SPECIFYING THE METHODOLOGY FOR THE CALCULATION OF VIBRATORY FEEDERS

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ABSTRACT. A methodology for the calculation of vibratory feeders is developed. The frequency of the vibrations, the dimensions of the discharge section of the bin, the length of the feeder's chute, the width and the height of the feeder's chute, the material velocity, and the amplitude of the vibrations are determined. Motor-vibrators are chosen for feeder's drive. On the basis of the developed methodology a concrete example is solved.
The developed methodology may be useful for the students, and also for the specialists, working in the mining and processing industry.

Keywords: chute, vibration, frequency, amplitude, motor-vibrator

УТОЧНЯВАНЕ НА МЕТОДИКАТА ЗА ИЗЧИСЛЯВАНЕ НА ВИБРАЦИОННИ ЗАХРАНВАЧИ

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РЕЗЮМЕ. Разработена е методика за изчисляване на вибрационни захранвачи. Определят се честотата на трептенията, размерите на разтоварната част на бункера и дължината на улея на захранвача, ширината и височината на улея на захранвача, скоростта на транспортиране на материала и амплитудата на трептенията. Избират се мотор-вибратори за задвижване на захранвача. На базата на разработената методика е решен конкретен пример.
Разработената методика може да се използва както от студентите, така и от специалистите, които работят в миннодобивната и преработвателната промишленост.

Ключови думи: улей, трептене, честота, амплитуда, мотор-вибратор

Introduction

The vibratory feeder (fig.1) is an inclined chute, hanged on springs under the unloading outlet of the bin. The chute is carried out in reciprocating motion with the help of a vibrator. The material loaded in the chute accomplishes infinitely following one after another short movements forward with a definite velocity. The particles of the material move away from the bottom of the chute and move with micro jumps.

The vibratory feeders are driven by an electromechanical or electromagnetic vibrator, situated under the bottom of the chute, or by two synchronized motor-vibrators, attached to the both sides of the chute (Fig.1). In order to ensure the movement of the material in a definite direction the vibrators are mounted in such a way, so that the line of action of the excitation force is directed at a definite acute angle *α* toward the longitudinal axis of the chute.

The vibratory feeders are used for unloading the bins and uniformly feeding the material to crushers and belt conveyors (of dry, both fine and coarse materials); in the loading points of the open pit mines, the concentration and floatation plants - for feeding rock, ore and coal to the crushers and from the crushers to the belt conveyors; in the concrete stations - for feeding sand and gravel to the belt conveyors; in cement plants - for feeding limestone to the belt conveyors; in power stations - for feeding gypsum and slag to the crushers.

The advantages of the vibratory feeders are the simple and light construction, the small energy consumption and the small wearing out of the chute. The disadvantages are difficult transportation of wet, stick and dust materials and the transfer of the vibratory loads to the supporting structure.

Since the vibratory feeders are vibratory conveyors with small length, the methodologies for the calculation of the vibratory conveyors are used for their calculation. But the calculation of the vibratory feeders has some peculiarities.

The methodologies for the calculation of the vibratory conveyors are given in the literature, referring the mining transport and the transport machines with continuous action. However, a methodology for the calculation of vibratory feeders is not given. In some company manuals are given recommendations for the dimensioning and choice of some elements of the vibratory feeders.

In Jost vibratory feeders and Syntron heavy industry feeders are given the technical characteristics of the vibratory feeders, designed for tough work conditions in the mining and processing industry, schemes for determination of the dimensions of the unloading section of the bins and guides for the choice of the velocity of transportation.

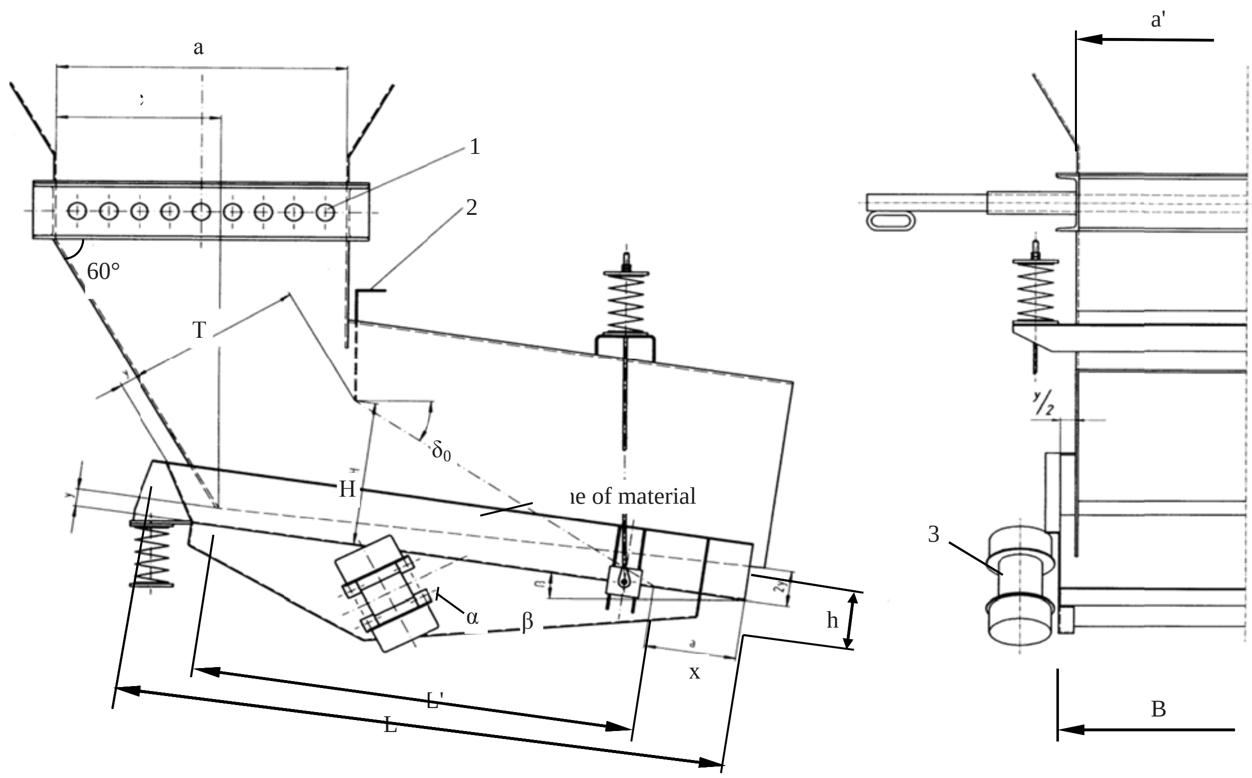

Fig.1. Scheme for the calculation of the vibratory feeder

L - length of the chute; *B* - width of the chute; *h* - height of the chute; *a*, *a'* - lengths of the sides of the bin's outlet; *H* - height of the outlet of the transitional section of the bin; *T* - height of the outlet of the transitional section of the bin; δ_0 - angle of repose of the material; *β* - angle of inclination of the feeder; *α* - angle between the line of action of the excitation force and the longitudinal axis of the chute; *x* - distance between the front end of the chute and the material; *y* - distance between the back wall of the chute and the bottom of the chute

1 - shutter for opening and closing the bin; 2 - shutter for regulating the thickness of the layer of the material; 3 - motor-vibrator

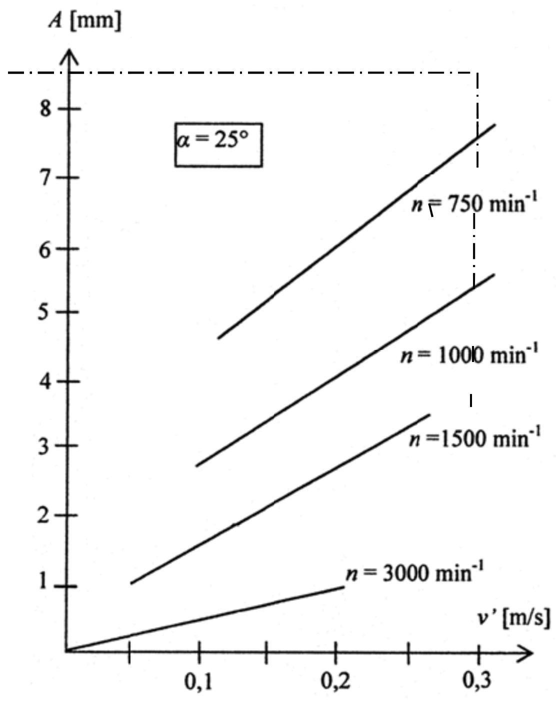

Fig. 2. Graphs for determination of the amplitude of the vibrations of the vibratory feeders

A - amplitude of the vibrations;
v' - velocity of material;
n - frequency of the vibrations;
α - angle between the line of action of the excitation force and the longitudinal axis of the chute

In Italvibras are given the technical characteristics of motor-vibrators and a methodology for their choice.

In Spivakovskii (1983) is given the theory of determination of the working regime (subresonant and overresonant) of the vibratory conveyors and a methodology for their calculation.

The aim of the present work is, on the basis of these references, a complete methodology for the calculation of vibratory feeders to be developed. A concrete example for a vibratory feeder with two motor-vibrators is solved.

Input data

The input data for the feeder's calculation is:
- Kind of the transporting material - crushed bauxite, sized;
- Density of the material ρ = 1.3 t/m^3;
- Angle of repose of the material δ_0 = 30°;
- Maximum size of the materials particles a_{max} = 75mm;
- Angle of inclination of the feeder β = -8° (β = -5 ÷ -10°);
- Necessary output *of the feeder* Q' = 650 t/h;
- Bin's outlet dimensions $a = a'$ = 950mm = 0.95m.

Frequency of the vibrations

The frequency of the vibrations n is chosen from Table 1 according to the size of the material.

Table 1.
Recommended frequency of the vibrations of the vibratory feeders (Syntron heavy-industry feeders)

Maximum size of the particles of the material a_{max} [mm]	< 10	10 - 100	> 100
Frequency of the vibrations n [min^{-1}]	1500; 3000	1000; 1500	750; 1000

Length of the chute of the feeder

The length of the chute L is determined graphically by the scheme, showed in Fig.1, according to the angle of repose δ_0 and the height of the outlet H of the transitional section of the bin. The height H is dependent on the size of the bin's outlet a. The drawing is done in the following sequence (according to Jost and Syntron):
- The size c=(0.3÷0.6).a=0.56.950=530mm is determined and a vertical line is passed on the distance c from the beginning of the bin's outlet;
- An inclined line is produced at an angle 60° toward the horizontal line to the intersection with the vertical line. An intercept is obtained, which refers to the bin's back wall;
- A vertical intercept is produced from the end point of the bin's outlet to a point, which is at a distance T from the bin's back wall, where T=560mm ≥ 4.a_{max}=4.75=300mm for sized material and T≥ 2.a_{max} for unsized material;
- From the end point of the vertical intercept an inclined line is produced at an angle δ_0=30°. This line determines the position of the material;
- An inclined line is produced, which is at an angle β=8° to the horizontal line, and is at a distance y from the point, corresponding to the end of the bin's back wall. This line corresponds to the bottom of the chute. The minimum distance y is recommended to be chosen (Jost vibratory feeders): y_{min}=30mm при n=3000min^{-1}; y_{min}=40mm при n=1500min^{-1}; y_{min}=60mm при n=1000min^{-1}; y_{min}=80mm при n = 750min^{-1}. For the calculated example it is accepted that $y=y_{min}$=60mm;
- The minimum length of the chute is determined $L_{min}=L'+x$=1440+300=1740mm=1.74m, where L' is the distance between the intersection point of the line of the bottom of the chute and the line of material and the point, corresponding to the end of the bin's back wall. The distance L' is obtained graphically according to the scheme on Fig.1. The distance x is accepted to be x=300mm ≥ 150mm;
- A check is made T/H=560/490 = 1.14 = 0.7÷1.25. The height of the outlet H = 490mm is obtained according to the scheme on Fig. 1. A standard length of the chute is accepted from Table 2 L = 2m > L_{min} = 1.74m.

Table 2.
Chute's dimensions and mass of the vibratory feeders (Jost vibratory feeders)

With two electromechanical motor-vibrators (L = 1÷2.5m)

B [m]	0.4	0.5	0.6	0.8
h [m]	0.15	0.15	0.2	0.2
L [m]	1; 1.5; 2	1; 1.5; 2	1; 1.5; 2	1; 1.5; 2
m [kg]	155; 190; 250	165; 205; 280	180; 250; 300	650; 760; 1140
B [m]	1	1.2	1.4	1.6
h [m]	0.2	0.2	0.2	0.2
L [m]	1; 2; 2.5	1.5; 2; 2.5	1.5; 2; 2.5	2; 2.5
m [kg]	730; 1010; 1150	810; 1130; 1380	1340; 1750; 1960	1730; 1920; 2350

With two electromechanical motor-vibrators (L = 3÷6m)

B [m]	0.4	0.5	0.6	0.8
h [m]	0.25	0.25	0.25	0.25
L [m]	3; 4; 5; 6	3; 4; 5; 6	3; 4; 5; 6	3; 4; 5; 6
m [kg]	365; 525; 750; 855	470; 635; 800; 890	505; 680; 855; 1090	650; 770; 1090; 1245

B [m]	1	1.2	1.4
h [m]	0.25	0.25	0.25
L [m]	3; 4; 5; 6	3; 4; 5; 6	3; 4; 5; 6
m [kg]	725; 1040; 1235; 1390	800; 1150; 1365; 1810	1140; 1590; 1890; 2400

With an electromagnetic vibrator (L = 0.75÷2.5m)

B [m]	0.2	0.4	0.6
h [m]	0.2	0.2	0.2
L [m]	0.75; 1; 1.25; 1.5	1; 1.25; 1.5; 1.75	1.25; 1.5; 1.75; 2
m [kg]	82; 110; 115; 125	125; 185; 195; 205	210; 300; 315; 330
B [m]	0.8	1	1.2
h [m]	0.25	0.25	0.25
L [m]	1.5; 1.75; 2; 2.25	1.5; 2; 2.25; 2.5	1.5; 2; 2.25; 2.5
m [kg]	355; 395; 420; 670	390; 675; 710; 735	660; 775; 1440; 1490

B - width of the chute; h - height of the chute; L - length of the chute; m - mass of the feeder including the mass of the vibrator.

Width and height of the chute of the feeder

The width of the chute B=1.2m and the height of the chute h = 0.2m are chosen from Table 2. The following conditions must be satisfied:

$$B = 1200 \text{ mm} \geq a' + y = 950 + 60 = 1110 \text{ mm} \quad (1)$$

$$Q = 3600.v.\rho.\psi.k_\beta.B.h \geq Q' \text{, t/h} \quad (2)$$

$$Q = 3600.0,23.1,3.2.1,3.1,2.0,2 = 670 \text{ t/h} > Q' = 650 \text{ t/h} ,$$

where: v [m/s] - velocity of transportation of the material for a horizontal chute (it is chosen from Table 3; when a_{max} = 75mm and a drive with two motor-vibrators it is accepted v=0.23m/s);
ψ - chute filling coefficient (ψ=2; it is assumed, that the height of the material's layer is two times greater than the height of the chute);
k_β - coefficient, which refers to the increasing of the transportation velocity with the increasing of the inclination of the chute (it is accepted from Table 4; (Spivakovskii, 1983) when β = -8° k_β = 1.3).

Table 3.
Recommended velocities for transportation of the material on a horizontal chute v [m/s] for the vibratory feeders (Syntron heavy-industry feeders)

Maximum size of the pieces of the material a_{max} [mm]	< 10	10 - 100	> 100
For an electromagnetic vibrator	0.15	0.13	0.11
For an electromechanical vibrator or two electromechanical motor-vibrators	0.25	0.23	0.19

Table 4.
Coefficient, which refers to the increase of the output of the feeder with the increase of the angle of inclination (Spivakovskii)

β [°]	0	- 5	- 8	- 10	- 12
k_β	1	1.2	1.3	1.4	1.5

Amplitude of vibrations

The amplitude of vibrations A [mm] is determined from the graphs shown on Fig.2 depending on the frequency of the vibrations n [min^{-1}] and the velocity of transportation $v' = v.k_\beta = 0,23.1,3 = 0,3$m/s. When n = 1000min^{-1} and v' = 0.3m/s A = 5.5mm.

The graphs are drawn at an angle between the line of action of the excitation force and the longitudinal axis of the feeder α = 25°. It is recommended for bin feeders to take α = 25°, and for screens – α = 35 or 45° (Italvibras).

Choice of motor-vibrators

The motor-vibrators are chosen from Table 5 according to the frequency of vibrations n [min^{-1}] and the necessary kinetic moment $M'_к$ [kg.mm]:

$$M'_к = 0,5.m.A = 0,5.1130.5,5 = 3110 \text{ kg.mm}, \quad (3)$$

where: m [kg] - mass of the feeder (it is given in Table 2 for the chosen dimensions of the chute; when B = 1.2m, h = 0.2m and L = 2m the mass is m = 1130kg).

Motor-vibrators are chosen with the following parameters: frequency of the vibrations (synchronous frequency of rotation of the electric motor) n = 1000min^{-1}; kinetic moment $M_к$ = 5838kg.mm > $M'_к$ = 3110kg.mm; power of the electric motor $P_{дв}$ = 4.3kW.

Table 5.
Characteristics of the motor-vibrators (Italvibras)

n= 3000min^{-1}	$M_к$ [kg.mm]	153; 179; 205; 230; 344; 387; 515; 895
	$P_{дв}$ [kW]	1.4; 2; 2.2; 2.2; 4; 4; 5; 9.3
n= 1500min^{-1}	$M_к$ [kg.mm]	163; 219; 286; 415; 561; 715; 958; 962; 1507; 1526; 1990; 2598; 3260; 2246; 4544
	$P_{дв}$ [kW]	0.3; 0.3; 0.525; 0.55; 0.9; 1.1; 1.6; 1.6; 2.2; 2.2; 3.6; 6; 7; 7.5; 10
n =1000min^{-1}	$M_к$ [kg.mm]	163; 286; 457; 723; 1012; 1443; 1464; 2309; 2326; 3422; 2658; 5838; 6083; 7197; 7752; 8673; 10996; 12662; 15500; 20025
	$P_{дв}$ [kW]	0.18; 0.35; 0.35; 0.68; 0.75; 1.1; 1.1; 1.96; 1.96; 2.5; 3.8; 4.3; 5; 7; 7.5; 7.6; 9; 10.6; 13; 19
n = 750min^{-1}	$M_к$ [kg.mm]	163; 286; 458; 722; 1012; 1443; 1464; 2309; 2326; 3421; 4658; 5838; 7197; 12390; 13816; 17946; 21337; 28633
	$P_{дв}$ [kW]	0.23; 0.28; 0.35; 0.4; 0.4; 0.95; 0.95; 1.5; 1.5; 2; 2.8; 4; 3.9; 6.8; 7.6; 9.2; 10.4; 12.5

n - frequency of the vibrations (synchronous frequency of rotation of the electric motor); $M_к$ - kinetic moment; $P_{дв}$ - power of the electric motor.

Conclusions

In the present paper, a methodology for the calculation of vibratory feeders is developed, based on several references, which consider the vibratory conveyors and the vibratory feeders.

The developed methodology may be useful for the students, and also for the specialists, working in the mining and processing industry.

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