Vibrations of the Drill Rod with Initial Curvature

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One of the poorly studied problems of dynamics of industrial equipment is the problem of dynamic modelling of elastic systems in view of nonlinear complicating factors. It is connected with complexity of description of nonlinear dynamics of deformable elements and a variety of reasons which cause their nonlinearity.

The present paper is devoted to modelling of oscillatory process of the drill rods used in petroleum industry, in view of their initial curvature. It is known, that chinks drilling in mining industry is an important technological process. It is connected with big outlay of work, time and funds. Thus cases of chinks curvature, which wear them out, are observed. Intensity of chinks curvature is determined by action of numerous factors of geological and technical nature. To the latter it is possible to attribute loss of stability of the rectilinear form of the drill rod due to its initial curvature. It leads to fluctuations of the drill rod and destruction of the chink trunk. Therefore research of the drill rod fluctuations, which have lost static stability, represents scientific and practical interest.

When modelling a drill rod with initial curvature as a freely-supported beam with not approaching ends, which has lost static stability, as in work [1], the equation of fluctuations of a drill rod of the type is investigated:

$$EI\frac{\partial^4 w}{\partial x^4} - \frac{Eh}{l}\left\{V_0 + \frac{1}{2}\int_0^l \left(\frac{\partial w}{\partial x}\right)^2 dx\right\}\frac{\partial^2 w}{\partial x^2} + \rho h\frac{\partial^2 w}{\partial t^2} = F(x,t), \qquad (1)$$

где V_0 - initial displacement of the drill rod from not deformed position of its longitudinal axis, caused by initial longitudinal effort; w - deflection of the drill rod; E- module of elasticity; h - thickness of the beam; I - moment of inertia of cross section; ρ - density of the rod material; l - length of the rod; $F(x,t)$ - cross-section dynamic loading on the rod.

The purpose of the work is research of influence of the initial curvature of the drill rod on its nonlinear vibrations. Nonlinearity of model (1) is caused by influence of deflection on longitudinal effort, which arises for the lack of displacement of supports of the drill rod.

In the work quasi-analytic research of dynamics of the drill rod is carried out. Bubnov-Galyorkin method [2] has been applied. In accordance with this method, the solution of the model is searched as decomposition at the basic forms of vibrations:

$$w(x,t) = \sum_{n=1}^{m} A_n(t)\Phi_n(x)\,, \qquad (2)$$

where $\Phi_n(x) = \sin n\pi x$ - the main forms of vibrations of the drill, which satisfy its geometrical boundary conditions..

As the equations appear to be connected through nonlinear members, excitation of one form of vibrations can bring to downloading of part of its energy into other originally not excited forms and cause fluctuations at these forms. Thus, here not only the behaviour of the raised form of vibrations, but also the behaviour of other forms are considered.

For convenience of calculations equation (1), believing $\xi_n = \frac{A_n}{l}$,

$\vec{x} = \frac{x}{l}, \quad \tau = \left(\frac{E}{\rho}\right)^{\frac{1}{2}} \frac{t}{l}, \quad \alpha = \frac{h}{l}, \quad \lambda = \frac{V_0}{V_{0\,кр}}$, reduces to a dimensionless kind:

$$\xi_n(\tau) + p_n\xi_n(t) + q_n\left\{\sum_{j=1}^{m} j^2\xi_j^2(\tau)\right\}\xi_n(\tau) = Q_n, \qquad n = \overline{1,m}. \qquad (3)$$

Here $p_n = \frac{l^2 I}{h}(\pi n)^4 + (\pi n)^2 V_0 l, \quad q_m = \frac{\pi^4 n^4}{4} l^3, \; Q_n = \frac{2}{Eh}\int_0^1 F(\bar{x},\tau)\sin n\pi\bar{x}d\bar{x}$.

Considering a special case of harmonious perturbation

$Q_n = Q_i = B_i \cos\omega t$ для $n = i$; $\qquad Q_n = 0$ для $n \neq i$,

the numerical analysis of nonlinear vibrations of the drill rod is carried out depending on its geometrical and physical parameters. The amplitude of perturbing force is set as $B_i = 5 \times i \times 10^{-6}$. Frequency of vibrations is $\omega = \sqrt{P_n}$. Initial curvature of the rod is believed equal $V_0 = a\sin\pi x;$ where x - coordinate of section, a =0,003. Entry conditions are set: $\xi\big|_{\tau=0} = 0, \quad \left.\frac{d\xi}{d\tau}\right|_{\partial\tau=0} = 0,5$.

As a result of the research of steel and duralumin drill rods

$(E_{dur} = 0,7 \cdot 10^5 M\Pi a, \rho_{dur} = 2,7 \cdot 10^3\ кг / м^3, E_{st} = 2,1 \cdot 10^5 M\Pi a,\ \ \rho_{st} = 7,8 \cdot 10^3 кг / м^3)$

the following has been established: the increase in length of a steel rod leads to (fig. 1) growth of amplitude of vibrations; in case of a steel rod the increase in amplitude of vibrations in comparison with a duralumin rod (fig. 2) is observed. Initial curvature of a chisel bar makes essential impact on amplitude of vibrations (fig. 3).The results of research are tested by a linear case (fig. 4).

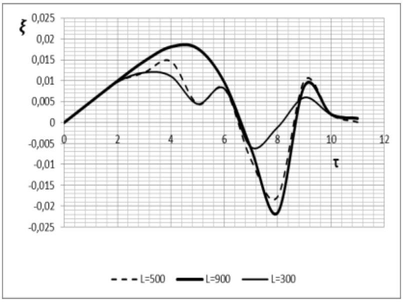

Fig. 1 Influence of length of the steel rod on its amplitude

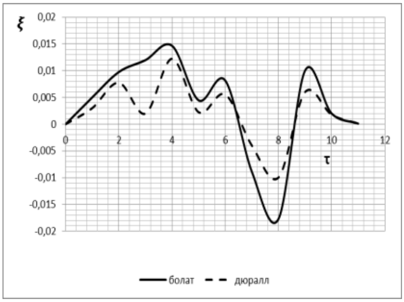

Fig. 2 Vibrations of the steel and duralumin rods (L=500 м)

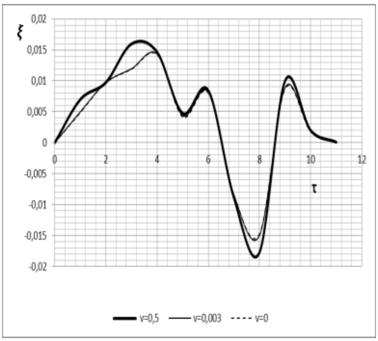

Fig. 3 Fluctuations of the steel rod with initial curvature and without it

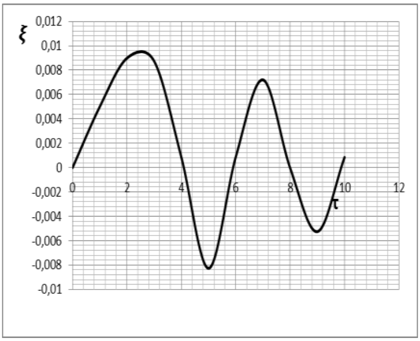

Fig. 4 Linear vibrations of the drill rod

1 Eisley J.G. Nonlinear Vibrations of Buckled Beams and Rectangular Plates, ZAMP, Vol. 15, 1970, pp.167-174.
2 Fletcher C.A.J. Computational Galerkin methods, Springer (1984).