COMPUTER MODELING OF TRANSIENTS PROCESSES IN THE NONLINEAR SYSTEM OF THE DRILLING ELECTRIC DRIVE INCLUDING THE PART WITH THE DISTRIBUTED PARAMETERS

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ABSTRACT

The new numerical method of calculation in nonlinear system of the drilling electric drive including a part with distributed parameters and which is based on the theory of discrete analogue of the integrated equation of convolution is offered here. In the considered case the operation of continuous integration by summation using the formula of trapezium is replaced.

Keywords: computer modeling, nonlinear system, drilling, electric drive, numerical method.

I. INTRODUCTION

The problems of drilling oil wells operation results by necessity of studying of complex character of movement of all parts of drilling installation which takes place in case of rotary way of drilling [1-3].

Distinctive feature of drilling electric drives in case of rotary drilling – the presence of a boring column through which the rotating moment from drive of engine goes to the executive mechanism – a drilling instrument. It is necessary to note, that coming on the input of system of the electric drive of the information about character of changing of loading on a drilling instrument occurs to some delay, owing to that circumstance, that the column of boring pipes is object with the distributed parameters. Therefore the studying of a question of dynamics in the electric drive which includes the part with distributed parameters represents doubtless scientific and practical interest [1-3].

In given article the further generalization on development of the specified numerical method [3] for calculation of transients processes in nonlinear system of the drilling electric drive with the distributed by the replacing operation of continuous integration by summation using the formula of trapezium.

The essence of the offered numerical method is based on the using of discrete analogue of the integrated equation of convolution [3]. Advantage of the offered approach is that it allows to find transients in nonlinear system of the drilling electric drive with the distributed parameters, without finding of roots of the characteristic equation, that considerably simplifies mathematical tricks and expands a circle of solved practical tasks.

II. MAIN PART

The equation of movement of the electric drive we shall present as:

$$I\frac{d\overline{\omega}_H(t)}{dt} = M_D(t) - M_c(t),$$

(1)

where $M_D(t), M_C(t)$ - the rotating moment of the electric motors and the moment of loading accordingly; I - the moment of inertia of a drive; $\omega_n(t)$-angular speed droved engine.

In expression (1) rotating moment is nonlinear function $M_D(t) = \Phi[\omega_n(t)]$.

We shall present nonlinear dependence $M_D(t) = \Phi[\omega_n(t)]$ as approximate its piece-linear functions as:

$$M_D(t) = a_j \pm b_j \omega_H(t), \qquad (2)$$

where $j = 1,2,3,..., z;$ a_j, b_j - parameters of linearization for corresponding districts of mechanical characteristic of the engine.

Expression (1) with the account (2) provided that prior to the beginning of transient angular speed of the engine was ω_{beg} in the operational form it is possible to present as:

$$(IS \pm b_j)\omega_e(S) = \frac{a_j}{S} + I\omega_{beg} - M_C(S), \qquad (3)$$

where $\omega_n(S)$, $M_C(S)$- Laplace image of functions $\omega_n(t)$, $M_C(t)$, s - the operator of Laplace transformation.

Passing from the equation (3) in area of originals, we shall receive:

$$\omega_H(t) = \frac{a_j}{b_j}(1 - k_2'(t)) +$$

$$+\overline{\omega}_{beg}k_2'(t)-\frac{1}{I}\int_0^t k_2'(\theta)M_c(t-\theta)d\theta, \qquad (4)$$

where

$$k_2'(t)=e^{\pm\frac{b_j}{I}t}.$$

In equation (4) $M_C(t)$ is unknown function. Definition of its value is carried out by the following technique.

The transients proceeding in a column of boring pipes as object with distributed parameters at rotation fluctuations without taking into account friction between a column of pipes and a clay solution are described by the wave equation [1,3]

$$-\frac{\partial\overline{\omega}}{\partial x}=k_1\frac{\partial M}{\partial t}, \qquad (5)$$
$$-\frac{\partial M}{\partial x}=k_2\frac{\partial\overline{\omega}}{\partial t},\ 0\le x\le l.$$

where $\omega=\omega(x,t)$, $M=M(x,t)$ -change of angular sped and he twisting moment to any point of a column of pipes during the any moment of time; k_1 -coefficient of elasticity; k_2 - the moment of inertia; l - length of a column of boring pipes.

Entry conditions:

$$\omega(x,t)_{t=0}=0,\ \ M(x,t)_{t=0}=0.$$

Boundary conditions look like:

$$\omega(x,t)_{t=0}=\omega_H(t),\ \ \omega(x,t)_{t=l}=M(x,t)_{t=l},$$

where μ - the factor determining communication between angular speed $\omega(x,t)$ and the moment of torsion $M(x,t)$ in a final point of a link with the distributed parameters.

In a considered case a part the chisel – working face is represented as active loading of a shaft by resistance μ. For the free and fixed ends it accepts values accordingly $\mu=\infty$ and $\mu=0$.

The solution of system of the differential equations (5) under the accepted initial and boundary conditions allows to receive the full information on change of angular speed and the moment of torsion, both on length of a column of pipes, and on time.

At the decision of a task in view at the first stage it is necessary to receive Laplace images for functions $\omega(x,t), M(x,t)$.

By using this method, we shall receive expression for the specified functions in the operational form:

$$\omega(x,t)=\frac{Sn\gamma(l-x)+\frac{M}{\pi}Cn\gamma(l-x)}{Sn\gamma l+\frac{M}{\rho}Cn\gamma l}\omega_H(s), \qquad (6)$$

$$M(x,s)=\frac{1}{\rho}\frac{Cn\gamma(l-x)+\frac{\mu}{\rho}Sn\gamma(l-x)}{Sn\gamma l+\frac{\mu}{\rho}Cn\gamma l}\omega(s), \qquad (7)$$

where

$$\gamma=s\sqrt{k_1k_2}=\frac{s}{c}$$

coefficient of distribution of a wave;

s - the operator of Laplace transformation;

$\rho=\sqrt{\dfrac{k_1}{k_2}}$ - wave loading;

$\omega(x,s), M(x,s)$-Laplace images of functions $\omega(x,t), M(x,t)$.

Expressions (6),(7) it is possible to present as:

$$\omega(\delta,s)\left[\frac{1}{s}-e^{\varphi}k_1(s)\right]=\left[k_2(s)-e^{\varphi}k_3(s)\right]\omega_H(s), \qquad (8)$$

$$M(\delta,s)\left[\frac{1}{s}-e^{\varphi}k_1(s)\right]=\frac{1}{\rho}\left[k_2(s)+e^{\varphi}k_3(s)\right]\omega_H(s), \qquad (9)$$

where

$$k_1(s)=\frac{1}{s}e^{-\frac{2l}{c}s},\quad k_2(s)=\frac{1}{s}e^{-\frac{2l\delta}{c}s},$$
$$k_3(s)=\frac{1}{s}e^{-\frac{2l(1-\delta)}{c}s},\ e^{\varphi}=\frac{\rho-\mu}{\rho+\mu},\ \delta=\frac{x}{2l}.$$

At the free end of a column of pipes $e^{\varphi}=-1$. For jammed on the end of a column of pipes $e^{\varphi}=1$.

Transition from the equation (8),(9) concerning images to the equation concerning originals, we shall receive:

$$\int_0^c\omega(t-\theta,\delta)1(\theta)d\theta-e^{\varphi}\int_{\frac{2l}{c}}^t\omega(t-\theta,\delta)k_1(\theta)d\theta=$$
$$=\int_{\frac{2l\delta}{c}}^t\omega_H(t-\theta)k_2(\theta)d\theta-$$
$$-e^{\varphi}\int_{\frac{2l}{c}(1-\delta)}^t\omega_H(t-\theta)k_3(\theta)d\theta. \qquad (10)$$

$$\int_0^t M(t-\theta,\delta)1(\theta)d\theta-e^{\varphi}\int_{\frac{2l}{c}}^t M(t-\theta,\delta)k_1(\theta)d\theta=$$
$$=\frac{1}{\rho}\int_{\frac{2l\delta}{c}}^t\omega_H(t-\theta)k_2(\theta)d\theta+$$
$$+\frac{1}{\rho}\int_{\frac{2l}{c}(1-\delta)}^t\omega_H(t-\theta)k_3(\theta)d\theta. \qquad (11)$$

The integrated equations (4),(10),(11) can be solved numerically if to repleace integrals with the sums.

In this connection, according to works [1,2], using communication between continuous time t and discrete n as $t=nT/\lambda$ (where λ-any integer), we make digitization of the integrated equations (4),(10),(11) at the chosen interval T/λ replacing operation of continuous integration by summation on a method of restangulars. Thus instead of (4),(10),(11) we shall receive

$$\omega_n(n)=\frac{a_j}{b_j}\left(1-k_2'(n)\right)+\omega_{beg}k_2'[n]-$$
$$-\frac{T}{\lambda I}\sum_{m=0}^{n}\left(k_2'[m]M_C[n-m]+k_2'[n-m+1]M_C[m-1]\right), \quad (12)$$

where $k_2^1[n]=e$, $\alpha=\dfrac{Tb_j}{\lambda I}$

$$\sum_{m=0}^{n}\left(1[m]\omega[n-m,\delta]+1[n-m+1]\omega[m-1,\delta]\right)-$$
$$-e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]\omega[n-m,\delta]+1[n-m+\lambda-1]\omega[m-1,\delta]\right)=$$
$$=\sum_{m=\lambda\delta}^{n}\left(\omega_H[n-m]1[m-\lambda\delta]+\omega_H[m-1]1[n-m+\lambda\delta+1]\right)-$$
$$-e^{\varphi}\sum_{m=\lambda(1-\delta)}^{n}\left(1[m-\lambda(1-\delta)]\omega_H[n-m]+1[n-m+\lambda(1-\delta)+1]\right). \quad (13)$$

$$\sum_{m=0}^{n}\left(1[m]M[n-m,\delta]+1[n-m+1]M[m-1,\delta]\right)-$$
$$-e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]M[n-m,\delta]+1[n-m+\lambda+1]M[m-1,\delta]\right)=$$
$$=\frac{1}{\rho}\sum_{m=\lambda\delta}^{n}\left(\omega_H[n-m]1[m-\lambda\delta]+\omega_H[m-1]1[n-m+\lambda\delta-1]\right)+$$
$$+\frac{1}{\rho}\sum_{m=\lambda(1-\delta)}^{n}\omega_H[n-m](1[m-\lambda(1-\delta)]+\omega_H[m-1]1[n-m+\lambda(1-\delta)+1]). \quad (14)$$

where $\omega[n,\delta]$, $M[n,\delta]$ -values of initial functions in the generalized form

$$\sum_{m=0}^{n}\left(1[m]\omega[n-m,\delta]+1[n-m+1]\omega(m-1,\delta)\right)=\omega[n,\delta]+$$
$$+\sum_{m=0}^{n-1}1[n-m]\omega[m,\delta]+1[m-1]\omega[n-m,\delta]. \quad (15)$$

$$\sum_{m=0}^{n}1[m]M[n-m,\delta]+1[n-m+1]M(m-1,\delta)=M[n,\delta]+$$
$$+\sum_{m=0}^{n-1}1[n-m]M[m,\delta]+1[m-1]N[n-m,\delta]. \quad (16)$$

Expression (13) with the account (15) will be:

$$\omega[n,\delta]+\sum_{m=0}^{n}\left(1[n-m]\omega[m,\delta]+1[m-1]\omega[n-m,\delta]\right)-$$
$$-e^{\varphi}\sum_{m=0}^{n}\left(1[m-\lambda]\omega[n-m,\delta]+1[n-m+\lambda+1]\omega(m-1,\delta)\right)=$$
$$=\sum_{m=\lambda(1-\delta)}^{n}\left(\omega_H[n-m]1[m-\lambda\delta]+\omega_H(m-1)1[n-m+\lambda\delta+1]\right). \quad (17)$$

From here we find the following recurrent ration allowing consistently to calculate function

$$\omega[n,\delta]=\sum_{m=\lambda d}^{n}\left(1[m-\lambda\delta]\omega_H[n-m]+\omega_H[m-1]1[n-m+\lambda\delta+1]\right)-$$
$$-e^{\varphi}\sum_{m=\lambda(1-d)}^{n}\left(1[m-\lambda(1-\delta)]\omega_H[n-m]+1[n-m+\lambda(1-\delta)+1]\right)+$$
$$+e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]\omega[n-m,\delta]+1[n-m+\lambda+1]\omega[n-m,\delta]\right)-$$
$$-\sum_{m=0}^{n-1}\left(1[n-m]\omega[m,\delta]+1[m-1]\omega[n-m,\delta]\right). \quad (18)$$

By carrying out of similar operations, we receive the following recurrent ration for definition of value of trellised function $M[n,\delta]$:

$$M[n,\delta]=\frac{1}{\rho}\sum_{m=\lambda\delta}^{n}\left(1[m-\lambda\delta]\omega_H[n-m]+1[n-m+\lambda\delta+1]\omega_H[m-1]\right)+$$
$$+e^{\varphi}\sum_{m=\lambda(1-\delta)}^{n}\left(1[m-\lambda(1-\delta)]\omega_H[n-m]+1[n-m-\lambda(1-\delta)+1]\omega_H[m-1]\right)+$$
$$+e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]M[n-m,\delta]+1[n-m+\lambda+1]M[m-1,\delta]\right)+$$
$$+e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]M[n-m,\delta]+1[n-m+\lambda+1]M[m-1,\delta]\right)-$$
$$-\sum_{m=0}^{n-1}\left(1[n-m]M[m,\delta]+1[m-1]M[n-m,\delta]\right). \quad (19)$$

At $x=0$ from a recurrent ration (19) it is received the following expressions for trellised function $M_H[n]$

$$M_H[n]=\frac{1}{\rho}\sum_{m=0}^{n}\left(1[m]\omega_H[n-m]+1[n-m+1]\omega_H[m-1]\right)+$$
$$+e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]\omega_H[n-m]+1[n-m-\lambda+1]\omega_H[m-1]\right)+$$
$$+e^{\varphi}\sum_{m=\lambda}^{n}\left(1[m-\lambda]M_H[n-m]+1[n-m+\lambda+1]M_H[m-1]\right)-$$
$$-\sum_{m=0}^{n-1}\left(1[n-m]M_H[m]+1[m-1]M_H[n-m]\right). \quad (20)$$

Taking into account expression (20) in expression (12) we determine values of trellised function $\omega_H[n]$.

III. CONCLUSION

The offered numerical method can be used at designing and operation of chisel systems at rotary drilling of oil wells.

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