theoretical investigations show that the principal generalized parameter affecting the magnitude of the resistances to transportation under the action of vibration is the oscillation acceleration. To verify this proposition, the same experimental data are presented in the graph of Fig. 2 in the coordinates $\frac{w_{\mathrm{v}}}{w}, A(2\pi n)^2$. Examination of the graph shows that the experimental points corresponding to various amplitudes and oscillation frequencies lie in a very narrow region, which can be replaced by a smooth curve. Thus, the experimental data fully con—

confirm the theoretical proposition that the acceleration of oscillations is the principal parameter determining the character of the action of vertical vibrations on bulk loads. Analyzing the experimental curve, we see that oscillations with an acceleration of 0.3 m/sec^2 have practically no effect on the magnitude of the resistance to transportation. In the range 3.0—12.0 m/sec^2, the resistance to transportation decreases in direct proportion to the magnitude of the oscillation acceleration, reaching, at $a = 12.0$ m/sec^2, 10% of the value of the resistance in the absence of vibration. With a further increase in the oscillation acceleration up to 24 m/sec^2, the resistance to transportation decreases less intensively, reaching 1—2% of the value of the resistance to transportation in the absence of vibration.

Fig. 3. Dependence of the coefficient of resistance to transportation w_{v} on the acceleration of oscillations $A(2\pi n)^2$. 1 —without allowing for energy expenditures in the vibration system; 2 —resonant vibration system; 3 —beyond-resonance vibration system.

It also follows from the graph that vibration has an effect on reducing the resis-

Fig. 3. Dependence of the coefficient of resistance to transportation w_{v} on the acceleration of oscillations $A(2\pi n)^2$. 1 —without allowing for energy expenditures in the vibration system; 2 —resonant vibration system; 3 —beyond-resonance vibration system.

Figure 3: Fig. 3. Dependence of the coefficient of resistance to transportation w_{v} on the acceleration of oscillations $A(2\pi n)^2$. 1 —without allowing for energy expenditures in the vibration system; 2 —resonant vibration system; 3 —beyond-resonance vibration system.

tance to transportation at smaller oscillation accelerations than is theoretically determined for the case of vibration of a single particle ($a_{\mathrm{min}} = g$). This can be explained by the fact that, when vibration acts on bulk loads, the qualitative picture of the process differs from the regularities that occur in the interaction of a single particle with a vibrating surface.

Thus, the graph in Fig. 2 makes it possible to establish the necessary oscillation accelerations in accordance with a specified degree of reduction of the resistance to transportation.

The dependence of the coefficient of resistance to transportation over a vibrating surface on the oscillation acceleration, taking into account the energy expenditures for producing oscillatory motion by resonant and beyond-resonance vibration systems, is given in Fig. 3.

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