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Research of the Movement of the Vibrating Tool with the Relay Control System

O.O. Yanochkina and A.V. Kiselev
Southwest State University, St. 50 Years of October, 94, 305040 Kursk, Russia

Abstract: In study are researched movement of the vibrating tool taking into account cross impact of oscillations of relay system of automatic control of the electric drive and the centrifugal unbalance vibration exciter taking into account properties of the technological environment. A source of vibration is the unbalance vibration exciter, controlled by the electric drive of a direct current with relay system of automatic control of the moment of the engine. Dependences of oscillation frequency of the casing of the tool on tension of the job of current of an anchor of the engine and mass of a unbalance are given. Results of numerical calculation of transient phenomenon of current of an anchor of the engine, relocation and speed of the vibrating tool and also mechanical angular speed of rotation of an anchor of the engine in case of launch of the electric drive are illustrated.

Key words: Relay systems of automatic control, vibration tools, modeling of systems of automatic control, technological environment, dependences of oscillation frequency

INTRODUCTION

Now the scope of vibration technologies, machines and tools is rather various and continues to extend. Vibration machines, devices and tools are used in mechanical engineering and instrument making, production of metals, agricultural production, the food and meat and dairy industry, medicine, ecology, mining and processing industry, geology (Blekhman, 1994). Research fluctuations vibrating tools are devoted numerous works, for example (Veyts *et al*., 1984; Yatsun and Bezman, 2012a, b). When developing vibration machines it is necessary to consider not only properties of electromechanical system the motor-exciter, but also properties of the technological environment. As shown in research (Volkova *et al*., 2010; Rudakova *et al*., 2011), interaction of the vibrating tool and the rotating part of the engine can lead to emergence of the nonlinear phenomena which at the moment are insufficiently studied.

In research (Panovko, 2006; Volkova *et al*., 2010; Rudakova *et al*., 2011), the dynamic modes of the vibration machines with the unregulated electric drive are studied. For example, in (Volkova *et al*., 2010; Rudakova *et al*., 2011) results of researches of dynamics of the inertial the vibration exciter taking into account mutual influence of the executive engine, mechanical oscillatory system and the technological environment are presented.

This research is devoted to a research of fluctuations of the vibrating tool. A source of vibration of such tool is the unbalance vibration exciter operated by the electric drive of a direct current with relay system of automatic control of the moment of the engine.

Formulation of the problem: In the Fig. 1, the system of automatic control of the vibration tool is presented. The vibration tool consists of the carrier case and working body (in the drawing it isn't shown) of the total weight, an elastic and viscous image connected with the motionless basis. In a cavity of the case the centrifugal unbalance

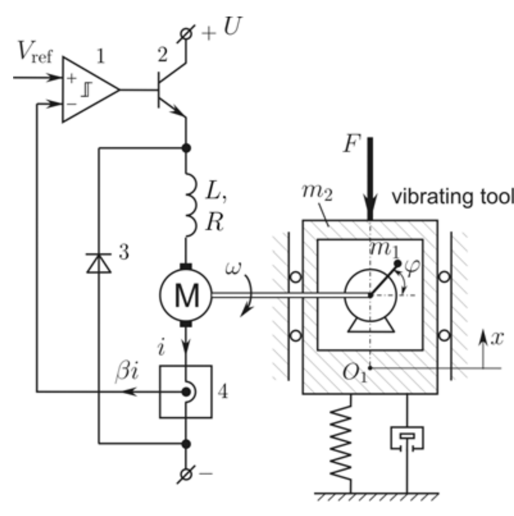

Fig. 1: Control system of the vibrating tool

Corresponding Author: O.O. Yanochkina, Southwest State University, St. 50 Years of October, 94, 305040 Kursk, Russia

vibration exciter weight with the electric drive of a direct current is located. The case of the tool moves in the vertical direction on ideal guides and is rigidly connected to working body which in turn influences the processed environment (Volkova *et al*., 2010; Rudakova *et al*., 2011).

In research the following assumptions are accepted: the case and working body of the tool are considered as a uniform rigid body which progress is described by the coordinate of the center of mass of the case (a point in the Fig. 1) counted from balance position.

The mass of a unbalance of the centrifugal vibration exciter is concentrated in the point remote from an electric motor M anchor axis on distance r. The provision of a unbalance concerning the case will be defined by a corner φ. From the processed environment (in the drawing it isn't shown) force F works.

The moment of the electric drive it is regulated by relay automatic system with a hysteresis (Tsypkin, 1974). The management system includes a relay element 1 with a hysteresis, a force key 2 in electric drive M supply circuits, the reverse diode 3, the current sensor 3 in a circuit of back coupling.

MATERIALS AND METHODS

Mathematical model: The movement of electromechanical system is described by system of the non-linear differential equations:

$$\begin{cases} m\dfrac{d^2x}{dt^2}+\mu_1\dfrac{dx}{dt}+c_1x=m_1r\left[\dfrac{d^2\varphi}{dt^2}\sin\varphi+\left(\dfrac{d\varphi}{dt}\right)^2\cos\varphi\right]+F; \\ J\dfrac{d^2\varphi}{dt^2}-m_1r\left(\dfrac{d^2x}{dt^2}\sin\varphi-g\cos\varphi\right)=M(i); \\ L\dfrac{di}{dt}+Ri+C_\omega\dfrac{d\varphi}{dt}=\dfrac{U_0}{2}\left(1+K_F(t)\right), \end{cases}$$

$$M(i)=C_E\cdot i,\ F=-c_2x-\mu_2\frac{dx}{dt} \tag{1}$$

Here, $m = m_1\text{-}m_2$the total weight of the carrier case, working body of the vibrating tool and unbalance; $J = J_1+J_2$: the moment of inertia of the electric drive including the moment of inertia of the engine J_1 and the moment of inertia of a unbalance $J_2 = m_1r^2$; given to an engine shaft; i: anchor current; M(i): the moment developed by the engine; L, R: inductance and resistance of an anchor chain; C_m, C_E - constructive coefficients of the engine; c_1 and μ_1: coefficients of rigidity and damping of fastening of the case of a vibrating tool to the basis; c_2 and μ_2: the coefficients of rigidity and damping considered at influence from technological loading (in the drawing it isn't shown), g: acceleration of gravity; U: supply voltage.

The first equation of system (1) describes progress of electromechanical system, the second equation rotary motion of an anchor of the engine and a unbalance and the third the equation of an electric part of the electric drive with relay system of automatic control.

The feedback signal from the sensor of current is given on a relay element with a hysteresis and compared to an engine anchor current task signal? At the exit of a relay element rectangular impulses for management of a power key in an electric drive power-supply circuit are formed.

Parameters of a control system and technological environment (Volkova *et al*., 2010; Rudakova *et al*., 2011): 0.2<i<1,5 B; $\beta = 1$ B/A; $\chi_0 = 0.001$ B, r = 0.01 m, $m_1 = 0.02$ кг, $m_2 = [0.02, 0.04, ..., 2.0]$ kg, $c = c_1+c_2 = 250\ \text{Hm}^{-1}$; $\mu = \mu_1+\mu_2$. In the electric drive the engine of a direct current with excitement from a permanent magnet of Maxon RE-25 which parameters is used: U = 12A; L = 0.238 . 10^{-3} Hz; Om; $C_m = 0.0235.10^{-3}$ B . C rad^{-1}, $C_E = 0.0235.10^{-3}$ H.m A^{-1}; J1 = 1.08.10^{-6} kgm^2.

RESULTS AND DISCUSSION

Research of fluctuations of system: Figure 2 shows the results of a numerical calculation of the transition process when starting the drive at.

Table 1 dependence of oscillation frequency of the vibrating tool f on tension of theassignment of current V_{ref} of an anchor in case of $m_1 = m_2 = 0.02$ kg.

Dependence of oscillation frequency f = 1/t of the casing of the tool on tension of the assignment V_{ref} of current of an anchor of the engine is given in Table 1. With increase V_{ref} frequency f monotonically grows, reaching the limit value responding to oscillation frequency of electromechanical system by operation of the engine on the automatic mechanical characteristic.

Table 1: Dependence of oscillation frequency

V_{ref} (A)	f (Hz)
0.2	13
0.3	23
0.4	39
0.5	52
0.6	64
0.7	75
0.8	85
0.9	87
1.0	89
1.1	90
1.2	91
1.3	91
1.4	91
1.5	91

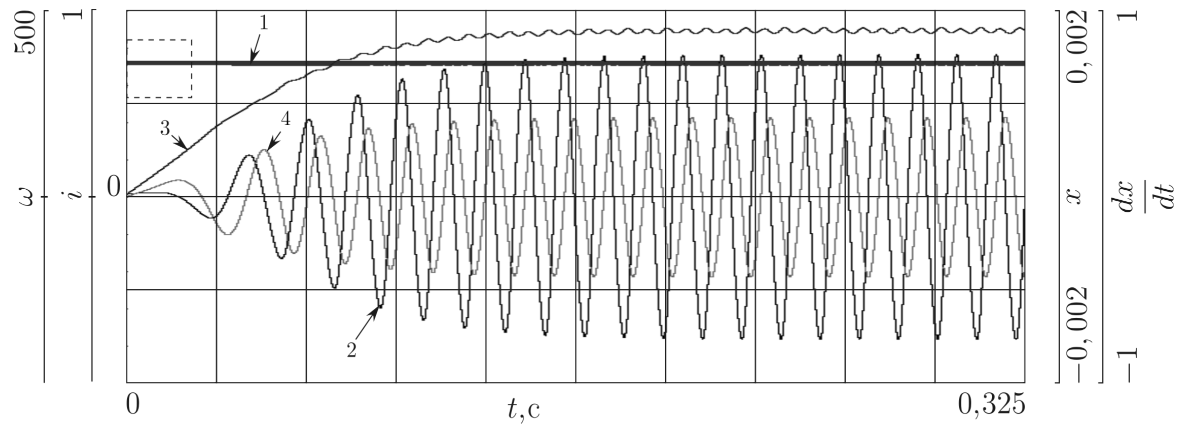

Fig. 2: The diagram of transition process at launch of the electric drive, kg; Here, 1: electric motor anchor current, A; 2: speed of movement of the vibration tool , m/c; 3: mechanical angular speed of rotation of an anchor of the engine, rad sec^{-1}; 4: movement of the vibration tool d_x/d_t, m

Table 2: Dependence of oscillation frequency of the vibrating tool

Values	V_{ref} = 0.2 A	V_{ref} = 0.3 A	V_{ref} = 0.5 A	V_{ref} = 0.7 A
m_2	f, Hz	f, Hz	f, Hz	f, Hz
0.02	13	23	52	75
0.04	48	75	96	97
0.06	90	99	100	100
0.08	100	101	101	101
0.10	102	102	102	102
0.12	102	102	102	102
0.14	102	102	102	102
0.16	103	102	102	103
0.18	103	103	103	103
0.20	103	103	103	103

Table 2 dependence of oscillation frequency of the vibrating tool on tension of the assignment of current of an anchor in case of change of mass of a unbalance m_1 = m_2 = 0.02 kg.

Dependence of oscillation frequency f = 1/t of the casing of the tool on tension of the assignment of current of an anchor of the engine in case of change of mass of a unbalance is given in Table 2. With increase in mass of a unbalance frequency f reaches the limit value responding to oscillation frequency of electromechanical system by operation of the engine on the automatic mechanical characteristic quicker.

CONCLUSION

The mathematical model of the vibrating tool controlled by the electric drive of a direct current with relational system of regulation of the moment of the engine is given. Movement of such system is described by system of non-linear differential equations of the fifth order with an explosive right part. The analysis of oscillations of the vibrating tool controlled by the electric drive of a direct current with relay system of regulation of the moment of the engine is made. As an example the dependence illustrating a possibility of regulation of oscillation frequency of the vibrating tool in case of voltage variation of the job of the moment of the executive engine is calculated.

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