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ABOUT OF THE DYNAMICS OF FORCED OSCILLATIONS IN NONLINEAR SYSTEMS

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The article discusses the issues of determining the effectiveness indicators of an electromagnetic vibration exciter in a dynamic mode of operation. It is established that this system is whole system of electrical and mechanical circuits. In this case, the mechanical part operates in the mode of forced vibrations. The oscillation parameters of the system, such as amplitude, frequency, and phase, largely depend on the parameters of the system load. For the analysis of this system, differential equations describing an electromagnetic vibration exciter have been compiled. For this purpose, the dependence L(x) of the inductance on the displacement is used. The dynamic modes of one of the ways of asynchronous excitation of an electromagnetic vibration exciter are investigated. The accuracy analysis and the evaluation of the results were performed by the Fisher criterion for the regression model. To analysis of transients in the electromagnetic vibration exciter, were used the software packages WinFact and MatLab to simulate and optimize dynamic systems. It is established that the system, depending on the initial conditions in the simulation, goes into one of two very different modes. In this case, the initial zero conditions switch the system into a “cyclic” mode, and in other, non-zero conditions, the system goes into an approximate cyclic mode, characterized by a higher speed of movement of the anchor. The parameters of the steady state cyclic movement are determined by the method of harmonic balance.

The obtained results allow us to describe autoparametric oscillations of the electric equivalent circuit. It has been established that the compilation of harmonic balance equations corresponding to a linear system helps simplify the solution of the task of determining the dynamics of forced oscillations. The expressions for determining the tractive force and the current flowing through the circuit are obtained, the wavelet spectra of vibration are constructed using the MatLab software package. As a result, for the mechanical part of a nonlinear system, in fact, it is necessary to solve only harmonic balance equation. The results show that this theoretical model allows a more qualitative and accurate assessment of the observed phenomenon. Based on this, the asymptotic conditions for solving the harmonic balance equations of a nonlinear system are determined. The expressions for the electromagnetic force acting on the anchor are obtained, the conditions for the harmonic balance of the mechanical part of the system are determined. The expressions obtained allow us to construct the amplitude-frequency characteristics of the electromagnetic vibration exciter. In conclusion, not only qualitative, but also quantitative estimates of the observed phenomena were obtained. It has been established that mechanical oscillations of a nonlinear system are insensitive to changes in the supply network and practically have a large amplitude with a constant frequency.

Key words: nonlinear system, electromagnetic exciter, mechanical fluctuations, Fisher criteria, harmonic balance condition, armature.

У статті розглядаються питання визначення показників ефективності електромагнітного збуджувача коливань в динамічному режимі роботи. Встановлено, що ця система є цілою системою електричних і механічних ланцюгів. У цьому випадку механічна частина працює в режимі вимушених коливань. Параметри коливань системи, такі як амплітуда, частота і фаза, багато в чому залежать від параметрів навантаження системи. Для аналізу цієї системи були складені диференціальні рівняння, що описують збудник електромагнітних коливань. Для цього використовується залежність L (x) індуктивності від зміщення. Досліджено динамічні режими одного з шляхів асинхронного збудження збудника електромагнітних коливань. Аналіз точності та оцінка результатів проводили за критерієм Фішера для регресійної моделі. Для аналізу перехідних процесів в електромагнітному збуднику коливань були використані програмні пакети WinFact і MatLab для імітації і оптимізації динамічних систем. Встановлено, що система, залежно від початкових умов моделювання, переходить в один з двох дуже різних режимів. У цьому випадку початкові нульові умови перемикають систему в «циклічний» режим, а в інших ненульових умовах система переходить в наближений циклічний режим, що характеризується більш високою швидкістю руху якоря. Параметри стаціонарного циклічного руху визначаються методом гармонійного балансу.

Отримані результати дозволяють описати автопараметричні коливання електричної еквівалентної схеми. Встановлено, що складання рівнянь гармонійних балансів, що відповідають лінійній системі, сприяє спрощенню розв'язання задачі визначення динаміки вимушених коливань. Отримано вирази для визначення тягової сили і струму, що протікає по контуру, вейвлет-спектри вібрації побудовані з використанням пакета програм MatLab. Як наслідок, для механічної частини нелінійної системи, по суті, необхідно розв'язати лише гармонійне рівняння балансу. Результати показують, що ця теоретична модель дозволяє більш якісно і точно оцінити спостережуване явище. Виходячи з цього, визначаються асимптотичні умови розв'язання рівнянь гармонійного балансу нелінійної системи. Отримано вирази для електромагнітної сили, що діє на якір, визначено умови гармонійного балансу механічної частини системи. Отримані вирази дозволяють побудувати амплітудно-частотні характеристики електромагнітного збуджувача коливань. На закінчення отримані не тільки якісні, але й кількісні оцінки спостережуваних явищ. Встановлено, що механічні коливання нелінійної системи нечутливі до змін в мережі живлення і практично мають велику амплітуду з постійною частотою.

Ключові слова: нелінійна система, електромагнітний збудник, механічні коливання, критерії Фішера, стан гармонійного балансу, арматура.

В статье рассматриваются вопросы определения показателей эффективности электромагнитного вибровозбудителя в динамическом режиме работы. Установлено, что данная система является единой системой электрического и механического контуров. При этом механическая часть работает в режиме вынужденных колебаний. Параметры колебаний системы, такие как амплитуда, частота и фаза – в значительной степени зависят от параметров нагрузки системы. Для анализа данной системы составлены дифференциальные уравнения, характеризующие электромагнитный вибровозбудитель. С этой целью использована зависимость индуктивности от перемещения L(x). Исследованы динамические режимы одного из вариантов асинхронного возбуждения электромагнитного вибровозбудителя. Точностной анализ и оценивание результатов выполнены по критерию Фишера для регрессионной модели. Для анализа переходных процессов в электромагнитном вибровозбудителе использованы программные пакеты WinFact и MatLab для моделирования и оптимизации динамических систем. Установлено, что система,в зависимости от начальных условий при моделировании, переходит в одно их двух сильно отличающихся режимов. При этом начальные нулевые условия переводят систему в «циклический» режим, а в других, отличающихся от нуля условиях, система переходит в приблизительный циклический режим, отличающихся более высокой скоростью перемещения якоря. Параметры установившегося режима циклического перемещения определены методом гармонического баланса. Полученные результаты позволяет описывать автопараметрические колебания электрической схемы замещения. Установлено, что построение уравнений гармонического баланса, соответствующих линейной системе способствует упрощению решения задачи определения динамики вынужденных колебаний. Получены выражения для определения тяговой силы и тока, протекающего по цепи, с помощью программного пакета MatLab построены вейвлет спектры колебаний. В результате, для механической части нелинейной системы, фактически, необходимо решить только уравнение гармонического баланса. Полученные результаты показывают, что данная теоретическая модель позволяет более качественно и точно оценивать наблюдаемое явление. Исходя из этого, определены асимптотические условия решенияуравнений гармонического баланса нелийной системы. Получено выражения для электромагнитной силы, действующей на якорь, определены условия гармонического баланса механической части системы. Полученные выражения позволяют построить амплитудно-частотные характеристики электромагнитного вибровозбудителя. В заключении получены не толко качественные, но и количественные оценки наблюдаемых явлений. Установлено, что механические колебания нелинейной системы нечувствительны к изменениям питающей сети и практически имеют большую амплитуду с постоянной частотой.

Ключевые слова: нелинейная система, электромагнитный возбудитель, механические колебания, критерии Фишера, состояние гармонического баланса, якорь.

1. Introduction

At present for intensification of processes applied different methods and means. Vibration is one of these methods. The vibration with low and high frequency may be used. Performed researches and obtained results show that most technology processes (for example, mixing of liquid and solid substances, melting of metals and so on) may be intensification via low frequency (20-100Hz) vibration. So task on obtaining the low frequency vibration is actually.

The different devices for obtaining the low frequency vibration are used. The electromagnetic exciter is more perspective and efficiency device. Such devices may be created as one phase - single-cycle, three phases - single-cycle and one phase - two-cycle. The one phase - single-cycle electromagnetic exciter is one of most useful solutions on technical and economical indicators. It consist of electromagnet, armature with springs, coil, capacitor connected to coil series.

2. Review and development

Exciter operating on low frequency (20-100 Hz) mechanical fluctuation is the one phase electromagnetic exciter connected to standard supply via capacitor series connected to its coil. An efficiency of given device is the rational forming of the attracting force on main mechanical fluctuation frequency.

The system considered here consist of related two oscillations (electrical and mechanical) circuits and operates in forced fluctuation mode, formed in mechanical part. So, vibration parameters (amplitude, frequency and phase) are very dependence on parameters of mechanical system and load. However, account all parameters that influence to operating of electromagnetic exciter complicate to define of main parameters of mechanical system. So to obtain the mathematical dependency for simple analysis we should accept following conditions [1,2,3]:

a) energy losses on eddy current should be very low;

b) inductivity should be nonlinear function of moving and other parameters of system should stay stabile;

c) magnetic system should be saturated and should has not hysteresis/

taking into account these conditions the investigated electromagnetic exciter system may be described as follow [4]:

$$\begin{cases} \frac{d}{dt}(Li) + ir + \frac{1}{C}\int idt = U \\ m\frac{d^2x}{dt^2} + k\frac{dx}{dt} + \mu x = F(x,t) \end{cases} \qquad (1)$$

here, $L=L(x)$ – inductivity of coil (Hn); i – current (A); C – capacity (F); r – active resistance (Om); $U=u_0 sin\omega t$ – voltage of supply (V) (U_0 - amplitude value of voltage, ω - angle frequency); m – mass that moving together with armature (kg); k – coefficient of elasticity (N/m); μ - coefficient damping (N/m); x – moving of armature (mm); $F(x,t)= -\left(\frac{i^2}{2\left(\frac{dL}{dx}\right)}\right)$ – attracting force (N); t – time (sec.).

3. **Result and discussion**

In this work investigated the dynamic modes of one variant of asynchrony exciting of the electromagnetic exciter via use sub harmonic resonance effect.

Building of dependency L=L(x)=L(Z) unifying mechanical and electrical parts of electromagnetic exciter is complicated and theoretically unsolved task of theory of electromagnet field.

In this investigate we will use experimental results and the regression model on Fisher criteria:

$$L(Z)=a_1+a_2Z+a_3Z^2 \qquad (2)$$

Experimentally defined that if

$$Z \geq \left(-\frac{a_2}{2a_3}\right)$$

the value of inductivity may be considered constant and equal to minimum value of approximation.

If take into account that mathematical model of electromagnetic exciter (EE) is nonlinear differential equation system, computer modeling is most wide method for solution of dynamic tasks. If take into account that mathematical model of EE is nonlinear differential equation system, computer modeling is most applied method for solution of such dynamic tasks. For analysis of transition process on EE are used application programs (Win Fact and Mat Lab) for modeling and optimization of dynamic systems (DSMO).

In dependency of initial conditions during the modeling the system cross from one mode to another significantly differed mode. Zero initial condition leads always motion of armature of electromagnet to "cyclical" mode corresponding to frequency of network supply. In another different conditions system cross to "probably mode" with more speed.

In another different conditions system cross to "approximately cyclical" mode with more speed. So, for example on modeling of motion in "cyclical" mode during 0.05 sec armature vibrates with amplitude 0.14 mm and with speed 0.4 m/sec., though in "approximately cyclical" mode these respectively are 15 mm and 1.2 m/sec. Fluctuations of current in supply circuit in both case are same, so "approximately cyclical" mode count as more profitable in terms of technology.

For calculation of established motion of EE we integrate (1a) and write dynamic equation of its equivalent electrical circuit. Herewith the dynamic equation of mechanical part can be simplify via excluding the very small second term of expression for electromagnet force that is proved on modeling of transition process of EE. Besides, the distance equation that unifying mechanical and electrical parts of system should be wrote as L=L(z). Then equation of EE will be in following form:

$$\begin{cases} L(x)i + R\int_{t_0}^{t} i(t)dt + \frac{1}{C}\int_{t_0}^{t}\int_{t_0}^{t} i(t)dtdt = u_0\omega\sin\omega t \\ m\ddot{x} + k\dot{x} + \mu x = -\left(\frac{i^2}{2\left(\frac{dL}{dx}\right)}\right) \\ L(x) = \alpha_1 + \alpha_2 x + \alpha_3 x^2 \end{cases} \quad (3)$$

Here α_1, α_2 and α_3 - coefficients of regression model and define as follow:

$$\begin{cases} \alpha_1 = a_1 + a_2\delta + a_3\delta^2 \\ \alpha_2 = -(a_2 + 2a_3\delta) \\ \alpha_3 = a_3 \end{cases} \quad (4)$$

Here a_1, a_2, a_3- coefficients that dependence of form of L(x).

The equation system (3) for established mode in approximately cyclical motion solved by harmonic balance method. Herewith used the following asimptotic results obtained in articles [7,8]:

$$\begin{aligned} & x = A\cos\nu t + d \\ & i = J_1\cos\omega t + J_2\sin\omega t + J_3\cos(\omega-\nu) + J_4\sin(\omega-\nu)t + J_5\sin(\omega-\nu) + J_5\sin(\omega+\nu) \end{aligned} \quad (5)$$

here, *A* – vibration amplitude of armature (main fluctuation of current); *d* – motion of vibration center of armature from established distance (δ); J_1,J_2,J_3,J_4,J_5 –amplitudes of relevant harmonics of current, ν - frequency of mechanical fluctuations.

Explanation of parametric exciting of electrical circuit of EE can be give if we put first equation of system (5) in expression *L=L(x)* that allow to get *L=L(t)* form:

$$\left.\begin{aligned} & L(t) = \lambda_0 + \lambda_1\cos\nu t + \lambda_2\cos 2\nu t \\ & \lambda_0 = \alpha_1 + \alpha_2 d + \alpha_3 d^2\left(\frac{d_3A^2}{2}\right) \\ & \lambda_1 = d_2A + 2\alpha_3Ad \\ & \lambda_2 = \frac{d_3A^2}{2} \end{aligned}\right\} \quad (6)$$

Expression (6) together with first equation of system (3) allow to compose the harmonic balance conditions and to describe auto parametric

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fluctuation in equivalent electrical circuit on frequencies ω and ω-ν.

Using these equations every term at left part of dynamic electrical equation can be writing as follow (7):

$$Li = \left[J_1\lambda_0 + \frac{J_3\lambda_1}{2} \right]\cos(\omega t) + \left[J_2\lambda_0 + \frac{J_4\lambda_1}{2} \right]\sin \omega t +$$

$$+\left[J_3\lambda_0 + \frac{J_1\lambda_1}{2} \right]\cos(\omega - \nu)t + \left[J_3\lambda_0 + \frac{J_1\lambda_1}{2} \right]$$

$$R\int i(t)dt = \frac{J_1 R}{\omega}\sin \omega t - \frac{J_2 R}{\omega}\cos \omega t + \frac{J_3 R}{\omega-\nu}\sin(\omega-\nu)t - \frac{J_4 R}{\omega-\nu}\cos(\omega-\nu)t$$

$$\frac{1}{C}\iint i(t)dt = -\frac{J_1}{C\omega^2}\cos \omega t - \frac{J_2}{C\omega^2}\sin \omega t - \frac{J_3}{C(\omega-\nu)^2}\cos(\omega-\nu)t -$$

$$-\frac{J_4}{C(\omega-\upsilon)^2}\sin(\omega-\nu)t$$

If take account that right part of this equation includes single term *(u₀/ω)sinωt*, the harmonic balance conditions on given frequency can be write as follow:

$$\begin{bmatrix} \left[l_0 - \frac{1}{C\omega^2}\right] & -\frac{R}{\omega} & \frac{l_1}{2} & 0 \\ \frac{R}{\omega} & \left[l_0 - \frac{1}{C\omega^2}\right] & 0 & \frac{l_1}{2} \\ \frac{l_1}{2} & 0 & \left[l_0 - \frac{1}{C(\omega-\nu)^2}\right] & -\frac{R}{\omega-\nu} \\ 0 & \frac{l_1}{2} & \frac{R}{\omega-\nu} & \left[l_0 - \frac{1}{C(\omega-\nu)^2}\right] \end{bmatrix} \begin{bmatrix} J_1 \\ J_2 \\ J_3 \\ J_4 \end{bmatrix} = \begin{bmatrix} 0 \\ u_0/\omega \\ 0 \\ 0 \end{bmatrix} \quad (8)$$

Note that linearity of initial differential equation related to its coefficients bring into linear system the relevant harmonic balance equations and it made task simplify.

In this case during the solving (5) must define only three unknowns instead of seven.

If take into account that during to define of A, d and v the values of amplitudes of currents J_1, J_2, J_3 , J_4 and J_5 calculate uniquely and during solving linear equations system (8) without any complication. So, for mechanical part of system actually solve only the harmonic balance equation. The solution of the balance equation of electrical part is Intermediate stage of calculations.

Writing the first equation of system (5) in second equation of system (3) we get alone frequency harmonic and free term:

$$m\ddot{x} + k\dot{x} + \mu x = \mu d + (\mu A - m\nu^2 A)\cos \nu t - kA\sin \nu t$$

Similarly if we write first equation of system (5) in third equation of system (3) we get expression:

$$\frac{dL}{dx}2a_3 x + a_2 = \frac{\lambda_1}{A} + 2a_3 A\cos \nu t$$

As seen from second equation of system (5) that

$$i^2 = \frac{J_1^2 + J_2^2 + J_3^2 + J_4^2}{2} + \frac{J_1^2 - J_2^2}{2}\cos\omega t + J_1 J_2 \sin 2\omega t + J_1 J_3 \cos 2\nu t + \left[J_2 J_3 - J_1 J_4\right]\sin \nu t$$

o, electromagnet force which influence to armature

$$F_e = -\frac{i^2}{2}\frac{dL}{dx} = \frac{\lambda_1\left(J_1^2 + J_2^2 + J_3^2 + J_4^2\right)}{4A} - \frac{\lambda_1\left(J_1^2 + J_2^2\right)}{4A}\cos\omega t - \frac{\lambda_1}{2A}J_1J_2\sin\omega t -$$
$$-\frac{\lambda_1}{2A}\cos\omega t - \frac{\left(J_2J_3 - J_1J_4\right)}{2A}\sin\omega t$$

and the harmonic balance conditions for mechanical part of system is the following equation system:

$$\begin{cases} J^2\lambda_1 - 4\mu dA = 0 \\ \dfrac{\lambda_1 J_2 J_4}{2A} + A\left(\dfrac{\alpha^2 J^2}{2} - \mu + m\nu^2\right) = 0 \\ \dfrac{\lambda_1\left(J_2J_3 - J_1J_4\right)}{2A} + k\nu A = 0 \end{cases} \quad (9)$$

here, $J^2 = J_1^2 + J_2^2 + J_3^2 + J_4^2$

Equations system (9) solved in computer by numerical method sistem. The values of parameters of system got values for unestablished operating mode of EE. Range of change parameters was accepted as follow: A=0,5...2,0 mm and U=20...230 V. The characterized results of calculating are present at the table 1. The results are show that exist theoretical model allows to accurately and quality evaluate observed process.

Increasing values of amplitude of current on frequency leads to increasing amplitude of output fluctuations

Increasing values of amplitude of current on frequency leads to increasing amplitude of fluctuations at output, i.e. we get possibility of regulation of amplitude of fluctuations via voltage.

However the quantity effect of such model of auto parametric exciting of fluctuations of electromechanical system has no explanation. So, current harmonic in difference frequency has small amplitude that commensurate with computational error. So an initial form of mathematical model (1) and its stationary solution found right.

Herewith accept that mismatch of system from main resonance frequency is very high and ratio of frequencies ω and ν is irrational. Then the approximate solution can be show as consist of two parts: forced frequency of voltage of supply of system and twin frequency of mechanical part (marked by index 1).

4. Conclusions

Then the approximate solution can be show as consist of two parts: forced frequency of voltage of supply of system and twin frequency of mechanical part Solution results of system (9) So asymptotic solution of harmonic balance method may be writing as follow:

$$\begin{aligned} & x = x_2 = A\cos\nu t = d \\ & i = i_1 + i_2 \\ & i_1 = J_2 \sin\omega t \\ & i_2 = J_3\cos(\omega - \nu)t + J_4\sin(\omega - \nu)t \end{aligned} \quad (10)$$

Table 1 – The characterized results of calculating.

A, mm	*C, mkF*	*J_1, A*	*J_2, A*	*J_3, mA*	*J_4, mA*
0.05	31.3	0.142	0.552	0.067	0.040
0.60	31.3	0.141	0.549	0.078	0.048
0.70	31.3	0.139	0.546	0.089	0.056
0.80	31.3	0.137	0.542	0.099	0.064
0.90	31.3	0.134	0.537	0.224	0.150
1.00	31.3	0.131	0.532	0.240	0.166
1.10	31.3	0.129	0.527	0.248	0.178
1.20	31.3	0.126	0.521	0.258	0.194
1.30	31.3	0.122	0.515	0.267	0.268
1.40	31.3	0.119	0.508	0.365	0.297
1.50	31.3	0.116	0.501	0.100	0.085

and values of J2 for electrical part of system is defined from amplitude balance conditions in frequency ω as following:

$$J_2 = u_0 C\omega \frac{\Omega_0^2}{\omega^2 - \Omega_0^2} \quad (11)$$

here, $\Omega_0^2 = \frac{1}{\alpha_0 C}$ specific frequency of electrical part of system in approaches to zero. Then the amplitude balance condition on frequency ω-υ will be as follow:

$$J_3 = -J_2\left(\frac{\lambda_1}{\lambda_0}\right)\frac{\omega_R(\omega-\nu)^3}{\left[(\omega-\nu)^2-\omega_0^2\right]^2+\omega_R^2(\omega-\nu)^2}$$

$$J_4 = -J_2\left(\frac{\lambda_1}{\lambda_0}\right)\frac{\left[(\omega-\nu)^2-\omega_0^2\right](\omega-\nu)^2}{\left[(\omega-\nu)^2-\omega_0^2\right]^2+\omega_R^2(\omega-\nu)^2} \quad (12)$$

here, $\omega = R/\lambda$ - cycle frequency of damper of electromagnetic exciter; $\omega_0^2 = \frac{1}{\lambda_0 c}$ – dynamic frequency that appeared as a result of moving of armature in system.

In this case the harmonic balance conditions of mechanical part of system becoming simpler:

$$\begin{cases} \lambda_1 J^2 + 4\mu d A = 0 \\ \lambda_1 J_2 J_4 + \left[\alpha_2 J^2 - \left(k - m\nu^2\right)\right]A^2 = 0 \\ \lambda_1 J_2 J_3 - 2k\nu A = 0 \end{cases} \quad (13)$$

here, $J^2 = J_1^2 + J_2^2 + J_3^2 + J_4^2$

Solution of task leads to system with three nonlinear equation with three unknowns (*A*, *d* and *v*). The amplitude values of currents are in the system mainly as coefficients that dependence from initial unknowns.

Numerical solution of equation system (9)-(13) allows building amplitude-frequency characteristic of electromagnetic exciter in tables 2 and 3.

Solution results of system (13) (*ε=1.433 kg·sec;* u_0*=70V;* $\sqrt{\frac{k}{m}} = 11Hs$ *(d=2.3mm).*

Table 2 – The amplitude frequency characteristics of electromagnetic exiter (A).

ω, Hs	*A, mm*	*ν, HS*	*J₂, A*	*J₃, A*	*J₄, A*
35	10.0	16.62	0.457	0.173	0.022
37	10.0	16.67	0.412	0.170	0.019
39	10.0	16.70	0.395	0.172	0.018
41	10.0	16.70	0.389	0.168	0.018
43	10.0	16.74	0.370	0.173	0.015
45	10.0	16.76	0.379	0.163	0.015
47	10.0	16.76	0.341	0.177	0.012
49	10.0	16.76	0.386	0.173	0.012
51	10.0	16.77	0.355	0.176	0.011
53	10.0	16.79	0.366	0.172	0.020
55	10.0	16.81	0.368	0.178	0.009
59	10.0	16.80	0.330	0.173	0.009
57	10.0	16.81	0.334	0.178	0.009
61	10.0	16.81	0.368	0.173	0.009
63	10.0	16.82	0.331	0.178	0.009
65	10.0	16.81	0.367	0.173	0.008

Solution results of system (13) (*ε=3.423 kg/sec,* u_0*=80V,* $\sqrt{\frac{k}{m}}$ *=17Hc (d=1.38 mm)*

Analysis of tables content show that adequate quality and also quantity explanations for observed process are obtained. Result mechanical waves practically have big amplitudes with stabile frequency and have no sensitivity to changes of main supply. Such features of Amplitude frequency response (AFR) systems allow using it for optimization homogenous processes in high efficiency devices with vibtatransportation.

Table 3 – The amplitude frequency characteristics of electromagnetic exiter (B)

ω, Hs	*A, mm*	*ν, HS*	J_2, *A*	J_3, *A*	J_4, *A*
35	-8.94	10.38	0.717	-0.095	-0.013
37	-8.77	10.31	0.762	-0.097	-0.013
39	-8.69	10.30	0.777	-0.097	-0.013
41	-8.61	10.30	0.775	-0.099	-0.013
43	-8.65	10.30	0.780	-0.098	-0.012
45	-8.59	10.29	0.785	-0.099	-0.011
47	-8.59	10.29	0.791	-0.098	-0.011
49	-8.46	10.28	0.805	-0.098	-0.010
51	-8.52	10.27	0.814	-0.098	-0.010
53	-8.30	10.25	0.824	-0.099	-0.009
55	-8.40	10.24	0.824	-0.099	-0.009
57	-8.37	10.24	0.833	-0.099	-0.009
61	-8.21	10.20	0.854	-0.100	-0.009
63	-8.17	10.18	0.867	-0.100	-0.009
65	-8.07	10.16	0.879	-0.100	-0.008

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