MATHEMATICAL MODEL OF STABILIZATION OF VIBRATION MOVEMENTS OF HYDRAULIC SYSTEMS OF TRANSPORT VEHICLES

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Abstract. *This article provides information on the mathematical model of the stabilization of vibration movements of hydraulic systems of vehicles and the theories of control stability and stabilization of hydraulic systems dynamics.*

Keywords: *hydraulic systems, mathematical modeling, stabilization law, stabilization, hydraulic distributor, wheeled machines, asymptotic stability.*

INTRODUCTION

In the world, a special place is given to the use of advanced information technologies, which allow to create competitive technical systems in modern conditions, as well as to solve the problems of reliable control of vehicles related to the improvement of production efficiency, development and improvement of technical, especially hydraulic systems. In this regard, in a number of countries of the world, including the USA, Japan, Germany, India, South Korea, Mexico, Spain, Brazil, France, and Uzbekistan, the rapid development of dynamic process research for the development of advanced control methods of dynamic processes to solve problems such as modern technical systems, in particular, scientific research is being conducted on the use of hydraulic systems.

In the world, scientific and research work is being carried out in the field of solving the problems of managing various physical dynamic processes, whose reliable operation is ensured and quality indicators are improved with the use of information and communication technologies. It is an important issue to ensure the operation within the given working regime for the management of the object in this direction.

In our republic, great attention is paid to the implementation of measures aimed at solving the problems of creation and development of new types of agricultural machinery. In the strategy for the further development of the Republic of Uzbekistan in 2017-2021, "... further modernization and modernization of the industry by transferring it to a qualitatively new level aimed at the rapid development of high-tech processing areas, ... introduction of information and communication technologies into the economy, ... agriculture issues of modernization and rapid development of the economy" [1] are defined.

PJHolmes, FCMoon, T.Hamamoto, B.Yao, H.Li, H.Watson, G.Dostal, J.Wagner, N.F.Metlyuk, V.P. Avtushko, N.S. Gaminin, A.I. Bozhenov, A.M. Selivanov, T.M. Bashta, N.A. Lakota, A.M. Lyapunov, V.D. Furasov, V.N. Afanasev , O.V. Lebedev, G.Q. Annaqulova, H.T. Toraev, A.A. Shermukhamedov, and other scientists made great contributions.

Problems of mathematical modeling of vibration processes in hydraulic systems of machines V.N. Prokofev, D.N. Popov, N.A. Lakota, N.S. Gaminin, O.V. Lebedev, B. Azimov, R.R. Ergashev, E. Considered in the works of Orinboev, F.Murodov, G.Q.Annakulova and others.

RESULTS

The practical results of the research are as follows:

developed an algorithm and program for calculating complex vibrations in wheeled machine structures;

in the control channel of the hydrodistributor (of the control valve in the closing part) by studying the process of hydraulic hammering, it was determined that the changes in the obtained pressures, the oscillograms of the damping of the pressure fluctuations in the pipe during a single pulse, obtained by other authors , correspond to the experimental data indicated to arrive;

Based on the determination of the law of stabilization, recommendations are offered for effective control of vibration processes in hydraulic systems of wheeled machines.

The reliability of the research results is based on the fact that the mathematical models are based on the laws describing dynamic processes (the law of conservation of energy), the strict formation of which is based on the use of theoretical and scientifically based computational mathematics methods, the calculated dynamic characteristics qualitatively correspond to the expected physical processes.

The results of the research scientific importance wheeled hydraulic systems of machines complicated It is explained by mathematical modeling of problems, numerical and analytical solution methods, effective calculation algorithms were developed and software tools were created using them.

The practical significance of the research results is explained by the development of methods for calculating the transition modes of vibration processes in the hydraulic systems of wheeled machines, as well as the determination of the conditions for the occurrence of stochastic and self-oscillations.

The controlled system, the controlled object and the motion excitation are described by the following equation:

$$\dot{x} = F(x,t) + G(x,t)u, \qquad (1)$$

here $x - n$ vector size ; $F(x,t)$ – vector-function, $G(x,t)$ – $(n \times m)$ dimensional matrix, $u - n$ dimensional control vector , $m \le n.$

A device that directly shapes the stabilization law is called a rectifier.

Stabilization issue t_0 and x_0 includes requirements for smooth asymptotic stability (stability). In all cases, the method of Lyapunov functions serves as the main method for solving such problems. The solution of the problem within this method is given as follows:

Desired management $u = u^*(x,t)$ for the law $S_t = \{x, t \mid \|x\| \le s^0 < r^0,\ t \ge 0\}$,

satisfactory to the industry

$$\left\langle \frac{\partial V}{\partial x}, F + Gu^* \right\rangle + \frac{\partial V}{\partial t} = -W(x,t), \qquad (2)$$

condition fulfillment, if $V(x,t)$ and $W(x,t)$ positive definite functions is the stabilization law.

If the Lyapunov function is defined by equation (1) and is applied to the left part of the expression (2), the function found after certain operations $W(x,t)$ must have a negative sign, then the stabilization law according to the theorem $\lambda(x,t) > 0$ when the condition is met it will lookike this:

$$u^* = -\frac{\lambda}{2} G^T \frac{\partial V}{\partial x}.$$

In the second part, the dynamics of the hydraulic system with nonlinear loading is studied. A pump with a variable uniform feed, connecting pipe and F we will consider a hydraulic system consisting of a hydraulic cylinder with an active surface.

Fluid consumption and load equations are written in the following form:

$$uQ_x = F\upsilon + \tau F^2 p + \vartheta F^2 \dot{p}, \quad pF = P_0 + cpF + C\upsilon + m\dot{\upsilon} + f, \tag{3}$$

The condition for the occurrence of self-oscillations was obtained by introducing new dimensionless variables presented in the dissertation work.

The system of equations (6) is presented in the following form:

$$\begin{cases} \dot{x}_1 = x_2, \\ \dot{x}_2 = -x_1 - 2\zeta x_2 - bx_1^2 - 2b\dfrac{\vartheta}{\tau T} x_1 x_2. \end{cases} \tag{4}$$

(4) $\frac{dV}{dt}$ obtained on the basis of the system of equations in the following form:

$$\frac{dV}{dt} = -x_1^2 - x_2^2 - bx_1^3 - \left(1 - \frac{b}{\zeta}\right) x_1^2 x_2 - \frac{2b\vartheta}{\zeta\tau T} x_1 x_2^2. \tag{5}$$

The third section deals with the issue of system stabilization. In consideration, the motion of the drive *is* described by the equation (4) taking into account the control:

$$\begin{cases} \dot{x}_1 = x_2, \\ \dot{x}_2 = -x_1 - 2\zeta x_2 - bx_1^2 - 2b\dfrac{\vartheta}{\tau T} x_1 x_2 + u_2. \end{cases}$$

According to expression (5), $V(x)$ it is a positive definite function, $W(x_1, x_2)$ and according to expression (4) it has the following form:

$$W(x_1,x_2) = -\frac{1}{2}\frac{\zeta+1}{\zeta} bx_1^2 x_2 - \frac{2b\vartheta(\zeta+1)}{\tau T\zeta} x_1 x_2^2 + 2\frac{\zeta^2+1}{\zeta} x_1 - \lambda\left[2\frac{\left(\zeta^2+1\right)^2}{\zeta^2} x_1^2 + \frac{1}{8}\frac{\left(\zeta+1\right)^2}{\zeta^2} x_2^2\right],$$

If $W(x_1, x_2)$ – is a positive definite function, then (4) is immutable

the motion is asymptotically stable, in which case the control law has the following form: $u_1^* = 0,\ u_2^* = -\lambda \frac{\zeta^2+1}{\zeta} x_2.$

1 as can be seen from the figure, u_2^* the introduction of the stabilization law transfers the system from the mode of self-oscillations to the mode of extinction, i.e., the system is in a stabilized state.

In the fourth section, the problem of determining the adjustment properties of the throttle hydraulic drive connected in series with the hydraulic motor is considered.

with a non - *linear characteristic (47 PG 11 type pump, GTs 75) hydraulic system and (NSh 32 type pump, GTs 80)* for the inlet part a = 0.5 and a= 1.

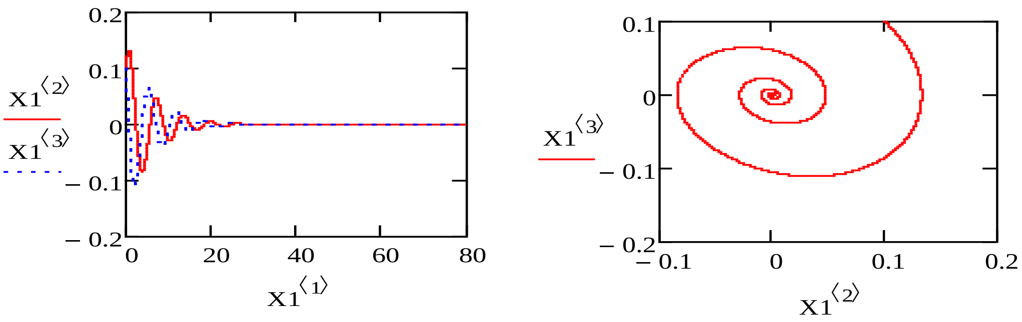

Figure 1 . Time variation of oscillations and system phase views: x =0.0001; b=1; θ = 0.01; t = 1; T=1

The results showed that among four families of obtained mechanical characteristics of throttle hydraulic systems, at nominal loads, the nonlinear characteristic system at α= 0.5 is the most preferred system.

For the KI-4815M hydraulic stand, stable and unstable movement areas R_1, R_2 and R_3 calculation zones, as well as self-oscillation movement zones are installed (Fig. 2).

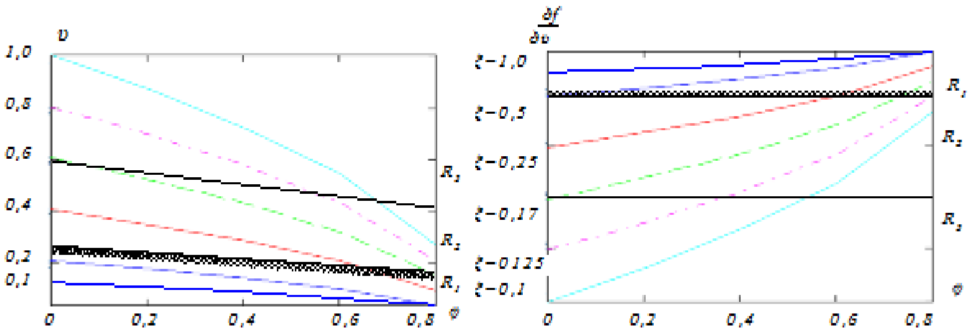

Fig. 2. Do not use hydraulics for stabilization three distinct areas of motion

In the first part, transition processes of the hydraulic system are taken.

The state of the control object is described by the following differential equations:

$$m\frac{d^2y_{\text{т}}}{dt^2} = p_{\text{ц}}F_{\text{ц}} - c_{\text{св}}\left(y_{\text{шт}} - y_{\text{т}}\right) - \left(P_{\text{тр.ц}}\right) \quad (6)$$

the equation of motion of the hydraulic cylinder piston, where $y_{\text{шт}}, y_{\text{т}}$ – the piston and mass displacement coordinates; $P_{\text{тр}}$ – friction force; $F_{\text{ц}}$ – hydraulic cylinder piston working surface; $c_{\text{св}}, c_{\text{н}}$ – right and left springs

$$m_n\frac{d^2y_{\text{шт}}}{dt^2} = F_{\text{ц}1}p_1 - F_{\text{ц}2}p_2 - c_{\text{св}}\left(y_{\text{шт}} - y_{\text{т}}\right) - P_{\text{тр.ц}},$$

the equation of motion of the hydraulic output link, here $P_{\text{тр}} = k_{\text{тр}}\frac{dy_{\text{шт}}}{dt}$. The mass applied to the hydraulic output link and the equation of motion of the output link:

$$m\frac{d^2y_{\text{т}}}{dt^2} + k_{\text{тр}}\frac{dy_{\text{шт}}}{dt} + c_{\text{св}}y_{\text{т}} + c_{\text{н}}y_{\text{т}} = c_{\text{св}}y_{\text{шт}}, \quad k_{\text{тр}}\frac{dy_{\text{шт}}}{dt} + c_{\text{св}}y_{\text{шт}} = -c_{\text{н}}y_{\text{т}} - F_{\text{ц}}p_{\text{н}}$$

Through the following substitutions:

$$\delta_1 = \frac{k_m}{m},\ m_1 = \frac{c_{св}}{m},\ k_1 = \frac{c_{св} + c_н}{m},\ \alpha_1 = \frac{F_ц p_н}{k_{шт}},\ \alpha = \frac{c_{св}}{k_{шт}},\ G_1 = \frac{c_н}{k_{шт}},$$

(6) we reduce the equation to the following form:

$$\begin{cases} \dot{x}_1 = -\delta_1 x_1 - m_1 x_2 - k_1 F(x_3), \\ \dot{x}_2 = G_2 x_1 - \alpha x_2 + G_1 x_3, \\ \dot{x}_3 = x_1, \end{cases} \quad (7)$$

here $m_1 = \frac{1}{m}, \delta_1 = \frac{\delta}{m}, k_1 = \frac{k}{m}; F(x) = x^2.$

(7) the characteristic coefficient of the system will have the following form:

$$\lambda^3 + p\lambda^2 + q\lambda + r = 0, \quad (8)$$

here $p = \alpha + \delta,\quad q = \alpha\ \delta_1 + m_1 G_2,\quad r = m_1 G_1.$

At the Andronov-Hopf bifurcation point, the characteristic polynomial must have only abstract roots. (8) is a polynomial λ^2 and λ if the product of the coefficients is equal to the free term, then two have only abstract roots, that is:

$$(\alpha + \delta_1)(\alpha\delta_1 + m_1 G_2) = m_1 G_1.$$

Figure 3 shows $m = 10;\ \delta = 0.9;\ \alpha = 1;\ G_1 = 0.75;\ G_2 = 0.75;\ k = 1$ the hydraulic system with non-linear characteristics in $x_1 x_2$ parameter values and $x_1 x_3$ plain shows the time variation and phase diagram of the transition mode in Figs.

CONCLUSION

The following conclusions were presented as a result of the dissertation research on the topic " Mathematical modeling of the processes of stabilization of vibrations of hydraulic systems of machines ":

1. Based on the laws of describing dynamic processes, a mathematical model for stabilization of hydraulic lines with a continuous load (continuous damping of the negative resistance type) was developed.

On the basis of Lyapunov's 2nd method, the control laws that ensure the asymptotic stability of the system and stabilize the system by constructing the Lyapunov function were established.

Chiziқsiz characterized (α=0.5, α=1) throttle ego [47PT11 tipidagi pump, Hz-75] va [НШ 32 pump, Hz80] hydraulic tisimlar mechanic characteristicalarining solistirma tagilili, nominal yuklanish holatida olingan mechanic characteristiclar ichida chiziқsiz characterized (α =0.5) hydraulic tizim afzalligini kўrsatdi. Olingan boshkaruv konuniyatlari gidraulik yuritma stabilligini taminlash imkonini beradi.

2. A mathematical model of stabilization of the inversely connected hydraulic mechanism in terms of displacement and speed was developed. The Lyapunov function ensuring the asymptotic stability of the system was constructed. Legitimacy of management ensuring stability through coercion was established. The developed algorithm and program can be used as an information source for researching complex vibration processes in hydraulic system nodes of wheeled machines.

3. A mathematical model of stabilization of wheeled car suspension was developed. Using the method of Lyapunov function, the stability reserve of the hydraulic shock absorber was estimated and field diagrams were constructed for different values of the system parameters. They can be used to study the effect of the rectifier mechanism on the stability reserve of the hydraulic system in the stationary mode.

4. Lyapunov's second method of stabilization, Brockett's stabilization problem and Sinai stochasticity criterion combined, a generalized method of qualitative research of the oscillatory movements of hydraulic systems of wheeled machines was proposed.

5. A mathematical model of the hydraulic hammering process occurring in the control channel of the hydraulic distributor was developed. Using Foure's method of separation of variables, the hydraulic shock that occurs in the closing part of the control valve in the control channel is studied, and the shock period is t_{ud} =0.1÷0.5 seconds (this corresponds to the time of shock in other parts of hydraulic systems), *determined that* the decreasing section in the diagrams corresponds to the real values of the working pressure occurring in the distributor (ie P_{rab} =10÷25 MPa).

Analysis of the results, pressure changes during the stroke, pressure damping oscillations (oscillograms) in the pipe when given a unit pressure pulse obtained by other authors are consistent with the experimental results. The created model made it possible to prevent the formation of the forging process in the system.

6. The calculated dynamic characteristics of the systems qualitatively correspond to the expected physical processes, which made it possible to draw a conclusion about the adequacy of the mathematical models.

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