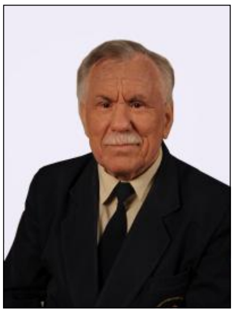
UDC 622.231
DOI: 10.21209/2227-9245-2017-23-8-19-24

TWO-MASSES RESONANT CLATTER WITH LINEAR CONTROLLED ENGINE

ДВУХМАССОВЫЙ РЕЗОНАНСНЫЙ ГРОХОТ С ЛИНЕЙНЫМ УПРАВЛЯЕМЫМ ДВИГАТЕЛЕМ




A. Afanasiev,
Ural State Mining University»,
Yekaterinburg
gmf.tm@ursmu.ru

V. Potapov,
Ural State Mining University»,
Yekaterinburg
gmf.tm@ursmu.ru

D. Suslov,
Ural State Mining University»,
Yekaterinburg
susdmitry@yandex.ru

A. Chirkova,
Ural State Mining University»,
Yekaterinburg
gmf.tm@ursmu.ru

А. И. Афанасьев,
Уральский государственный горный университет,
г. Екатеринбург

В. Я. Потапов,
Уральский государственный горный университет,
г. Екатеринбург

Д.Н. Суслов,
Уральский государственный горный университет,
г. Екатеринбург

А. А. Чиркова,
Уральский государственный горный университет,
г. Екатеринбург

Resonant vibration-transport machines originated in the USSR in the middle of the XX[th] century and were used in coal industry. The machines imported into Russia and some machines manufactured in Russia are implemented with equilibrated scheme. The domestic machines of PAV series are constructed with the vibration-isolated scheme, and their generator of vibration is rigidly connected to the box. The resonant frequency of oscillations of these machines is 50 Hz, and the maximal acceleration is significantly greater than g. These resonant machines, working with the amplitudes up to 2,2 mm, have the work mode's coefficient greater than one. The practice of operation of these machines shows their relatively low effectiveness when working with thin products. The common disadvantage of unequilibrated resonant VTM is relatively big load of elastic supports and a massive chassis. The common disadvantage of equilibrated resonant VTM is the presence of reactive mass or multiple operating parts of equal weight. One of the ways to reach this goal (to decrease the load of elastic supports) is to find the rational construction of VTM. It is possible to make by converting the traditional oscillating system into the system equivalent to dynamical decrementor of oscillations. This will allow significantly to decrease the mass of the machine and the load of elastic supports

Key words: *vibration-transport resonant machines; angular frequency and amplitude of oscillations; acceleration; weight; rigidity; supports; vibro-exciter; engine; resonant screen; machine operation*

Резонансные вибротранспортные машины появились в СССР в середине XX в. и были использованы в угольной промышленности. Машины импортного производства и часть отечественных машин выполнены по уравновешенной схеме. Отечественные машины серии ПЭВ выполнены по виброизолированной схеме, а вибровозбудитель жестко соединен с коробом. Резонансная частота колебаний у этих машин равна 50 Гц, а максимальное ускорение существенно больше g. Эти резонансные машины, работающие с амплитудой до 2,2 мм, имеют коэффициент режима работы больше единицы. Практика эксплуатации этих машин показывает их относительно низкую эффективность при грохочении тонких продуктов. Общим недостатком

неуравновешенных резонансных ВТМ является относительно большая нагруженность упругих элементов (опор) и наличие массивной рамы, а уравновешенных – наличие реактивной массы или нескольких рабочих органов с одинаковой массой. Одним из путей достижения этой цели является определение рациональной конструкции ВТМ. Это возможно сделать путем превращения традиционной колебательной системы в систему эквивалентную динамическому гасителю колебаний, что позволит существенно уменьшить массу машины и нагруженность упругих опор

Ключевые слова: *Вибротранспортые резонансные машины, угловая частота и амплитуда колебаний, ускорение, масса, жесткость опор, вибровозбудитель*

Resonant vibration-transport machines (VTM) – feeders, transporters, screeners originated in the USSR in the middle of the XXth century and were used in coal industry.

The VTMs of resonant type were applied in coal industry of Poland, Germany but today the resonant VTMs of type DN3 IQR are manufactured in USA. Resonant screeners are divided for one-mass, two-mass and multi-mass machines. With respect to the quantity of oscillating masses, resonant screeners are divided into classes: one-mass machines, two-masses machines and multi-masses machines. Oscillating masses boxes may all be placed parallel or sequentially relative to the chassis, but in most cases their oscillations occur with the phase shift of 180 degrees. It provides the minimal load of elastic elements and respectively, of the chassis and of base. Usually resonant screeners work with relatively big amplitudes and low frequencies [11; 14].

The vibration conveyors for ore manufacture-ВКВС are an exclusion because they work with the amplitude up to 0,75 mm and frequency 47 Hz [9].

The operating parts of conveyors like ВР-50 or ВУР-1 have a lower than ВКВС, frequency of oscillations 9…15 H z and by 4…10 times greater amplitude.

The table 1 contains basic parameters of resonant VTMs [14; 9; 10; 13; 6].

Table 1

Parameters of resonant VTMs

№	Type of VTM	Quantity of masses	Amplitude, A,мм	Frequency, osc/min	Power, kW	Max acceleration, m/c^2
1	EV	2	5...15	500...1000	5...8	39...51
2	DV	4	5...15	500...1000	5...8	39...51
3	EF	2	5...15	500...1000	6	39...51
4	RS	3	5...14	500...1000	6	36...51
5	RJ	2	5...14	500...1000	6	36...51
6	S	2	5...14	500...1000	6	36...51
7	RMS-2,25	2	5...14	500...1000	3,5...5	36...51
8	RMN-4,5	2	5...14	500...1000	5...9	36...51
9	GC	4	10...12	500...1000	6...8	51...72
10	VR-50	1	4	750	10	24
11	VR-100	1	7,5	550	2*14	25
12	VUR-80	2	4	930	10	38
13	VUR-80M	2	4	930	15	38
14	BKBC	2	0,65	2800	1,6	55
15	PEV-1...3	2	0,6	3000	1,0	60
16	PVG-1,0...2,6	2	0,75	3000	11	75
17	79-TS	1	0,8	3000	2,0	80
18	95-TS	1	0,9	3000	4,0	90
19	106-TS	2	0,75	3000	1,0	75
20	GRL62	2	10	500	13	27
21	GRL72	2	10	510...550	17	28...34

Machines (No. 1...9, imported into Russia), are implemented with equilibrated scheme. The generators of vibration of these VTM are implemented in the form of: eccentric mechanisms with rigid rod; crank-balance weight mechanisms with rigid elements. Their angle of vibration (α) is not greater than 15 deg., and their operating part is located horizontally. The coefficient of vibration-transport mode ($\Gamma = A\omega^2 \sin\alpha$) of these machines is greater than 1 (fast mode).

The parameters of domestic resonant VTM are listed in rows 10...21 of the table 1. One-mass machines BP-50, BP-100, 79-TC, 95-TC are implemented with unequilibrated scheme. Two-mass machines ВУР-80 and GRL-62 are implemented with equilibrated scheme. Equilibrating mass is equal to the mass of the box.

The common disadvantage of unequilibrated resonant VTM is relatively a bigger load of elastic elements (support) and presence of heavy chassis. The common disadvantage of equilibrated resonant VTM is the presence of reactive mass or multiple operating parts of equal mass.

Machines of series PEV (rows 15, 16) are implemented with vibration-isolated scheme, and the resonant generator of vibration is rigidly fixed at the box. The resonant frequency of oscillations of these machines is equal or multiple the frequency of power supply – 50Hz. All these machines have the coefficient of work mode G>1. The transporting and screening of rock mass occur with a throw, and for small classes it often decreases the effectiveness of screening [14].

Domestic VTM are equipped with the vibration-generators of various types: kinematic (eccentric), force (inertial) and mixed (electromagnetic and piston).

Inertial vibration-generators are applied in over-resonant VTM at frequencies greater than 15 Hz. At the relatively low frequencies (less than 10 Hz) inertial vibration-generators are not applied, because relatively big unbalances must be installed to get the necessary revolting force. In resonant VTM inertial vibration-generators cannot provide the stability of resonance when technological load is changing. Recently technical solutions [2; 3; 4; 5; 7] have appeared, that enable us to get relatively stable resonant mode. However these solutions complicate the design of vibration-generator and don't allow to stabilize the resonant mode quickly when technological load is changing.

Linear electro-magnetic engines are used in mining industry from the middle of 20 century. The main disadvantage of all electromagnetic linear engines is their relatively low efficiency and high frequency of revolting force.

In the process of dry screening the rock mass of fineness less than 0,5 mm, VTM have insufficient effectiveness of separation [8]. Plane (almost impassable) parts of rock mass fill these parathion surface and it decreases the performance and effectiveness of screening.

The high priority aim of improving the design of VTM is achievement of maximal productivity, reduction the mass of machine and respectively, its cost, and also decrease of the power consumption of the technological process. It enables us significantly increase the effectiveness of its work.

One of the ways to reach this aim is definition of the rational design of VTM. You can decrease the work load of support and mass of the machine by transforming the traditional oscillation system into the system equivalent to dynamical vibration damper (fig. 1) [1].

At UrSMU we have developed experimental-industrial two masses feeder-screener (fig. 2).

For a screener, the resonant frequency of oscillations (ω_0) of the first mass (m_1) – moveable frame, is equal to the frequency of compelling force (ω):

$$\omega^2 = C_1 / m_1 = \omega_0^2, \quad (1)$$

here C_1 – rigidity of elastic supports of the first mass, H/m;

m_1 – mass of frame, kg.

In order to provide the minimal work load of elastic supports (F_{y1}), the following condition must be maintained

$$C_1 m_2 = m_1 C_2, \quad (2)$$

here C_2 – rigidity of elastic elements of upper mass, Н/m;

m_2 – mass of nets with frame (upper mass), kg.

The amplitude of established oscillations of the second mass is calculated by the formula [15]

$$A_2 = [A_1 F/(2\gamma\beta\mu)^{-1}]^{0,5}, \quad (3)$$

here A_1 – amplitude of oscillations of lower mass.

$\beta = m_2/m_1$; $\mu = b/(2\,\omega_0 m_2)$ – constant coefficients.

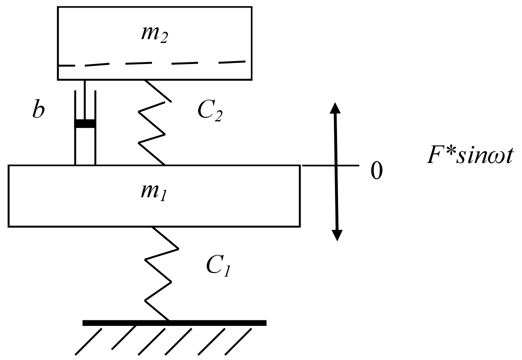


Fig. 1. Two-masses model of operating part of VTM: b – coefficient of resistance; F – amplitude of external workload

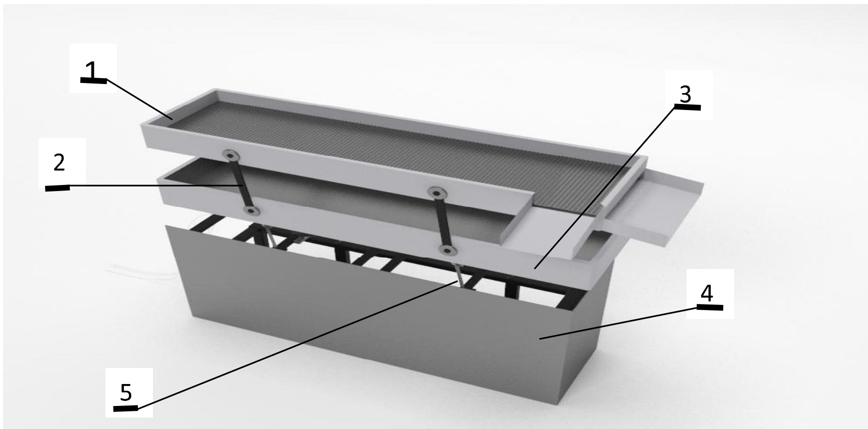


Fig. 2. Experimental-industrial two masses feeder-screener: 1 – Uppermass (m_2) – box with net; 2 – Rigidly suppressing supports(C_2); 3 – First mass (m_1) – moveable frame; 4 – Non-moveable frame; 5 – Rigid supports (C_1)

Ratio of partial frequencies:

$$\gamma = \omega_1/\omega_0. \quad (4)$$

hereω_1 – partial frequency of oscillations of lower mass,

$$\omega_1 = (C_1/m_1)^{0,5} \quad (5)$$

The coefficient of resistance (b) depends basically on coefficient of absorption [12]

$$b = \psi C_2/[2\varpi\,(C_2/m_2)^{0,5}], \quad (6)$$

here ψ – coefficient of absorption.

The coefficient of absorption is determined by the experiment. For this screener it is determined by losses in supports and by friction of rock mass about net. We have discovered in our investigations that the coefficient of absorption varies in wide range: when no-load operation ψ=0,06...0,16, when screening ψ= 0,16...0,5 (half-fast mode of movement of rock mass).

As a result of the tests it has been established that when amplitude of oscillations of the first mass is 5...10 mm, the amplitude of oscillations of the net varies from 20 to 40mm and it well coincides with the results of calculations by formula (3). In one-mass system (before modernization) amplitude of oscillations was 20...25 mm. Thus, the load of rigid supports of lower mass has decreased by 2...4 times.

Conclusion. This scheme of the dynamical system enables us to decrease significantly the value of the first mass, amplitude of its oscillations, and respectively, the mass of whole screener. Also it enables us to decrease the rigidity of elastic supports, their mass and work load.

Список литературы

1. Afanasiev A. I., Maltsev V. A., Andryushenkov D. N., Lagunov D. V., Chirkova A. A. Resonant two-masses feeder-screener. News of higher education institutions. Mining journal. 2011. No. 3. P. 27–29.

2. Antipov V. I., AstashevV. K. About the principles of creation of power-saving vibration machines // Problems of machines-manufacturing and reliability of machines. 2004. No. 4. P. 3–8.

3. Antipov V. I., Ruin A. A. The dynamics of resonant low-frequency parametrically exciting vibration machine // Problems of machines-manufacturing and reliability of machines. 2007. No. 5. P. 7–13.

4. Antipov V. I. Using combined parametrical resonance for improving vibration machines // Problems of machines-manufacturing and reliability of machines. 1998. No. 4. P. 16–21.

5. Antipov V. I. Vibration-generator: Patent № 2072660 RF. MKIB 06 B 1/16 // Bul. no. 3, 1997.

6. Concentrating equipment: Industry catalogue 18-2-82. Part 2. CNIITEItyazhmash. M., 1982. 103 p.

7. Dmitriev V. N., Gorbunov A. A. Resonant vibration electric drive of manually controlled machines // News of Samara's scientific center of Russian academy of science. 2009. b. 11. No. 3.

8. Investigation of classification effectiveness of small classes of rock mass by resonant machine /A. I. Afanasiev [and others] // Materials of Ural's mining-industrial decade. Yekaterinburg, 2007. P. 118–119.

9. Iofin S. L., Kudryavtsev U. I., Sergeev V. E., Shkarpetin V. V. The experience of developing and applying of vibration mechanisms for production and transport of ore. M.: Tsvetmetinformatsiya, 1971. 86 p.

10. Litvak A. G., Poturaev V. N., Markovsky F. I. Resonant screener for dehydration of coal slime // Coke and chemistry. 1960. No. 5. P. 17–21.

11. Poturaev V. N. Resonant screeners. M.: TsNIEI-coal, 1963. 94 p.

12. Rivin E. I. Dynamics of drives of machines. M: Mashinostroenie, 1965. 203 p.

13. Spivakovsky A. O., Goncharevich I. F. Vibration conveyors, feeders and additional devices. M.: Mashinostroenie, 1972. 326 p.

14. Spivakovsky A.O. Goncharevich I. F. Mountain-transport vibration machines. M.: Ugletehizdat, 1959. 219 p.

15. Timoshenko S. P. Oscillations in engineering. M.: Science, 1967. 444 p.

References

1. Afanasiev A. I., Maltsev V. A., Andryushenkov D. N., Lagunov D. V., Chirkova A. A. *Gorny zhurnal* (Mining journal), 2011, no. 3, pp. 27–29.

2. Antipov V. I., AstashevV. K. *Problemy mashinostroeniya i nadezhnosti mashin* (Problems of machines-manufacturing and reliability of machines), 2004, no. 4, pp. 3–8.

3. Antipov V. I., Ruin A. A. *Problemy mashinostroeniya i nadezhnosti mashin* (Problems of machines-manufacturing and reliability of machines), 2007, no. 5, pp. 7–13.

4. AntipovV. I. *Problemy mashinostroeniya i nadezhnosti mashin* (Problems of machine-manufacturing and reliability of machines), 1998, no. 4, pp. 16–21.

5. AntipovV. I. *Byul.* (Bul.), 1997, no. 3.

6. *Obogatitelnoe oborudovanie* (Concentrating equipment: Industry catalogue 18-2-82). Part 2. TsNIITEItyazhmash. Moscow, 1982. 103 p.

7. Dmitriev V. N., Gorbunov A. A. *Izvestiya Samarskogo nauchnogo tsentra Rossiyskoy akademii nauk* (News of Samara's scientific center of Russian academy of science), 2009, b. 11, no. 3.

8. *Issledovanie effektivnosti klassifikatsii melkih klassov gornoy porody na rezonansnom grohote* [Investigation of classification effectiveness of small classes of rock mass by resonant machine]: Materials of Ural's mining-industrial decade. Yekaterinburg, 2007, pp. 118–119.

9. Iofin S. L., Kudryavtsev U. I., Sergeev V. E., Shkarpetin V. V. *Opyt sozdaniya i primeneniya vibratsionnyh mehanizmov dlya vypuska i dostavki rudy* [The experience of developing and applying of vibration mechanisms for production and transport of ore]. Moscow: Tsvetmetinformatsiya, 1971. 86 p.

10. Litvak A. G., Poturaev V. N., Markovsky F. I. *Koks i himiya* (Coke and chemistry), 1960, no. 5, pp. 17–21.

11. Poturaev V. N. *Rezonansnye grohoty* [Resonant screeners]. Moscow: TsNIEI-coal, 1963. 94 p.

12. Rivin E. I. *Dinamika privoda stankov* [Dynamics of machine gearing]. Moscow: Mashinostroenie, 1965. 203 p.

13. Spivakovsky A. O., Goncharevich I. F. *Vibratsionnye konveyery, pitateli i vspomogatelnye ustroystva* [Vibration conveyors, feeders and additional devices]. Moscow: Mashinostroenie, 1972. 326 p.

14. Spivakovsky A.O. Goncharevich I. F. *Gornotransportnye vibratsionnye mashiny* [Mining-transport vibration machines]. Moscow: Ugletehizdat, 1959. 219 p.

15. Timoshenko S. P. *Kolebaniya v inzhenernom dele* [Oscillations in engineering]. Moscow: Science, 1967. 444 p.

Briefly about the authors

Alexander Afanasiev, doctor of technical sciences, professor, Technical Mechanics department, Ural State Mining University, Yekaterinburg, Russia. Sphere of scientific interests: mining, concentrating, transport machines
gmf.tm@ursmu.ru

Vladimir Potapov, doctor of technical sciences, professor, Mining Mechanics department, Ural State Mining University, Yekaterinburg, Russia. Sphere of scientific interests: mining, concentrating, transport machines
gmf.tm@ursmu.ru

Dmitriy Suslov, candidate of technical sciences, leading software engineer JSC «Plant No. 9», Ural State Mining University, Yekaterinburg, Russia. Sphere of scientific interests: vibration-transport machines
susdmitry@yandex.ru

Alyona Chirkova, candidate of technical sciences, associate professor, Technical Mechanics department, Ural State Mining University, Yekaterinburg, Russia. Sphere of scientific interests: mining, concentrating, transport machines
gmf.tm@ursmu.ru

Коротко об авторах

Афанасьев Анатолий Ильич, д-р техн. наук, профессор кафедры «Техническая механика», профессор, Уральский государственный горный университет, г. Екатеринбург, Россия. Область научных интересов: математическое моделирование
gmf.tm@ursmu.ru

Потапов Валентин Яковлевич, д-р техн. наук, профессор кафедры «Техническая механика», Уральский государственный горный университет, г. Екатеринбург, Россия. Область научных интересов: математическое моделирование
gmf.tm@ursmu.ru

Суслов Дмитрий Николаевич, канд. техн. наук, ведущий инженер-программист АО «Завод № 9», г. Екатеринбург, Россия. Область научных интересов: вибротранспортные машины
susdmitry@yandex.ru

Чиркова Алёна Анатольевна, канд. техн. наук, доцент кафедры «Техническая механика», г. Екатеринбург, Россия. Область научных интересов: горные, обогатительные, транспортные машины
gmf.tm@ursmu.ru

Образец цитирования

Афанасьев А. И., Потапов В. Я., Суслов Д. Н., Чиркова А. А. Two-masses resonant clatter with linear controlled engine// Вестн. Забайкал. гос. ун-та. 2017. Т. 23. № 8. С. 19–24. DOI: 10.21209/2227-9245-2017-23-8-19-24.

Afanasyev A. I., Potapov V. Ya., Suslov D. N., Chirkova A. A. Two-masses resonant clatter with linear controlled engine // Transbaikal State University Journal, 2017, vol. 23, no. 8, pp. 19–24. DOI: 10.21209/2227-9245-2017-23-8-19-24.

Date of receipt of the article: 07.07.2017.
Date of publication of the article: 31.08.2017.