

NEW SIMPLICITY NUMERICAL METHOD FOR COMPUTER SIMULATION OF TRANSIENTS PROCESSES IN THE MAIN OIL PIPELINE WITH CENTIFUGAL PUMPING STATIONS

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ABSTRACT

The new simplicity numerical method for computer simulation of transients processes in the mains oil pipeline what objects with distributed parameters, with centrifugal pumping stations. The algorithms convenient for carrying out of calculations on a computer are received.

Keywords: numerical method, computer simulation, transients processes, centrifugal

I. INTRODUCTION

Now due to wide introduction of computer techniques in produce of engineering calculation, to creation of numerical methods of calculation of transient's processes in the mains oil pipeline pays steadfast attention.

One of effective numerical methods of calculation of dynamic processes in object with me distributed parameters, described by the equations in individual derivatives of hyperbolic type is the numerical method, is based on use of discrete analogue of the integrated equation of convolution [1-3].

In given article the further generalization and development of the given numerical method [1-3], for creation simplicity of method of transients processes in the mains oil pipeline with centrifugal pumping stations.

II. MAIN TEXT

In given case main pipeline considered as endlessly lain with distributed parameters [1]. The transition processes in the main oil pipelines describes by the telegraph equations [1].

$$\begin{aligned} -\frac{\partial H}{\partial x} &= K_1 \frac{\partial Q}{\partial t} + K_3 Q, \\ -\frac{\partial Q}{\partial x} &= K_2 \frac{\partial H}{\partial t}, 0 \leq x \leq l \end{aligned} \quad (1)$$

Where H, Q change of pushing and flow rate to any of main oil pipeline to any moment of time

$$k_1 = \frac{1}{gF}, k_2 = \frac{gF}{c^2}, k_3 = \frac{2a}{gF}, 2a = \frac{\eta \omega_{cp}}{2D}$$

Coefficient loss of inebriated by I.A.Charniy.

F - Cross section, D -inner pipe diameter, η – Darcy - Wasatch fraction factor, ω_{cp} - velocity of flow stationary regimes, C -the velocity of sound in flow, g -acceleration, l - pipe length.

Entry conditions:

$$H(x, t)_{t=0} = 0, \quad Q(x, t)_{t=0} = 0$$

Where H_0 – entry pushing.

Boundary conditions:

$$H(x, t)_{x=0} = H_H(t),$$

Where $H_H(t)$ – arbitrary changing of pushing in the beginning pipelines.

In the initial of decision given task as unknown. It is determine for of decision given of task.

The equation of movement of the pumping us shale present as:

$$T_{\mathcal{A}} \frac{dv(t)}{dt} = Mg(t) - M_c(t), \quad (2)$$

Where $T_{\mathcal{A}} = \frac{n_c}{M_H} \cdot \frac{\theta D^2}{375}$ constant of time, n_c – the

synchrony current angular speeds of rotation of a rotor of the electric motor of the pumping

M_H - nominal moment, θD^2 – the sun of the moments of inertia of pumping, $Mg(t) = \frac{M_a(t)}{M_H}$ - the rotating moment

of the electric motor and the moment resistance of loading accordingly, $v(t) = \frac{n_a(t)}{n_c}$ - change speeds of rotation of a

rotor of the motor.

In expression (2) rotating moment in nonlinear function

$$Mg(t) = \Phi[v(t)].$$

We shall present nonlinear dependence $Mg(t)=\Phi[v(t)]$ as approximate its piece – linear functions as:

$$Mg(t) = \hat{a}_j \pm \hat{b}_j v(t), \quad (3)$$

Where, $j=1, k'_0, k'_0$ – parameters of linearization for corresponding districts of mechanical characteristic of the engine.

The power characteristics of centrifugal pumping as approximate of expression:

$$P(t) = \hat{C} v^3(t) + \hat{d} v^2(t) q_H(t), \quad (4)$$

Where, $\hat{c} \hat{d}$ – parameters of linearization of power characteristics of pumping, $q_H(t) = \frac{Q_H(t)}{Q_{nom}}$ – change of

few in the point $x=0$ of pipeline.

The moment resistance of loading accordingly determine from of expression:

$$M_c(t) = \frac{P(t)}{v(t)} = \hat{C} v^2(t) + \hat{d} v(t) q_H(t), \quad (5)$$

The pushing characteristics of pumping ass approximate of expression:

$$h_{HC}(t) = a_1 v^2(t) - b_1 q_H^2(t) \quad (6)$$

Where, a_1, b_1 – parameters of linearization of pushing characteristics of pumping.

The change of pushing on outlet of pumping determine from of expression:

$$h_H(t) = h_0 + h_{HC}(t),$$

We h_0 – are pushing on entrance of pumping.

The solution of system of the differential equations (1) under the accepted initial and boundary condition allow to receive the full information on change of angular pushing and the from rate, both on length of a column of pipeline, and on time.

At the decision of a task in view at the first stage it is necessary to receive replace images for functions $H(x,t), Q(x,t)$.

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

$$H(x,s) = \left(H_H(s) - \frac{H_0}{s} \right) e^{-\gamma x} + \frac{h - H_0}{s}, \quad (8)$$

$$Q(x,s) = \frac{1}{b(s)} \left(H_H(s) - \frac{H_0}{s} \right) e^{-\gamma x}, \quad (9)$$

Where $\gamma(s) = \sqrt{sk_2(sk_1 + k_3)}$ – operator constant of wave

spreading, $b(s) = \sqrt{\frac{sk_1 + k_3}{sk_2}}$ – operator wave resistance

pipeline with account of losses, S – operator of replace transformation.

Expression (8), (9) one may present in the form:

$$\frac{1}{s} H(\delta, s) = K_1(s) \left(H_H(s) - \frac{H_0}{s} \right) + \frac{H_0}{s^2}, \quad (10)$$

$$\frac{1}{s} Q(\delta, s) = \frac{1}{b} K_2(s) \left(H_H(s) - \frac{H_0}{s} \right), \quad (11)$$

Where $b = \sqrt{\frac{k_1}{k_2}}$ – wave resistance of pipeline without taking into account losses,

$$k_1(s) = \frac{1}{s} e^{-\gamma \delta}, \quad k_2(s) = \frac{e^{-\gamma \delta}}{\sqrt{s(s+2a)}}, \quad \delta = \frac{x}{1} - \text{constant.}$$

On the base of the theorem of convolution [1, 3], passing from the equations (10), (11) concerning images to the equations concerning originals, we shall receive:

$$\int_0^t H(t-\theta, \delta) l(\theta) d\theta = \int_{\delta/c}^t (H_H(t-\theta) - H_0) K_1(\theta) d\theta + H_0 \int_0^t l(\theta) (t-\theta) d\theta, \quad (12)$$

$$\int_0^t Q(t-\theta, \delta) l(\theta) d\theta = \frac{1}{b} \int_{\delta/c}^{t/c} (H_H(t-\theta) - H_0) K_2(\theta) d\theta, \quad (13)$$

The integrated equations (12), (13) can be solved numerically it to replace integrals with the sums. Therefore, using connection between continuous time t and discrete n as $T=nT/\lambda$ [1, 3] ($n=1, 2, \dots, E=l/c$), we make digitization of the equations (12), (13) at chosen interval T/λ replacing operations of continuous integration by summation using the formula of trapezium.

He instead (12), (13) we receive the following recurrent equation for functions determinations

$$h[n, \delta] = \sum_{m=\delta}^n (h_H[n-m] - h_0) k_1[m] + k_1[n-m+1] (h_H[m-1] - h_0) + h_0 \sum_{m=0}^n (l[m] [n-m] + l[n-m+1] [m-1]) - \sum_{m=1}^n (h[n-m, \delta] l[m] + l[n-m+1] h[m-1, \delta]) \quad (14)$$

$$q_{[n]} = \sum_{m=\lambda\delta}^n (h_{H[n-m]} - h_0) k_2[m] + k_2[n-m+1] (h_{H[m-1]} - h_0) - \sum_{m=1}^n (q_{[n-m, \delta]} l[m] + l[n-m+1] q_{[m-1, \delta]}) \quad (15)$$

$$\text{Where } k_1[n] = \begin{cases} 0 & \text{for } n < \lambda\delta \\ e^{-a\delta\tau} + \frac{a\delta\tau}{2} \sum_{m=\lambda\delta+1}^n \sum_{i=0}^n B[m-i], \end{cases}$$

$$\text{For } n > \lambda\delta \quad B[n] = e^{\frac{a\tau}{\lambda} n} \frac{I_1\left(\frac{a\tau}{\lambda} \sqrt{n^2 - (\lambda\delta)^2}\right)}{\sqrt{n^2 - (\lambda\delta)^2}}$$

$$k_1[n] = \begin{cases} 0 & \text{при } n < \lambda\delta \\ e^{-a\delta\tau} I_0\left(\frac{a\tau}{\lambda} \sqrt{n^2 - (\lambda\delta)^2}\right) & \text{For } n > \lambda\delta \end{cases}$$

$I_0[n], I_1[n]$ – Bessel functions of zero and first degree.

The error of calculations connected, as the continuous functions characteristics smaller varied from the corresponding grid functions.

In (14), (15) for determinate meaning function $h_H[n]$ from recurrent formulas by $x=0$ we shall receive:

$$q_H[n] = h_{nc[n]} + B[n], \quad (16)$$

Where,

$$B[n] = \sum_{m=1}^n (h_{HC[n-m]} k'_2[m] + k'_2[n-m+1] h_{HC}[m-1]) - \sum_{m=1}^n (q_{H[n-m]} l[m] + l[n-m+1] q_{H}[m-1])$$

$$k_2'[n] = e^{-\frac{a\tau}{\lambda}n} I_0\left(\frac{a\tau}{\lambda}n\right)$$

Expression (6) any may present in the discrete form:

$$h_{hc}[n] = a_1 v^2[n] - b_1 q_H^2[n] \quad (17)$$

Expression (16) with account (17) we shall:

$$q_{H[n]} = \frac{-1 + \sqrt{1 + 4b(av^2[n] + B[n])^2}}{2b} \quad (18)$$

In (18) for determine meaning function $v[n]$

(2) We shall:

$$v[n+1] = \frac{T}{\lambda T_g} (Mg[n] - M_c[n]) + v[n], \quad (19)$$

Where $Mg[n] = \hat{a}_j \pm \hat{b}_j v[n]$, $v[n]_{n=0} = 0$

$$M_c[n] = \hat{c} v^2[n] + \hat{d} v[n] q_H[n]$$

Received recurrent formulas (14), (15) are easily realized on the computer.

III. CONCLUSION

Thus, the new simplicity numerical method for computer simulation of transients processes in the mains oil pipeline what objects with distributed parameters, with centrifugal pumping stations is presented. The algorithms convenient for carrying out of calculations on a computer are received.

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