Mathematical modeling and optimization MECHANICAL MOVEMENT discrete-continuous SYSTEMS

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These differential equations that describe the motion of discrete-continuous systems for transient (transient) processes that can be used to improve and clarify the existing engineering design procedures of such systems.

Mathematical modeling, discrete-continuous systems, optimization of traffic.

Problem. The question of mathematical modeling and optimization of mechanical motion discrete-continuous systems and their dynamic calculation when passing through resonance discussed in numerous papers. This review focused on systems with one degree of freedom (within models with lumped parameters), which also enables relatively easy to study mechanical systems with a finite number of degrees of freedom. Of particular importance of this issue in the analysis of non-stationary fluctuations deformed mechanical systems (eg, dynamic analysis vibroizolovanyh foundations for machines and processes in research vibration-wave / vibroudarnoho formation of different mixtures).

Among the various methods of extinguishing puskozupynnoho resonance is known, along with the improvement of conventional dampers used dynamic Oscillation; Oscillation calculations require a rather complete study of unsteady vibrations

mechanical (Deformed) systems (eg, foundations for machines) on the basis of the nature of load changes. For quality vibration and forming products for agriculture, industry also requires accurate and comprehensive analysis of these oscillations / waves generated in the "working body vibration - mix". Despite the presence of a number of important results obtained in the calculation of passage through resonance, simulation and optimization of traffic deformed mechanical systems (discrete-continuous type), as reflected in numerous publications, many of this theory, simulation, optimization of motion of such systems in times start / brake (called transients) require further study, refinement and improvement (especially engineering calculation methods for loading machines working body or foundation under them).

Analysis of recent research. It is known [1-3], the literature is very well represented calculation methods based on the use of exact solutions expressed in various special functions, as well as modeling and optimization of continuum and discrete movements (with lumped parameters) mechanical systems based on integrated criteria / action functional equations and Poisson Eylera- [4].

In the monographs [5, 6] driven a number of results, based on the use of probability integrals and functions Lommel two variables; These functions are also used in [7], and numerous articles on the subject.

The purpose of research - View method of mathematical and physical-mechanical modeling of discrete-continuous systems based on the approaches and means / tools of mathematical physics [1,2], Euler's method [3], in addition, to expand changing the frequency and amplitude of the forces that cause fluctuations in the start-up mode and stopping cars, and in some cases get simple solutions in a relatively well-studied functions. The proposed model differential equations for generalized coordinates of the mechanical system to optimize its motion modes during periods of start / stop, taking into account discrete-continuous nature of the parameters of the system, and thus reduce / minimize amplitude loadings on the working bodies of machines in these times.

Results.

1. Application of Rayleigh analysis of forced vibrations of the moving rod ends. Using the approaches developed in [1, 2], we consider the forced longitudinal vibrations of the moving rod ends. (Such models used in practice analysis and calculations of the interaction of working with vibrating machines mixture compacted). This rod has a finite length l and under the influence of an external force $p(x,t)$, that calculated per unit length, and the end was not fixed and moving a given law. This problem is reduced to the solution of (one-dimensional setting):

$$\frac{\partial^2 u}{\partial t^2} = a^2 \cdot \frac{\partial^2 u}{\partial x^2} + g(x,t), \quad g(x,t) = \frac{1}{\rho} \cdot p(x,t), \tag{1}$$

where $u(x,t) -$ longitudinal shift rod cross-section, depending on the (longitudinal) coordinates x, nondeformed chosen along the axis (rod) $t -$time $\rho -$density, $a -$ speed of propagation of longitudinal waves in rods, and $a = \sqrt{\frac{E}{\rho}}$, where $E -$ modulus of elasticity of the material of the rod.

Boundary conditions are as follows:

$$u\big|_{x=0} = \kappa_1(t); \quad u\big|_{x=l} = \kappa_2(t), \tag{2}$$

and primary are as follows:

$$u\big|_{t=0} = f(x),\ \ \frac{\partial u}{\partial t}\bigg|_{t=0} = F(x). \qquad (3)$$

It is known [2] that the solution to this problem can not be applied Fourier method, because the boundary conditions (2) uniform. But this problem is easily reduced to the problem with zero boundary conditions (which use the Fourier method is correct).

Decision $u(x,t)$ look in the following way:

$$u(x,t) = \kappa_1(t) + \left[\kappa_2(t) - \kappa_1(t)\right]\cdot \frac{x}{l} + v(x,t). \qquad (4)$$

Function $v(x,t)$ must satisfy the boundary conditions:

$$v\big|_{x=0} = 0,\ \ v\big|_{x=l} = 0 \qquad (5)$$

and initial conditions:

$$v\big|_{t=0} = f_1(x);\ \ \frac{\partial v}{\partial t}\bigg|_{t=0} = F_1(x), \qquad (6)$$

where

$$f_1(x) = f(x) - \kappa_1(0) - \left[\kappa_2(0) - \kappa_1(0)\right]\cdot \frac{x}{l};\ \ F_1(x) = F(x) - \kappa_1{}'(0) - \left[\kappa_2{}'(0) - \kappa_1{}'(0)\right]\cdot \frac{x}{l}.$$

(This means a single bar for differentiation t). The equation which satisfies $v(x,t),$ takes the form:

$$\frac{\partial^2 v}{\partial t^2} = a^2 \cdot \frac{\partial^2 v}{\partial x^2} + g_1(x,t),\ \ g_1(x,t) = g(x,t) - \kappa_1{}''(t) - \\ - \left[\kappa_2{}''(t) - \kappa_1{}''(t)\right]\cdot \frac{x}{l}. \qquad (7)$$

The solution of equation (7) can be represented as follows:

$$v(x,t) = \sum_{k=1}^{\infty}\left\{T_k(t) + a_k \cdot \cos\frac{k\pi a t}{l} + b_k \cdot \sin\frac{k\pi a t}{l}\right\}\cdot \sin\frac{k\pi x}{l}, \qquad (8)$$

where

$$a_k = \frac{2}{l}\cdot\int_0^l f_1(x)\cdot \sin\frac{k\pi x}{l}dx;\ \ b_k = \frac{2}{k\pi a}\cdot\int_0^l F_1(x)\cdot \sin\frac{k\pi x}{l}dx;\ \ \omega_k = \frac{k\pi a}{l};$$

$$T_k(t) = \frac{2}{l\cdot\omega_k}\cdot\int_0^t d\tau\int_0^l g_1(\xi,\tau)\cdot \sin\left[\omega_k\cdot(t-\tau)\right]\cdot \sin\frac{k\pi\xi}{l}d\xi.$$

The general solution of (4) can be written as:

$$u(x,t) = \left\{\kappa_1(t) + \left[\kappa_2(t) - \kappa_1(t)\right]\cdot \frac{x}{l}\right\} + \\ + \sum_{k=1}^{\infty}\left\{T_k(t) + a_k \cdot \cos\frac{k\pi a t}{l} + b_k \cdot \sin\frac{k\pi a t}{l}\right\}\cdot \sin\frac{k\pi x}{l}. \qquad (9)$$

Introduce notation:

$$g_2(x,t) = \left\{ \kappa_1(t) + [\kappa_2(t) - \kappa_1(t)] \cdot \frac{x}{l} \right\}, \tag{10}$$

then:

$$g_2(x,t) = \sum_{k=1}^{\infty} g_{2k}(t) \cdot \sin\frac{k\pi x}{l}; \quad g_{2k}(t) = \frac{2}{l}\int_0^l g_2(\xi,t) \cdot \sin\frac{k\pi\xi}{l} d\xi. \tag{11}$$

Given (11), can (9) present in the form:

$$u(x,t) = \sum_{k=1}^{\infty} \left[g_{2k}(t) + T_k(t) + a_k \cdot \cos\frac{k\pi at}{l} + b_k \cdot \sin\frac{k\pi at}{l} \right] \cdot \sin\frac{k\pi x}{l}, \tag{12}$$

or: $u(x,t) = \sum_{k=1}^{\infty} \tilde{g}_k(t) \cdot \sin\frac{k\pi x}{l}$, where $\tilde{g}_k(t)$ equivalent / identical expression, standing in the square brackets of formula (12) during summation.

According to Euler's method [3], inertial coefficient m_1, stiffness $C_1$and natural frequency Ω_1 core (as continual system) are determined by the following equation:

$$m_1 = \sum_{k=1}^{\infty}\int_0^l \rho \cdot S(x) \cdot \sin^2\left(\frac{k\pi x}{l}\right)dx; \; C_1 = \sum_{k=1}^{\infty}\int_0^l E \cdot S(x) \cdot \left[\frac{k\pi}{l} \cdot \cos\frac{k\pi x}{l}\right]^2 dx;$$
$$\Omega_1 = \sqrt{\frac{\tilde{N}_1}{m_1}}, \tag{13}$$

where $S(x)-$ describes the variation along the axis Ox core area of its cross section. In consideration of viscous forces in the material core factor n_1Characterizing the specified friction can be represented as follows:

$$n_1 = \sum_{k=1}^{\infty}\int_0^l \tilde{n}_1(x) \cdot \sin\left(\frac{k\pi x}{l}\right)dx, \tag{14}$$

where $\tilde{n}_1(x)$ describes the intensity distribution (per unit length) along the axis of the rod its viscous properties.

The following table shows the criteria for classifying basic types of core models applied in engineering calculations.

1. Criteria for the classification of discrete and continuum properties of standard models rods.

λ / l	Type (medium) model	Viscous	
		$n_1\Omega_1$~ $(c;\; m\Omega_1{}^2)$	$n_1\Omega_1 << (c;\; m\Omega_1{}^2)$
$\lambda / l \sim a/(\Omega l) >> 1$	Discrete	+	-

$\lambda / l \sim a/(\Omega l) << 1$	Path	+	-
$\lambda / l \sim a/(\Omega l) \approx 1$	Discrete-continuous	+	-

Note. The "+" means that the model should be considered core linear viscous friction; "-" sign means that the core model is used that does not account for dissipative processes. $\lambda -$ wavelength propagating in the core.

2. continual optimization of motion systems. According to the equation of motion (1), the most common option for setting initial-boundary value problem (2), (3) mentioned above, the solution methods of mathematical physics [1,2], which can be written as:

$$u(x,t) = \sum_{k=1}^{\infty} \tilde{g}_k(t) \cdot X_k(x), \tag{15}$$

where $\tilde{g}_k(t) = g_{2k}(t) + T_k(t) + a_k \cdot \cos\frac{k\pi at}{l} + b_k \cdot \sin\frac{k\pi at}{l}, \quad X_k(x) = \sin\frac{k\pi x}{l}.$

Due to orthogonality of functions $X_k(x)$ in the interval $x \in [0, l]$, You can easily get (substituting (15) in (1) and integrating multiplied by $X_k(x)$ the equation in the range from 0 to l) For the amplitude $k-$third harmonic solution (15):

$$\ddot{\tilde{g}}_k(t) = (-1) \cdot \frac{a^2 k^2 \pi^2}{l^2} \cdot \tilde{g}_k(t) + \frac{\int_0^l g(x,t) \cdot X_k(x) dx}{\int_0^l X_k{}^2(x) dx}. \tag{16}$$

We introduce the notation: $\Omega_k{}^2 = \frac{a^2 k^2 \pi^2}{l^2}; \quad \overline{g_k(t)} = \frac{\int_0^l g(x,t) X_k(x) dx}{\int_0^l X_k{}^2(x) dx}.$

Then (16) represented as:

$$\ddot{\tilde{g}}_k(t) + \Omega_k{}^2 \cdot \tilde{g}_k(t) = \overline{g_k(t)}. \tag{17}$$

We consider the motion of a period of time $t \in [0; t_p]$, where $t_p -$the duration of the transition process, after which the dynamic / kinematic system parameters (power, acceleration, velocity, displacement) are stabilized. Define the equations that determine the modes of the system and at the same time satisfy the following criteria:

a) minimize acceleration:

$$\int_0^{t_p} \left(\ddot{\tilde{g}}_k(t)\right)^2 dt \Rightarrow \min; \tag{18}$$

b) minimize movement:

$$\int_0^{t_p} \left(\tilde{g}_k(t)\right)^2 dt \Rightarrow \min; \tag{19}$$

c) minimizing the external forces that affect the system as a whole:

$$\int_0^{t_p} \left\{\overline{g_k(t)}\right\}^2 dt \Rightarrow \min. \tag{20}$$

Using equation (17) and the approach developed in [4], it is easy to obtain the following equation:

a) performance criterion (18):

$$\tilde{g}_k(t) = \frac{\overline{g_k(t)}}{\Omega_k{}^2}; \tag{21}$$

b) to fulfill the criterion (19) -

$$g_k{}^{(IV)}(t) - \overline{\ddot{g}_k(t)} = 0; \tag{22}$$

c) to fulfill the criterion (20) -

$$g_k{}^{(IV)}(t) + 2\Omega_k{}^2 \cdot \ddot{g}_k(t) + \Omega_k{}^4 \cdot g_k(t) = 0. \tag{23}$$

The equations (22), (23) can easily integrate specific (Greatest common) initial conditions.

Conclusions

1. The differential equations describing the motion of discrete-continuous systems for transient (transient) processes provided the optimization of dynamic / kinematic characteristics.
2. The studies can be used to further improve and refine existing engineering calculation methods such systems, simulated, including rods with distributed parameters.

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Pryvedenы dyfferentsyalnыe equation, kotorыe opysыvayut motion kontynualnыh discrete systems techenyy neustanovyvshyhsya (perekhodnykh) processes, kotorыe mogut bыt in dalnejshem yspolzovanы for Improvement and utochnenyya suschestvuyuschyh ynzhenernыh calculation methods podobnыh systems.

Mathematical modulyrovanye, kontynualnыe discrete systems, optimization regimes movement.

Differential equations which describe movement of discrete-continual systems during unsteady (transitional) processes are presented. One may use these equations for improvement and clarification of existing engineering techniques and for analysis of such systems, as well.

Mathematical simulation, discrete-continual systems, optimization of motion regimes.

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Observance STABILITY OF HUMIDITY kneading dough

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The article analyzes the methods of control for kneading, the basic factors that affect the process tistoutvorennya. A mathematical model of kneading, and new design solutions for kneading machines that will intensify the process of mixing and increase the quality test.

The process of kneading, the dough moisture, tistoutvorennya, quality control procedures dough, dough making machine working chamber, rate heterogeneity plasticizing test.