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ALGORITHM FOR IDENTIFYING OBJECTS MANAGED BY SECOND-ORDER LINKS WITH DELAY TIME

Gurin O.M., Duryshev O.A., Kobzarev E.V., Loriia M.G.

АЛГОРИТМ ІДЕНТИФІКАЦІЇ ОБ'ЄКТІВ УПРАВЛІННЯ ЛАНКАМИ ДРУГОГО ПОРЯДКУ З ЧАСОМ ЗАПІЗНЮВАННЯ

Гурін О.М., Дуришев О.А, Кобзарев Є.В., Лорія М.Г.

The object of research is the optimal parameters for regulator adjustment and the quality indicators of transient processes.

The current problem is that modern technological processes are complex control objects. Therefore, when designing automation systems, the tasks of identifying the control object, calculating the regulator parameters, and their further optimization become particularly important. Optimal settings ensure the highest possible product quality and reduce its cost at a given production volume. Direct determination of controller parameters through experiments on a real object can lead to a loss of finished product quality and damage to raw materials and catalysts. To avoid these risks, the calculation algorithm was implemented in the Maple software package environment.

The study developed and tested an algorithm for identifying control objects with different characteristics of transient processes, described by second-order links, taking into account the delay time. Based on the obtained transfer functions of equivalent objects, P-, PI-, and PID-controllers (proportional, proportional-integral, and proportional-integral-derivative) were tuned. The parameters were determined using the triangle method, the method of undamped oscillations (Nicholas–Ziegler), and the proposed algorithm. The results obtained are intended for use in automatic control systems.

A comparative analysis of the quality of transient processes in systems tuned using different methods was performed. It was found that the parameters obtained using the new algorithm significantly improve the dynamic characteristics of the system (reduction of overshoot, control time, static and dynamic errors). In addition, an algorithm for searching for controller parameters taking into account the overshoot limitation was proposed, which also showed positive results. The identification error does not exceed 3%, which is acceptable for calculations of this type.

Keywords: *second-order link, controller parameters, control time, identification algorithm, transient process, delay time.*

1. Introduction. The continuous rise in global raw material prices has significantly increased production costs for Ukrainian enterprises. For example, in chemical industries, the share of natural gas expenses can account for up to 75% of total production costs. To maintain competitiveness in international markets, it is essential to use raw materials and energy resources more efficiently, which requires optimizing technological processes. Despite extensive technical modernization and improvements in control systems at many enterprises, these measures often prove insufficient if the core element of an automatic control system (ACS)—the controller—is improperly tuned. The controller generates the control signal to achieve the required accuracy and quality of the transient process, yet research indicates that more than 50% of industrial controllers are incorrectly adjusted [1].

Direct determination of optimal tuning parameters on a real system is associated with considerable risks: reduced product quality, damage to raw materials or catalysts, and even potential emergencies such as fires, explosions, or hazardous emissions. This highlights the importance of developing reliable theoretical methods for calculating optimal controller settings [2].

The object of the study is the optimal controller tuning and transient process quality indicators. The **subject of the study** is single-loop automatic control systems.

The main challenge arises from the complexity of modern technological processes, which makes tasks such as system identification, parameter calculation, and optimization of controller settings particularly critical. Properly optimized settings ensure high product quality and reduced production costs for a given output volume. However, performing experimental parameter searches directly on operating systems carries the risks mentioned above.

Existing tuning methods have significant shortcomings, and therefore experimental adjustment remains the most common practice, despite its limitations. System quality is usually evaluated not by instantaneous error functions—which are difficult to compute due to higher-order differential equations and dependence on multiple parameters—but by performance criteria. Among these, the integral quality criterion is considered the most universal, as it allows simultaneous evaluation of accuracy, stability, and response speed.

The aim of this research is to develop an algorithm for identifying control objects with time delay, based on the step response of a second-order system with delay. To achieve this goal, the following tasks were set:

- determine optimal controller settings using an integral quadratic optimization function with overshoot constraints;
- compare transient process quality indicators of automatic control systems tuned by different methods. Prior studies have emphasized the rapid dynamics of technological processes, the presence of disturbances caused by internal interactions and external conditions, and the time-dependent behavior of equipment, which all necessitate advanced ACS solutions [1, 2]. Some works approximate oscillatory transient processes using delayed oscillatory elements [3, 4], with further determination of the critical frequency and amplitude required for modeling second-order systems with delay. Research on system identification generally follows several approaches:
- least squares estimation [5];
- instrumental variables [6];
- frequency response identification [7];
- randomized algorithms [8];
- active identification with test signals [9, 10].

However, these methods often face challenges such as lack of guaranteed convergence, limited applicability in high-dimensional systems with numerous unknown parameters, and the high cost of specialized software.

Overall, the analysis confirms that the development of theoretical methods for calculating optimal controller parameters is both highly relevant and promising. The proposed calculation algorithm was implemented in the *Maple* software environment. Importantly, transient processes of control objects—whether aperiodic or oscillatory—can be adequately described by a second-order differential equation [1].

Let us consider the structural diagram of a single-loop ACR shown in Fig. 1.

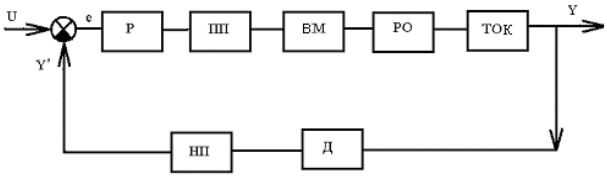

Fig. 1. Structural diagram of a single-loop automatic control system:
R – regulator; PP – intermediate converter;
VM – executive mechanism;
RO – control element; TOK – technological control object; D – sensor; NP – standardizing converter

When measuring the acceleration curve on a real control object, the transition process of an equivalent control object is actually obtained (an open system from PP – intermediate converter to NP – normalizing converter, provided that the transfer function of the secondary device is equal to 1). That is, if the equivalent control object is identified by the acceleration curve as a second-order link, then the functional diagram of a single-loop ACS can be presented as follows (Fig. 2).

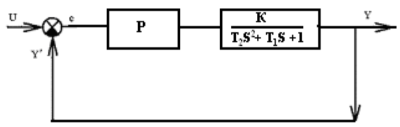

Fig. 2. Converted block diagram of a single-loop automatic control system

The differential equation of the second-order control link is as follows:

$$(T'')^2\frac{d^2y}{dt^2}+T'\frac{dy}{dt}+y=K_p u_0, \tag{1}$$

where T'' , T' – time constants; – coefficient.

The nature of the transition process of this link depends on the value of the ratio $\frac{T'}{T''}$.

If $\frac{T'}{T''}\geq 2$, then the transition process will be aperiodic, and if $\frac{T'}{T''}\geq 2$ – oscillatory.

Let us find the roots of the differential equation (1):

$$P_{1,2} = -\frac{T'}{2(T'')^2} \pm \sqrt{\left[\frac{T'}{2(T'')^2}\right]^2 - \frac{1}{(T'')^2}}. \tag{2}$$

If $\frac{T'}{T''} > 2$, then the roots P1 and P2 will always be real and negative. Then the equation of the transfer function will be:

$$y(t) = K_P u_0 \left[1 - \frac{\alpha_2}{\alpha_2 - \alpha_1}\exp(-\alpha_1 t) + \frac{\alpha_1}{\alpha_2 - \alpha_1}\exp(-\alpha_2 t)\right], \tag{3}$$

where $\alpha_1 = -P_1;\ \alpha_2 = -P_2;\ u_0 -$ the disturbance is stepwise.

At $\frac{T'}{T''} < 2$ the root, they will be complex:

$$P_{1,2} = \alpha_0 \pm j\omega_0, \tag{4}$$

where $\alpha_0 = \frac{T'}{2(T'')^2};\ \omega_0 = \sqrt{\frac{1}{(T'')^2} - \left[\frac{T'}{2(T'')^2}\right]^2}.$

In this case, the transfer function is described by the equation:

$$y(t) = K_P u_0 \left[1 - \exp(-\alpha_0 t)\left(\cos\omega_0 t + \frac{\alpha_0}{\omega_0}\sin\omega_0 t\right)\right]. \tag{5}$$

Let us consider the identification of control objects using the example of a fifth-order link with a transfer function:

$$W = \frac{1}{1.5\cdot s^5 + 4\cdot s^4 + 10\cdot s^3 + 10\cdot s^2 + 5\cdot s + 1}. \tag{6}$$

Let's construct the acceleration curve (Fig. 3).

To determine the delay time of the fifth-order link, we construct a tangent to the acceleration curve, as shown in Fig. 3, find the delay time, and substitute it into the transfer function of the fifth-order link (6):

$$W = \frac{e^{-2s}}{1.5\cdot s^5 + 4\cdot s^4 + 10\cdot s^3 + 10\cdot s^2 + 5\cdot s + 1}. \tag{7}$$

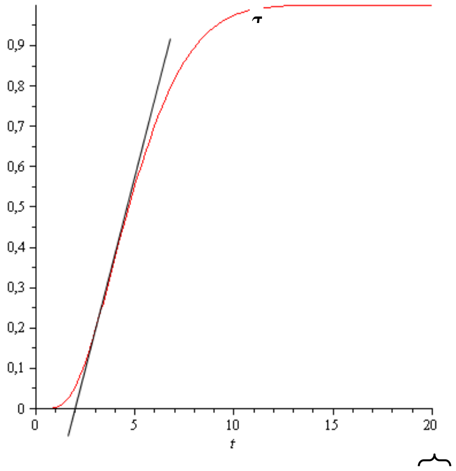

Fig. 3. Fifth-order link acceleration curve

We construct again the acceleration curve of the fifth order link, but now with a time delay (Fig. 4).

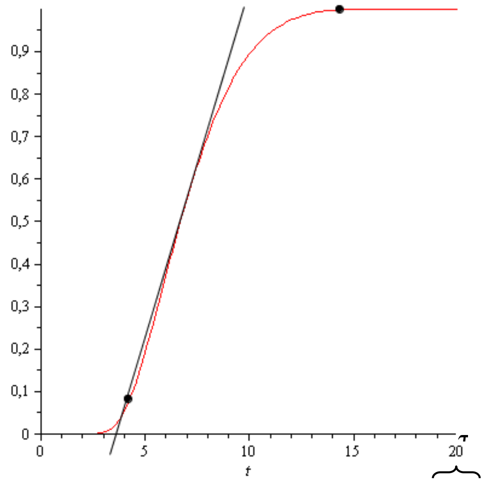

Fig. 4. Acceleration curve
of a fifth-order link with delay time

By redrawing the tangent line (Fig. 4), the time delay for the second-order element was determined. As shown in Fig. 4, the step response curve exhibits an aperiodic character; therefore, equation (3) can be used to describe it.

The coefficient *K* is obtained directly from the step response curve (*K =1*). This equation still contains two unknown parameters, α_1, α_2. To determine them, two characteristic points are selected on the step response curve (their approximate location is indicated in Fig. 4).

Based on these selected points, a set of equations is formulated, which ultimately yields a system of equations for calculating the required parameters.

$$\begin{cases} 0.0368 = 1\cdot u_0\left[1-\frac{\alpha_2}{\alpha_2-\alpha_1}\exp(-\alpha_1\cdot 3.71)+\frac{\alpha_1}{\alpha_2-\alpha_1}\exp(-\alpha_2\cdot 3.71)\right], \\ 0.997 = 1\cdot u_0\left[1-\frac{\alpha_2}{\alpha_2-\alpha_1}\exp(-\alpha_1\cdot 14.35)+\frac{\alpha_1}{\alpha_2-\alpha_1}\exp(-\alpha_2\cdot 14.35)\right], \end{cases} \quad (8)$$

We will solve the resulting system of two equations with respect to α1 and α2. The easiest way to find these variables is using the Maple mathematical software package.

We find the variables α1 and α2. We substitute these values into equation (3) to find the equation of the transfer function. After substitution, we obtain the following equation:

$$y(t)=1-5.58\cdot 10^5\exp(-0.558\cdot t)+5.58\cdot 10^5\exp(-0.558\cdot t). \quad (9)$$

Let us construct on the same graph the acceleration curve of the fifth order link and the curve corresponding to the obtained equation (9), Fig. 5.

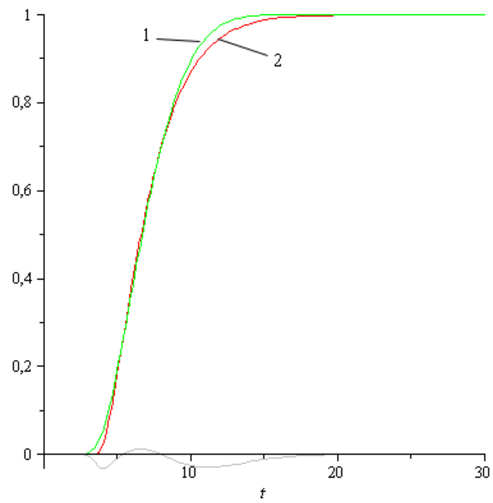

Fig. 5. Initial and obtained acceleration curves of the equivalent object:
1 – acceleration curve of the fifth-order link with delay time; 2 – transient process of the second-order link with delay time

Analyzing Fig. 5, we can conclude that the second-order aperiodic link with a delay time accurately describes the aperiodic control object with a delay time. The maximum deviation between curves 1 and 2 does not exceed 3%. Therefore, in further calculations, we will use a second-order link with a delay time instead of an equivalent control object. Let us perform the inverse Laplace transform of the equation to obtain its transfer function:

$$W=\frac{7.942\cdot 10^9\cdot e^{-3.6\cdot s}}{2.5\cdot 10^{11}\cdot s^2+2.8\cdot 10^{11}\cdot s+7.784\cdot 10^{10}}. \quad (10)$$

Thus, based on two points of the acceleration curve of an aperiodic control object with a delay time, it is possible to accurately identify its second-order aperiodic link with a delay time.

Let us consider the identification of control objects using the example of a fifth-order link, which has a transfer function:

$$W=\frac{1}{s^5+4\cdot s^4+7\cdot s^3+12\cdot s^2+4.5\cdot s+1}. \quad (11)$$

Let's construct the acceleration curve (Fig. 6).

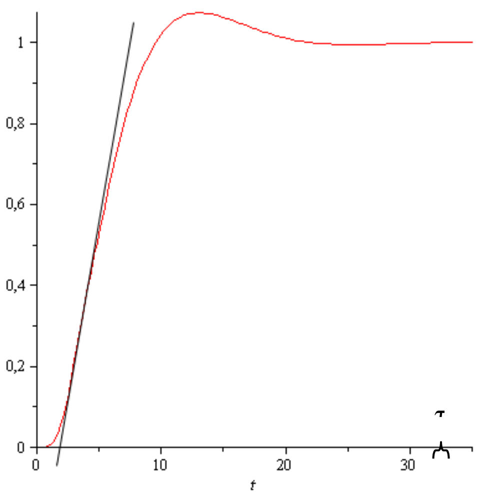

Fig. 6. Acceleration curve of a fifth-order link with delay time from the tangent line

To determine the delay time of the fifth-order link, we construct a tangent to the acceleration curve, as shown in Fig. 6. We find the delay time and substitute it into the transfer function of the fifth-order link:

$$W=\frac{e^{-2\cdot s}}{1.5\cdot s^5+4\cdot s^4+10\cdot s^3+10\cdot s^2+5\cdot s+1}. \quad (12)$$

We construct again the acceleration curve of the fifth order link, but now with a time delay, as shown in Fig. 7.

When reconstructing the tangent (Fig. 7), the delay time for the second-order link was found.

Fig. 7 shows that the acceleration curve is oscillatory, so equation (5) can be used to find the equation of the acceleration curve.

The coefficient K is found from the acceleration curve (K=1). There are two more unknown parameters in this equation: α0 and ω0. To find them, we take two points on the acceleration curve (Fig. 7) and select these points approximately as shown in Fig. 7.

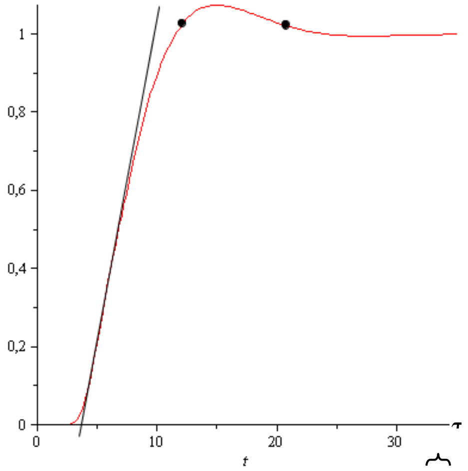

Fig. 7. Acceleration curve of a fifth-order link with delay time (oscillatory nature)

We compose equations for these two points. As a result, we obtain a system of equations:

$$\begin{cases} 1.025 = 1\cdot u_0\left[1-\exp(-\alpha_0\cdot 12.06)\left(\cos\omega_0\cdot 12.06+\dfrac{\alpha_0}{\omega_0}\sin\omega_0\cdot 12.06\right)\right], \\ 1.026 = 1\cdot u_0\left[1-\exp(-\alpha_0\cdot 20.21)\left(\cos\omega_0\cdot 20.21+\dfrac{\alpha_0}{\omega_0}\sin\omega_0\cdot 20.21\right)\right], \end{cases} \tag{13}$$

We will solve the resulting system of two equations with respect to α0 and ω0. The easiest way to find these variables is using the Maple mathematical software package.

We find the variables α0 and ω0. We substitute these values into the equations:

$$y(t) = K_P u_0\left[1-\exp(-\alpha_0 t)\left(\cos\omega_0 t + 0.1\cdot\frac{\alpha_0}{\omega_0}\sin\omega_0 t\right)\right], \tag{14}$$

to find the equation of the transfer function. After substitution, we obtain the equation:

$$y(t) = 1-\exp(-0.1935t)\left(\cos(0.2081t)+0.093\sin(0.2081t)\right). \tag{15}$$

Let us construct on the same graph the acceleration curve of the fifth order link and the curve corresponding to the obtained equation (15), Fig. 8.

Analyzing Fig. 8, we can conclude that the second-order oscillatory link with a delay time accurately describes the oscillatory control object with a delay time. The maximum deviation between curves 1 and 2 does not exceed 3%. Therefore, in further calculations, we will use a second-order link with a delay time instead of an equivalent control object. Let's perform the inverse transformation of the Laplace equation to obtain its transfer function:

$$W = \frac{0.25\cdot(1.74\cdot 10^9\cdot s + 8.1\cdot 10^{18})\cdot e^{-3.8\cdot s}}{2.5\cdot 10^{19}\cdot s^2 + 9.675\cdot 10^{18}\cdot s + 2.02\cdot 10^{18}}. \tag{16}$$

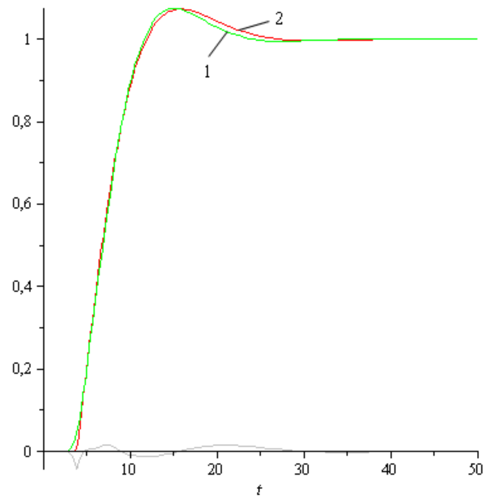

Fig. 8. Comparison of the initial and obtained acceleration curves of the equivalent object: 1 – acceleration curve of the fifth-order link with delay time; 2 – transient process of the second-order link with delay time

Thus, when studying automatic control systems in which complex technological processes are the control objects, the following conclusion can be drawn. The equivalent transfer function can be given in the case of an aperiodic acceleration curve with a delay time by an aperiodic second-order link with a delay time, and in the case of an oscillatory acceleration curve – by an oscillatory second-order link with a delay time. This will greatly facilitate the process of analyzing and optimizing the dynamic characteristics of the ACR.

Having obtained the transfer function of the equivalent object from the experimental acceleration curve, we can synthesize the ACR. Let us consider a single-loop ACR. Such an ACR, taking into account the transfer function of the equivalent object, can be represented as an ACR with unit feedback (Fig. 2).

Existing methods have a number of significant drawbacks, which is why experimental search is currently the most effective method of finding regulator settings in terms of optimal control.

The quality of any control system is determined by the magnitude of the error:

$$\varepsilon(t) = u(t) - y(t), \tag{17}$$

where u(t) is the reference signal; y(t) is the output signal (Fig. 9).

However, it is difficult to determine the error function ε(t) for any given moment in time, since it is described by a high-order differential equation and depends on a large number of system parameters. Therefore, the quality of control systems is evaluated based on some of its properties, which are determined using quality criteria.

Among all known quality criteria, the most universal is the integral quality criterion, which evaluates the generalized properties of the ACS: accuracy, stability margin, and speed.

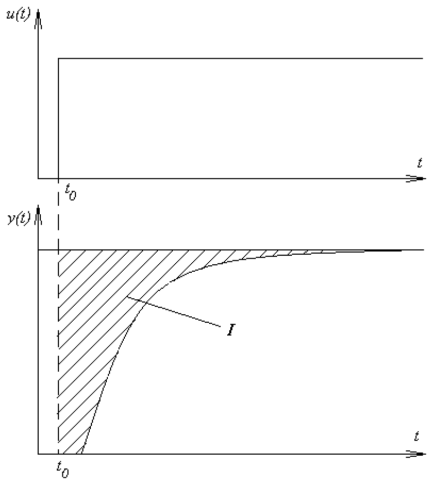

Fig. 9. Integral quality criterion

Therefore, the essence of this work is that an algorithm based on an integral quadratic optimization function has been developed, with the help of which the optimal regulator settings were calculated. The integral criterion proposed in [6, 7] provides a generalized estimate of the decay rate and the deviation of the controlled variable in the form of a single numerical value. It is found using the formula [5, 6]:

$$I = \int_0^T \left[y(t) - u(t) \right]^2 dt = \int_0^T \varepsilon^2(t) dt, \tag{18}$$

where *T* is the control time.

This integral determines the square of the area between the setpoint u(t) and the transient process curve u(t). This integral will depend on the controller settings, i.e., in the case of a *PID* controller (proportional-integral-derivative controller), on the control coefficient Kp, the integration time *Ti*, and the differentiation time *Td*, $I = f(K_p, T_{\text{і}}, T_{\text{д}})$, . The proposed algorithm is based on solving an optimization problem: finding such values of *Kp*, *Ti, Td* for which the quadratic integral criterion would be minimal

$$I = f(K_p, T_{\text{і}}, T_{\text{д}}) = \min. \tag{19}$$

These values of *Kr; Ti*, and *Td* will be the optimal tuning parameters for the controller. For most processes, the integral criterion is a unimodal function, which makes it possible to apply the proposed algorithm.

The research results showed an improvement in the dynamic properties of the system when using the optimal controller settings calculated by the proposed method compared to the most common engineering methods for finding controller settings for CAP with aperiodic and oscillatory OK. Overshoot was reduced by 10 times, control time was reduced by 30%, and static and dynamic errors were reduced by 2–3 times.

A characteristic feature of an oscillatory process is overshoot. High overshoot is considered a disadvantage of automatic control systems and is completely unacceptable for some systems, as it causes system overload, etc. The permissible value of overshoot is determined by the specific operating conditions and the purpose of the ACS. Therefore, an important task is the synthesis of systems with specified (limited) quality indicators of the transient process.

In this work, we propose a developed algorithm for searching for controller settings with the introduction of a restriction on the overshoot of the transient process.

This algorithm consists in constructing the region of possible overshoot using the transformed formula (22):

$$\sigma = \frac{y_{\max} - y_{уст}}{y_{уст}}, \tag{20}$$

$$y = 1 + \sigma, \tag{21}$$

$$y = \frac{y_{\max}}{y_{уст}}. \tag{22}$$

After that, the area is limited by the required overshoot value (a line for a P-controller and a plane for PI and *PID* controllers) (Fig. 13).

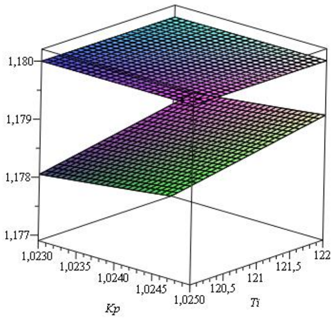

Fig. 13. Finding regulator settings with overshoot limitation

The intersection point of two planes (lines) will be the optimal tuning parameter of the controller with a given value of overshoot of the transient process.

Based on the analysis of the research results, it can be stated that the dynamic properties of the system improve when using the controller parameters calculated according to the proposed algorithm:

– reduction of overshoot by up to 10 times;

– reduction of control time by up to 10 times.

When analyzing systems with a P-controller, it is worth noting an increase in the amount of overshoot, but at the same time, the static error is reduced by 2–3 times compared to other methods.

Strengths. The paper proposes and investigates an algorithm for identifying control objects with different characteristics of transient processes, modeled by second-order links with delay time taken into account. The identification error does not exceed 3%, which is acceptable for calculations of this type. A comparative analysis confirmed that the regulator settings determined using the proposed algorithm significantly improve the dynamic properties of the system (overshoot, control time, static and dynamic errors). An algorithm for searching for controller parameters with a limitation on the amount of overshoot has also been developed and tested, which has shown positive results.

Weaknesses. The quality of the control system is determined by the magnitude of the error, but it is difficult to determine the error function at any given moment in time, since it is described by a high-order differential equation and depends on a large number of system parameters. Therefore, quality is usually assessed using criteria that reflect individual properties of the system.

A promising direction for further research is the improvement of the algorithm for searching for regulator settings with given, limited quality indicators of transient processes.

The results of the experiments confirmed the improvement of the dynamic characteristics of the system when using the optimal settings calculated by the proposed method, compared to common engineering methods for APC with aperiodic and oscillatory control objects. Overeating was reduced by 10 times, the control time was reduced by 30%, and static and dynamic errors were reduced by 2–3 times. The implementation of the proposed control object identification algorithm does not require significant additional equipment costs. At the same time, there are many theoretical and experimental methods for tuning PID controllers. However, there is still no universal approach that would allow determining the optimal parameters for different types of systems.

Conclusions. An algorithm for identifying control objects with different characteristics of transient processes modeled by second-order links with delay time has been proposed and investigated. The identification error does not exceed 3%, which is acceptable for this type of task. Based on the obtained transfer functions of equivalent objects, the parameters of P-, PI-, and PID-controllers for ACS were determined using the triangle method, undamped oscillations (Nicholas–Ziegler method), and the proposed algorithm.

A comparative analysis of the quality indicators of transient processes in the studied ACS using different tuning methods was performed. It was found that the parameters determined by the proposed algorithm significantly improved the dynamic properties of the system, in particular, reduced overshoot, control time, as well as static and dynamic errors.

Література

1. Verhaegen M. Filtering and System Identification: A Least Squares Approach. 2 nd ed. / M. Verhaegen, V. Verdult. Cambridge University Press, 2012. 422p. https://books.google.com.ua/books/about/Filtering_and_System_Identification.html?id=vlOUuAAACAAJ&redir_esc=y
2. Soderstrom T. Instrumental variable methods for system identification // Circuits, Systems and Signal Processing / T. Soderstrom, P. Stoica. 2002. Vol. 21, Issue 1. Pp. 1–9. https://link.springer.com/article/10.1007/ BF01211647 https://sat.bntu.by/jour/article/view/64?locale=ru_RU
3. Loriia M. Experimental investigation of the method of determination of optimal controller settings / M. Loriia

// EURIKA: Physics and Engineering. 2019. № 2. P. 16–22. https://journal.eu-jr.eu/engineering/article/view/864

4. Maryna Loriia, Principles and stages of creation of automatic control systems with a model of complex technological processes / Olexii Tselishchev, Petro Eliseyev, Olga Porkuian, Oleksandr Hurin, Alla Abramova, Sergii Boichenko // Eastern-European Journal of Enterprise Technologies 2022. DOI: https://doi.org/10.15587/1729-4061.2022.270519
5. Driankov, D. Palm R. Advances in Fuzzy Control [Text] / D.Driankov, R.Palm // Physica-Verlag. Heidelberg. Germany - 1988. P. 129-137.
6. Duryshev O. A., Study of the impact of discrete control of the cooling and condensation unit on the efficiency of ammonia production/Kobzarev E. V., Gurin O.M., Loriia M.G. //№ 4 (290) (2025): Вісник Східноукраїнського національного університету імені Володимира Даля DOI: https://doi.org/10.33216/1998-7927-2025-290-4-72-77
7. Karakawa K., Abe N., Ichihara H. Joint design method of closed-loop identification and IMC structure for temperature control system with time delay. SICE 2002. http://dx.doi.org/10.1109/SICE.2002.1196548

References

1. Verhaegen M. Filtering and System Identification: A Least Squares Approach. 2 nd ed. / M. Verhaegen, V. Verdult. Cambridge University Press, 2012. 422p. https://books.google.com.ua/books/about/Filtering_and_System_Identification.html?id=vlOUuAAACAAJ&redir_esc=y
2. Soderstrom T. Instrumental variable methods for system identification // Circuits, Systems and Signal Processing / T. Soderstrom, P. Stoica. 2002. Vol. 21, Issue 1. Pp. 1–9. https://link.springer.com/article/10.1007/ BF01211647 https://sat.bntu.by/jour/article/view/64?locale=ru_RU
3. Loriia M. Experimental investigation of the method of determination of optimal controller settings / M. Loriia // EURIKA: Physics and Engineering. 2019. – № 2. R. 16–22. https://journal.eu-jr.eu/engineering/article/view/864
4. Maryna Loriia, Principles and stages of creation of automatic control systems with a model of complex technological processes / Olexii Tselishchev, Petro Eliseyev, Olga Porkuian, Oleksandr Hurin, Alla Abramova, Sergii Boichenko // Eastern-European Journal of Enterprise Technologies 2022. DOI: https://doi.org/10.15587/1729-4061.2022.270519
5. Driankov, D. Palm R. Advances in Fuzzy Control [Text] / D.Driankov, R.Palm // Physica-Verlag. Heidelberg. Germany. 1988. P. 129-137.
6. Duryshev O. A., Study of the impact of discrete control of the cooling and condensation unit on the efficiency of ammonia production/Kobzarev E. V., Gurin O.M., Loriia M.G. //№ 4 (290) (2025): Visnyk Skhidnoukrainskoho natsionalnoho universytetu imeni Volodymyra Dalia DOI: https://doi.org/10.33216/1998-7927-2025-290-4-72-77
7. Karakawa K., Abe N., Ichihara H. Joint design method of closed-loop identification and IMC structure for temperature control system with time delay. SICE 2002. http://dx.doi.org/10.1109/SICE.2002.1196548.

Гурін О.М., Дурышев О.А, Кобзарев Є. В., Лорія М. Г. Дослідження впливу дискретного управління вузлом охолодження та конденсації на ефективність виробництва аміаку

Об'єктом дослідження є оптимальні параметри налаштування регулятора та показники якості перехідних процесів.

Сучасна проблема полягає в тому, що сучасні технологічні процеси є складними об'єктами управління. Тому при проектуванні систем автоматизації особливо важливими стають завдання ідентифікації об'єкта управління, розрахунку параметрів регулятора та їх подальшої оптимізації. Оптимальні налаштування забезпечують найвищу якість продукції та зменшують її вартість при заданому обсязі виробництва. Пряме визначення параметрів регулятора шляхом експериментів на реальному об'єкті може призвести до втрати якості готової продукції та пошкодження сировини та каталізаторів. Щоб уникнути цих ризиків, алгоритм розрахунку було реалізовано в середовищі програмного пакета Maple.

У ході дослідження було розроблено та протестовано алгоритм ідентифікації об'єктів управління з різними характеристиками перехідних процесів, описаних зв'язками другого порядку, з урахуванням часу затримки. На основі отриманих передавальних функцій еквівалентних об'єктів було налагоджено P-, PI- та PID-регулятори (пропорційний, пропорційно-інтегральний та пропорційно-інтегрально-диференційний). Параметри визначалися за допомогою трикутного методу, методу незагасаючих коливань (Ніколас-Зіглер) та запропонованого алгоритму. Отримані результати призначені для використання в системах автоматичного регулювання.

Було проведено порівняльний аналіз якості перехідних процесів у системах, налаштованих за допомогою різних методів. Було встановлено, що параметри, отримані за допомогою нового алгоритму, значно покращують динамічні характеристики системи (зменшення перевищення, часу регулювання, статичної та динамічної похибок). Крім того, було запропоновано алгоритм пошуку параметрів регулятора з урахуванням обмеження перевищення, який також показав позитивні результати. Похибка ідентифікації не перевищує 3 %, що є прийнятним для розрахунків такого типу.

Ключові слова: *ланка другого порядку, параметри регулятора, час керування, алгоритм ідентифікації, перехідний процес, час затримки.*

Гурін Олександр Миколайович – аспірант кафедри комп`ютерно-інтегрованих систем управління, Східноукраїнський національний університет імені Володимира Даля, gurin@ukr.net

Дуришев Олександр Андрійович – аспірант кафедри комп`ютерно-інтегрованих систем управління, Східноукраїнський національний університет імені Володимира Даля, duryshev@snu.edu.ua

Кобзарев Євген Володимирович – аспірант, асистент кафедри комп`ютерно-інтегрованих систем управління, Східноукраїнський національний університет імені Володимира Даля, kobzarev@snu.edu.ua

Лорія Марина Геннадіївна – д.т.н., професор, завідувач кафедри комп`ютерно-інтегрованих систем управління, Східноукраїнський національний університет імені Володимира Даля, m_loria@snu.edu.ua

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