TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2015, Vol. 15, No.2, 9-14

Mathematical modeling automatic elektrogidraulic drive of machine building equipment

Ya. Sokolova, O. Krol, Yu. Rasskazova, V. Sokolov

Volodymyr Dahl East-Ukrainian National University, e-mail krolos@yandex.ru

Received July 1. 2015: accepted July 20. 2015

Summary. The mathematical models of the dynamic features automatic electrohydraulic drive with three-dimensional volume adjustment of the machine-building equipment are offered. The structured schemes of the mathematical models for equipment with hydraulic drive rotary action as object of the autocontrol are presented.

Key words: pump, hydraulic motor, three-dimensional regulation, transfer functions,

INTRODUCTION

The Expansion of the functional possibilities and increasing efficient machine-building equipment, in particular, equipment for mechanical processing material, can be reached by development and using the systems of the autocontrol [1, 2, 4]. The achievement random kinematics worker element, possibility programme implementation of the optimum laws of its motion is provided by using hydraulic drives and, in particular, automatic electrohydraulic drive (EHD) with three-dimensional regulation in equipment by power over 8 kW.

Using hydraulic drive in machine-building equipment allows to simplify the kinematics a tool, reduce amount of metal, raise accuracy, reliability and level to automations. Broad use hydraulic drives is defined beside their essential advantage over the other types drive and, first of all, possibility of the reception big effort and powers under limited size of hydraulic motors.

Hydraulic drives provide the broad range without step velocities, possibility of the work in dynamic mode with required by quality of the transient processes, system protection from overloading and exact checking acting effort.

In this connection actual problem for syntheses and system studies of the autocontrol is a development reliable mathematical models worker processes, running in EHD and taking into account particularities of technological purpose of the equipment.

MATERIALS AND METHODS

The Problem of mathematical modeling of the features automatic EHD machine-building equipment it is enough is broadly presented in literature [1, 2, 3, 22]. The Study worker processes in equipment is founded on fundamental equations hydromechanics, mechanics of the rigid body, electrical engineers; but for study of stability and quality regulations of such systems, for their correction uses methods of theories for the autocontrol and regulations.

The certain difficulties appear under mathematical modeling of the dynamic features drive machine-building equipment with description non stationary hydramechanical processes, running in them. There are particularities in hydrasystem dynamics, conditioned interaction hydraulic element, as well as presence of the motion worker medium on pipe line, slot and channel with local resistances. Except processes, appearing when performing by system scheduled operation in hydraulic drives, exist the fluctuations of the pressures, expenses, separate details in consequence of compressibility worker medium, influences worker medium on adjusting device, leaks on clearance and other reasons. The combination of all these phenomena's brings about complex non stationary hydramechanical process, which necessary account when designing the machine-building equipment with hydraulic drive.

Together with that, expansion of the functional possibilities and increasing to efficiency of the machine-building equipment, in particular equipment for mechanical processing material, to account of the development and using the systems of the autocontrol requires the unbulky reliable of the mathematical models worker processes, running in drives and it is enough packed taking into account particularities technological purpose of the equipment.

PURPOUSE AND OBJECTIVE

The Purpose given work is a development of the mathematical models of the dynamic features automatic electrohydraulic drive with three-dimensional regulation of the machine-building equipment, as well as structured schemes of the mathematical models of the equipment with hydraulic drive rotatable actions as object automatic control.

RESULTS OF RESEARCH

The schemes and principle of the work automatic EHD machine-building equipment with three-dimensional regulation, in particular equipment for mechanical processing material with hydraulic drive rotatable action, usually include two axial-piston hydra machine: the main pump and hydra motor [5, 6, 8, 11]. The shaft of the pump happens to in rotation from asynchronies electric motor, but feed the pump is the angle of the slopping of the block cylinder adjusted by change (Fig. 1).

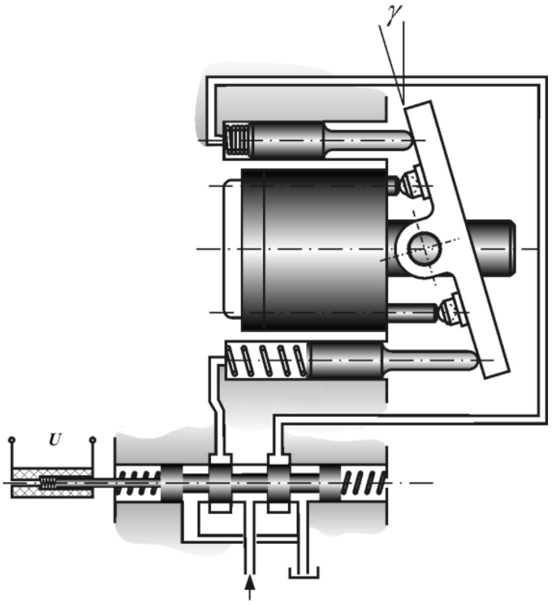

Fig. 1. Control to angle slopping of the washer axial-piston pump

At development of the circuital decisions automatic EHD machine building equipment for use advantage three-dimensional way of the regulation important is a right choice system control for feed the pump. The analysis of the systems of the different purpose shows [5, 6] that using electrohydraulic amplifiers (EHA) allows on all amounts to realize the functional requirements to equipment.

Analog EHA as independent device came up for relationship with need of the creation high-quality system control and have found using in branch of industry, where new technologies required qualitative other approach to management process. EHA are a connected section between not powerful electric controlling devices and power hydraulic mechanism. Besides, EHA enable to use computer for governing special technological equipment.

Device EHA in contrast with the other types of the amplifiers, for instance electromechanical, possess beside advantage: the best dynamic characteristic, greater reliability, simplicity to designs and very high gain factor on powers (over $3 \cdot 10^6$). Enough to note that attitude of the mass to powers hydraulic amplifiers reaches 0,04 kg/kW while in electromechanical amplifier this factor approximately 20 kg/kW, but magnetic - before 70 kg/kW.

EHA possible to use practically with any type three-dimensional hydraulic machine. In machine building it is enough broadly axial-piston machines, which possess good weight feature (under equal power they in 2-3 times easier machines of the other types), speed of response and others [9, 13, 16].

The Scheme of the regulation of the angle of the slopping of the washer axial-piston pump EHA is submitted for fig. 1. Is it here used one-stage EHA, beside which rod of the proportional electromagnet is bound directly with slide valve controlling hydraulic control valve with throttle. The fourth-slot hydraulic control valve with throttle gives the liquid to plunger, which move the tilted washer axial-piston pump.

Controlled axial-piston pumps with tilted washer, most often, in nomenclature serial produced hydra equipment presented as hydra unit with built-in EHA [10,14, 15]. With use passport given possible to build the dynamic model of the second order to the process for the regulation of the angle slopping of the pump's washer γ on control voltage U:

$$T_{2y}{}^2 \frac{d^2\gamma}{dt^2} + T_{1y} \frac{d\gamma}{dt} + \gamma = k_{\gamma U} U , \qquad (1)$$

where: $k_{\gamma U}$ – a factor of the transmission, which possible define on nominal value controlling voltage $U_{ном}$ and nominal angle slopping of the washer axial-piston pump $\gamma_{ном}$:

$$k_{\gamma U} = \frac{\gamma_{ном}}{Q_{ном}} . \qquad (2)$$

Constant time T_{2y}, and T_{1y} known image are defined on frequency of the shift on phase accordingly on -45^0 and -90^0 [4, 6]:

$$T_{2y} = \frac{1}{2\pi\nu_2}; T_{1y} = \frac{1}{2\pi\nu_1} - \frac{2\pi\nu_1}{\left(2\pi\nu_2\right)^2} . \qquad (3)$$

The givenned approach to building of the dynamic model of the autocontrol by angle slopping of the washer to axial-piston pump shall wholly use and in the event of use EHA as independent device, which in nomenclature serial produced hydra equipment having appeared-flaxes as hydraulic control valve with throttle or distributors with distributor by control [17, 18, 21].

Follows to note that regulation of the feed the pump can realize not only change the angle slopping of the washer, but and the other way, for instance, change the angle slopping of the cylinder block. Not difficult make sure, as in this instance dynamic model of the process of the regulation to angle slopping for cradle of the cylinder block will have like type.

Thereby, transmission function of the process of the regulation for angle slopping of the washer (cylinder block) in accordance with (Eq. 1) is of the form of:

$$W_{np}(s) = \frac{k_{\gamma U}}{T_{2y}^2 s^2 + T_{1y} s + 1} , \qquad (4)$$

where: s – variable Laplas.

What have shown further experimental studies, as well as analysis of the features EHA, used in controlled pump, transfer function of the process of the regulation worker volume of the pump possible to consider as apereodical first-order section

, $$W_{np}(s) = \frac{k_{\gamma U}}{T_{np}s+1}, \quad (5)$$

where: T_{np} – constant time of the process of the regulation:

$$T_{np} = \frac{1}{2\pi\nu_1}. \quad (6)$$

In working the authors [19, 22] is received transmission function power part of EHD with three-dementional regulation for angle rotate of shaft of the hydra motor α on angle slopping of the cylinder block (or washer) γ:

$$W_{\alpha\gamma}(s) = \frac{\alpha(s)}{\gamma(s)} = \frac{1}{T_{gn}s\left(T_m^2 s^2 + 2\zeta_m T_m s + 1\right)}, \quad (7)$$

where T_{gn} – constant time hydra drive; T_m – constant time hydra motor; Z_m – a factor relative damping hydra motor.

For building of the mathematical model EHD with three-dimensional adjustment as object of the autocontrol transmission function for angle rotate of shaft on angle slopping of the washer (cylinder block) of the drive (7) form in the manner of:

$$W_{\alpha\gamma}(s) = \frac{\alpha(s)}{\gamma(s)} = \frac{\alpha(s)}{\Omega(s)}\frac{\Omega(s)}{\gamma(s)} = \frac{1}{s}W_{cn}(s) = \frac{k_{\Omega\gamma}}{s\left(T_m^2 s^2 + 2\zeta_m T_m s + 1\right)}, \quad (8)$$

where: $W_{cn}(s)$ - carried in consideration transmission function power part of drive (transmission function for angular velocity of the rotation shaft of hydra motor on angle slopping of the washer or cylinder block)

$$W_{cn}(s) = \frac{\Omega(s)}{\gamma(s)} = \frac{k_{\Omega\gamma}}{T_m^2 s^2 + 2\zeta_m T_m s + 1}, \quad (9)$$

where: $k_{\Omega\gamma}$ – a factor of the transmission of the power drive, which in accordance with [1, 2] possible define on expression:

$$k_{\Omega\gamma} = \frac{2\pi k_{Q\gamma}}{q_m}. \quad (10)$$

Necessary to note following. The Angular velocity of the rotation to shaft of hydra motor, in general event, is defined not only worker by volume of pump, but also value loading moment M on shaft of the motor. Degree influence is fixed for concrete drive, moreover, increase loading moment uniquely brings about reduction angular velocity rotations that in linear approach can be reflected by transfer function:

$$W_{\Omega M}(s) = \frac{\Omega(s)}{M(s)} = -k_{\Omega M}, \quad (11)$$

where: $k_{\Omega M}$ – a factor of the transmission for angular velocity of the rotation on loading moment, value which possible evaluate on steady-state feature of the three-dimensional hydraulic drive [5, 6].

Thereby, considering principle superposition:

$$\Omega(s) = W_{sp}(s)\gamma(s) + W_{\Omega m}(s)M(s). \quad (12)$$

The mathematical model of the machine-building equipment with hydraulic drive rotatable actions as object of the autocontrol possible present the structured scheme, brought on Fig. 2.

Calculation of the dynamic features EHD with three-dimensional regulation with use specially designed software in ambience of the package of the applied programs Matlab has shown that in majority events for real drive of the equipment for mechanical processing materials transmission function power part of drive (9) possible simplified consider as aperiodic first-order section:

$$W_{sp}(s) = \frac{k_{\Omega\gamma}}{T_{sp}s+1}, \quad (13)$$

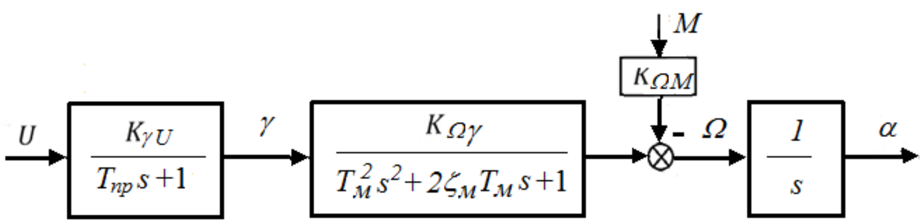

Fig. 2. Structured scheme to mathematical model EGP as object of the autocontrol

where: T_{sp} - constant time of the power part of drive, importance which possible define according to theoretical dependencies, as well as on base of the experimental estimation of the dynamic features of the drive [20, 22, 23, 24].

In this case simplified mathematical model of the equipment with hydra motor rotatable actions as object of the autocontrol possible to present the structured scheme, brought on Fig. 3.

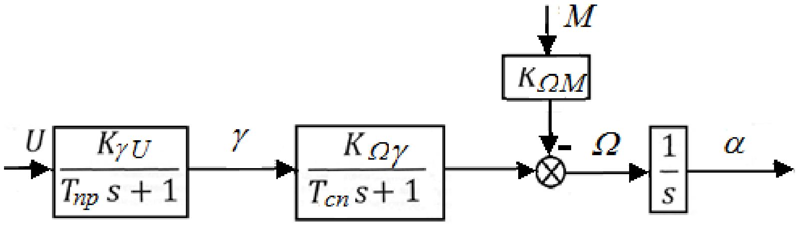

Fig. 3. Structured scheme simplified mathematical model

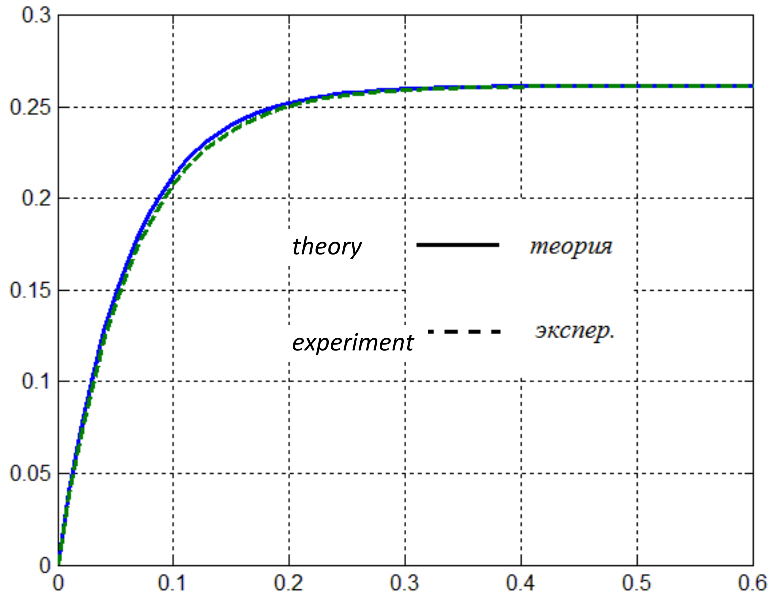

Fig. 4. Connecting process for block of the regulation to pump (change the angle slopping of the washer Δγ, rad, when feed controlling voltages)

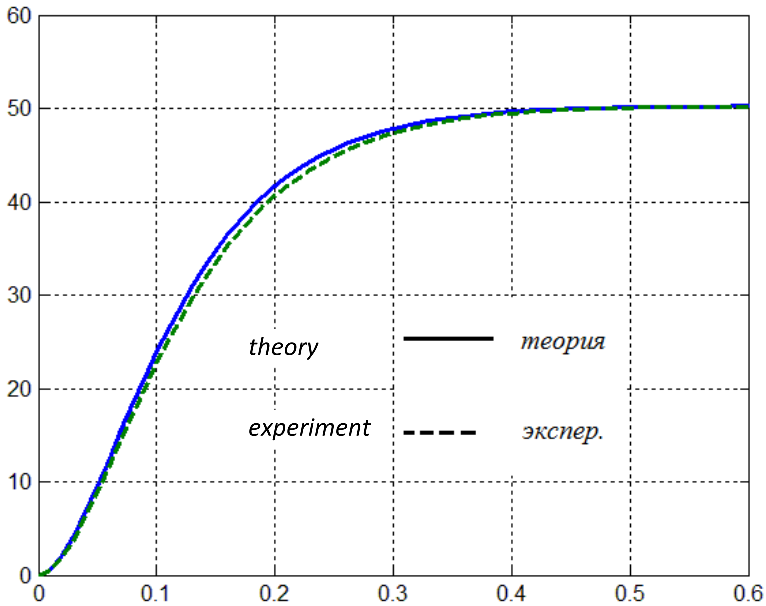

Fig. 5. Connecting process for drive as a whole

For check of adequacy got mathematical models designed automatic stand of the experimental studies and methods processing experienced data [9, 10] (on stand is used pump type HAC 0,04/20 with maximum worker by volume 0,04 l and hydra motor M type PM 2,5 A with worker by volume 0,0317 l).

On fig. 4, 5 are matched experienced and accounting connecting processes for block of the regulation of the pump when feed controlling voltages and drive as a whole when change controlling signal. Follows to note that design values of the connecting process for drive as a whole (Fig. 5) complied with accuracy of the graphic building for full and simplified mathematical models. Experimental importance criterion Fisher (less 1,2) did not exceed tabular importance ≈ 1,8 under confidential probability. So designed models dynamic features possible consider identical and assume as a basis further investigations on syntheses of the system of the autocontrol equipment for mechanical processing material.

CONCLUSIONS

1. Mathematical models of the dynamic features automatic elecrtrohydraulic drive with volume regulation of the machine-building equipment are designed,

2. Structured schemes of the mathematical models for the equipment with hydra drive rotatable actions as object of the autocontrol are presented.

3. The adequacy mathematical models of the process for regulation worker volume pump, as well as drive is as a whole confirmed experimental.

4. The mathematical models of the machine-building equipment with hydra drive rotatable actions as object automatic control prescribed in base of the further studies on syntheses of the system automatic of equipment control.

REFERENCES

1. **Andrijchuk N., Vyalikh A., Kovalenko A., Sokolov V., 2008.** Hydraulic and hydra-pnevmo drive. Textbook, East-Ukrainian National University named by V. Dahl, 320 (in Russian).
2. **Andryuschenko V., 1990.** Theory of the systems for autocontrol: Textbook, Leningrad, Leningrad university, 256. (in Russian).
3. **Azarenko N., 2013.** The experimental stand for investigating steady-state and dynamic features automatic electrohydraulic drive, Messenger of the East-Ukrainian National University named by V. Dahl, Vol.3(192), 5-9. (in Russian).
4. **Bashta T., Rudnev S., Nekrasov B., 1982.:** Hydraulic, hydraulic motor, hydraulic drive. Textbook, Moscow, Machine building, 423. (in Russian).
5. **Bazhenov A., 2002.:** The Helmsmen hydraulic drive with jet-throttle regulation: Textbook, MAI, 68.
6. **Bazhin I., Berengard Yu., 1988.** The Computer aided design machine building hydraulic drive, Moscow, Machine building, 312.
7. **Bazhin I., Goido M., Troitsky V., 1989.** Designing axial-piston pump with use CAD: Textbook , Chelyabinsk: CHPI, 57.
8. **Bocharov Yu., 1972.** Hydraulic drive of blacksmith's-press machine, Moscow, Machine building, 76. (in Russian)
9. **Chernetskaya-Beletskaya N., Kushchenko A., Varakuta E., Shvornikova A., Kapustin D., 2014.** Define the operational hydro-solid vaste handing system, TEKA, Commision of Motorization and Power Industry in agriculture Vol. 19, No. 1, 10-17.
10. **Dorf R., Bishop R., 2002.** Modern systems of management, Moscow, Laboratory of Base Knowledge, 831. (in Russian).
11. **Emtsev B., 1978.** Technical hydramechanics, Moscow, Machine building, 463. (in Russian).
12. **Goodwin G., Grefe, F., Salgado M., 2004.** Design of Control Systems, Moscow, Knowledge Lab, 218.
13. **Hohlov V., 1964.** Electrohydraulic watching drive, Moscow, the Science, 173. (in Russian).
14. **Kim D., 2003.** The Theory of the autocontrol. T.1. Linear system. Textbook, Moscow, Fizmatlit, 288. (in Russian).
15. **Leschenko V., 1975.** Hydraulic watching drives tool with program control, Moscow, Machine building, 288. (in Russian).
16. **Navrotsky K., 1991.** Theory and designing hydro- and pnevmo drives, Moscow, Mechanical engineering, 38. (in Russian).
17. **Popov D., 1982.** Non-stationary's hydra ulit mechanical processes, Moscow, Mechanical engineering, 240. (in Russian).
18. **Popov D., 1987.** Dynamics and regulation hydro- and pneumatic systems, Moscow, Mechanical engineering, 464. (in Russian).
19. **Sokolov V., Azarenko N., Sokolova Ya., 2012.** Simulation of the power unit of the automatic electrohydraulic drive with volume regulation, TEKA Commission of Motorization and Energetic in Agriculture, Vol. 12, N 4, 268-273.
20. **Sokolova Ya., Azarenko, N., Greshnoy D., 2014.** The improvement elertrohydraulic drive of the machine-building equipment: monograph, Lugansk, Messenger of the East-Ukrainian National University named by V. Dahl, 100. (in Russian).
21. **Sokolova Ya., Ramazanov S., Tavanuk T., 2010.** Nonlinear modeling of the electrohydraulic watching drive, TEKA, Commision of Motorization and Power Industry in agriculture Vol. XC, 234-242.
22. **Sokolova Ya., Tavanuk T., Greshnoy D., Sokolov V., 2011.** Linear modeling of the electrohydraulic watching drive, TEKA, Commision of Motorization and Power Industry in agriculture, Vol XI B, 167-177.
23. **Sveshnikov V., Usov A., 1988.** Moustaches hydraulic drives: the Directory, Moscow, Mechanical engineering, 512. (in Russian).
24. **Syomin D., Rogovoy A., 2010.** Power characteristics of super-chargers with vortex work chamber, TEKA, Commision of Motorization and Power Industry in agriculture, Vol. 14, 232-240.

МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ АВТОМАТИЧЕСКОГО ЭЛЕКТРОГИДРОПРИВОДА МАШИНОСТРОИТЕЛЬНГО ОБОРУДОВАНИЯ

Я. Соколова, О. Кроль, Ю. Рассказова, В. Соколов

Аннотация. Предложены математические модели динамических характеристик автоматического электрогидравлического привода с объемным регулированием машиностроительного оборудования. Представлены структурные схемы математических моделей оборудования с гидроприводом вращательного действия как объекта автоматического управления.

Ключевые слова: насос, гидромотор, объемное регулирование, передаточная функция, структурная схема, переходной процесс.