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Determination the dynamic parameters of the controlled technological processes of coal preparation by using the semi graphical method

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S u m m a r y . Presented a graphic-analytical method for determining the dynamic parameters of the regulated coal preparation processes using the experimental data. The algorithm of the proposed method stems from graph-analytical analysis of the transition function, built for the aperiodic link second order. The proposed method allows determining the dynamic parameters of the controlled system with a minimum amount of experimental data.
K e y w o r d s . Coal preparation, graphic-analytical method, dynamic parameters of characteristic equation

INTRODUCTION

The events in Ukraine over the last decade suggest that there has been a strengthening of scientific research in the field of mining and mineral processing, and, in particular, mining and processing of coal. This fact is confirmed by the appearance of a number of new scientific publications, the development of new technological tools and systems, new proposals for the use of innovative methods of analysis and synthesis of automatic control system (ACS), ensuring optimum economic process.

In this context, the definition of the dynamic parameters of the regulated objects is particularly important because the positive effect of the use of innovative methods of synthesis of ACS may be offset by significant errors in determining the parameters of the controlled system.

Much of the fact, noted above, refers to the analysis and synthesis of the major ACS process coal (flotation, jigging, and preparing coal in severe environments) for coal preparation plants.

The latter is due to the following circumstances.

Input and (or) output parameters of the regulated objects are mainly the parameters that characterized the quality indicators of enriched coal and products of its enrichment. Today industrial equipment for automatic analysis of coal quality and product enrichment are not mounted yet at coal-preparing plant (CPP). That is why the required information can be obtained only by sampling and analysis. Researcher is forced to develop the plans of experiment taking in account high labor and cost of testing process but not the data that he got from statistical analysis.

In addition, the researcher, as a rule, tends to make all measurements to determine the dynamic characteristics of the object under the same conditions. From this point of view, the ideal conditions of the experiment would be constant quality and quantity of enriched material that is raw coal. CPP equipped by special averaging device to stabilize the fractional composition and particle size of raw coal. However, the statistical analysis of the qualitative and quantitative characteristics of the raw coal shows that these devices are not solving completely the problem of instability in the separated coal. That is why the qualitative and quantitative characteristics of the raw coal are not permanent. The maximum frequency of the qualitative and quantitative characteristics of the raw coal is on average $8*10^{-4}$ s^{-1}. This frequency corresponds to the oscillation period equal to 2.2 hours (about 130 seconds).

Provided suggestions for determining the dynamic parameters of the coal preparation processes using the least possible amount of experimental data in light of this information are important and their realization is an urgent task.

THE RELEVANCE OF THE STUDY

Plan of experimental studies of controlled object in the conditions of the action of disturbance should be developed taking in account matching the value magnitude of the first harmonic of disturbance and the time constant of the object. The results of the comparison of these parameters will allow to choose a strategy of measurement that ensures the reliability of the results.

It is believed that the time constant to the channel input - output for the machine which receive and process a continuous stream of technological resources is close in meaning to the value K. The value K is equal to the ratio of the volume of the material is in the machine to the performance of this device on the processed raw materials [Tikhonov O. 1973].

Let's take as example of an object of regulation the hydraulic jig for coal preparation. Let's choose the jig VBP (MO) with the volume of material 5-6 m^3 and average performance of the raw coal 180-320 t/h (about 180-320 m^3/h). In this case, the time constant will be equal to 40 - 100 s. Let's write the model of this jig as aperiodic link of second order by the channel "raw coal capacity - coal concentrate quality" [Lehtsier O. 2005]. Then the transfer function of the object $W(p)$ can be written as

$$W(p) = \frac{k}{T^2 p^2 + 2\rho T\, p + 1} = \frac{k}{(T_1 p + 1)\,(T_2 p + 1)},$$

where k, T, T_1 and T_2, ρ - the gain coefficient (*k*), time constants of the object (T, T_1 and T_2) and the damping factor (ρ).

Taking in account the above numerical parameters, the transfer function of the object can be of the form

$$W(p) = \frac{k}{20^2 p^2 + 2*1.5*20p + 1} = \frac{k}{(52_1 p + 1)\,(7.6_2 p + 1)}.$$

Frequency function for this expression is:

$$W(j\omega) = \frac{k}{20^2 (j\omega)^2 + 60 j\omega + 1}.$$

The graph of frequency function in the frequency range [0 - 0.5 1/s] is presented in figure 1.

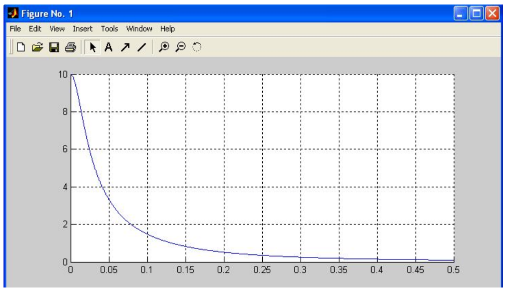
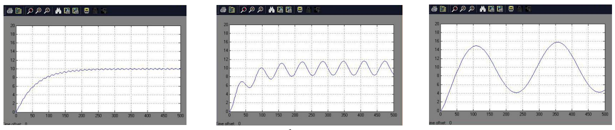


Fig.1. Graph of frequency function with the k = 10

Analysis of the graph given in fig. 1, shows that value of harmonic signal is virtually absent when the value of the oscillation period is less than 60 seconds. More clearly this fact illustrated by three separate graphs, (look fig.2) obtained by computer simulation for the frequencies ω 0.5, 0,1 and 0.025 1/s.



a b c

Fig. 2. Graphs of the transition functions with k = 10; x (t) = 1 + sin ωt, ω - frequency of the periodic component of the input signal; a) ω = 0.5 1/c (~4,8 cycles per minute), b) ω= 0.1 1/c (~1 cycles per minute), c) ω= 0.025 1/c (~0,24 cycles per minute)

From these graphs, it follows that a periodic signal of disturbance which has a frequency less than

ω = 0.1 1/s significantly distorts the output signal of the controlled system. And only when the frequency of the disturbance ω ≥ 0.5 1/s, we may assume that the disturbance has almost no effect on the output signal.

In connection with the above, the intervals between the steps of the experiment should be selected taking in account fluctuations of the parameters of the initial coal.

In addition, we note that the fixed fact impairs the quality of regulation in the existing ACS. To improve the quality of control by coal preparation processes necessary to equip ACS not only by control loops in the deviation, but by feedforward control loop also.

MATERIALS AND RESEARCH RESULTS

Graphic-analytical method of data processing assumed to provide sufficient representative of data for initial and final phases of the experiment. This provides two reliable stages: point in which time t = 0 (start of the experiment) and the ordinate of the asymptote, which gives (approximately) point for t = ∞, ie point at which the transition designedly is over.

In addition to this information, need several points, which will submit the curvature of the transient.

Let's review the use of this method with the following example. Let's agree to identify our control object by aperiodic link of the second order. Differential equation of such object has the form

$$T_2^2 \frac{d^2 y(t)}{dt^2} + T_1 \frac{dy(t)}{dt} + y(t) = k\,x(t) \qquad (1)$$

Transfer function

$$W(p) = Y(p)/X(p) = k/(T_2^2 p^2 + T_1 p + 1).$$

Let k = 1. The characteristic equation of the link will be

$$T_2^2 p^2 + T_1 p + 1 = 0.$$

The roots of the characteristic equation:

$$p_{1,2} = (-T_1 \pm \sqrt{T_1^2 - 4T_2^2})/2T_2^2.$$

The general solution of (1) which defining the free movement:

$$y(t) = C_1 e^{p_1 t} + C_2 e^{p_2 t}.$$

A particular solution we'll obtain taking into consideration the zero initial conditions

$$y(0) = 0; \quad y'(0) = 0.$$

Let's agree that in our case $T_1 \geq 2T_2$, then both roots are real

The transition function of the object with k = 1 is:

$$y(t) = 1 - \frac{-T_1}{T_1 - T_2} * e^{\frac{-t}{T_1}} + \frac{T_2}{T_1 - T_2} * e^{\frac{-t}{T_2}}.$$

Suppose, for example, the transfer function of our object is equal:

$$W(p) = \frac{1}{20^2 p^2 + 60\,p + 1}.$$

The characteristic equation of this link is equal

$$20^2 p^2 + 60\,p + 1 = 0.$$

The roots of the characteristic equation are:

$$p_1 = -0.0191,$$
$$p_2 = -0.1309.$$

Let's denote

$$p_1 = -\frac{1}{T_3}, \quad T_3 = -\frac{1}{p_1} = 52.356;$$
$$p_2 = -\frac{1}{T_4}, \quad T_4 = -\frac{1}{p_2} = 7.639.$$

The transition function for these values is

$$y(t) = 1 - \frac{T_3}{T_3 - T_4} * e^{\frac{-t}{T_3}} + \frac{T_4}{T_3 - T_4} * e^{\frac{-t}{T_4}} \qquad (2)$$

Graph of the transition function of our object is shown in fig. 3.

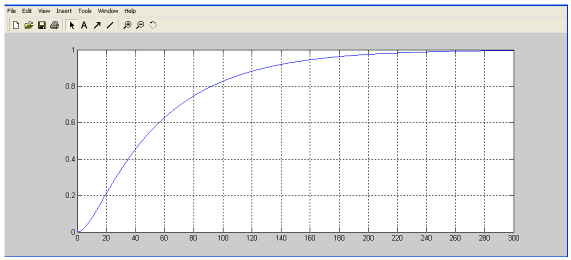


Fig. 3. Graph of the transition function

The shape of the curve of the transition function schematically shown in figure 4.

It can be seen that the argument t increases when derivative of this function (which is tangent to the curve) also increases at the beginning.

At point M the derivative reaches a maximum and then, after a point M, the value of the derivative begins to decrease.

Thus, at M tangent line is tangent simultaneously to the ascending and descending branches of the curve of the transition process. And the second derivative at the point M equal zero. With that said, we have:

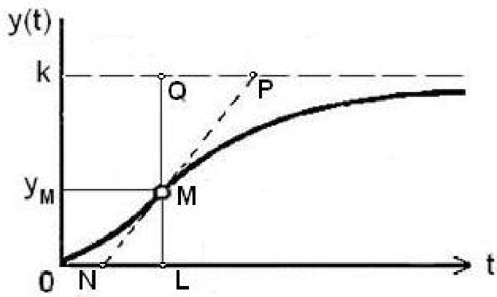


Fig. 4. Schematic picture of the curve of transition function

Let's define the value of the second derivative of the transfer function (2) to determine the abscissa of the point M:

$$y' = \frac{1}{T_3 - T_4} * e^{\frac{-t}{T_3}} - \frac{1}{T_3 - T_4} 1 * e^{\frac{-t}{T_4}} \qquad (3)$$

$$y'' = -\frac{1}{(T_3 - T_4) * T_3} * e^{\frac{-t}{T_3}} + \frac{1}{(T_3 - T_4) * T_4} * e^{\frac{-t}{T_4}}$$

For a point M is true $y''=0$. Then

$$\frac{e^{\frac{-t}{T_3}}}{e^{\frac{-t}{T_3}}}=\frac{T_3}{T_4}, \quad \ln\frac{T_3}{T_4}=-\frac{t}{T_3}+\frac{t}{T_4};$$

$$t=\frac{T_3 T_4}{T_3-T_4}\ln\frac{T_3}{T_4} \qquad (4)$$

We'll obtain the value of the segment 0L substituting in equation (4) the values T3 and T4: $t_M=17.21\ c$.

Ordinate of the point M can be obtained from equation (2) with a value of t = 17.21. The tangent of the slope in point for which $y''=0$. can be calculated from the equation (3) for first derivative using the obtained coordinates of point M.

We can now find a point P of intersection line NM and line k=const, indicated in fig. 5. This can be done by jointly solving the equation of the tangent with the value of the abscissa (in our case k = 1)

Now, we can determine the sum of the time constants (T3+T4 graphically, by measuring segment QP.

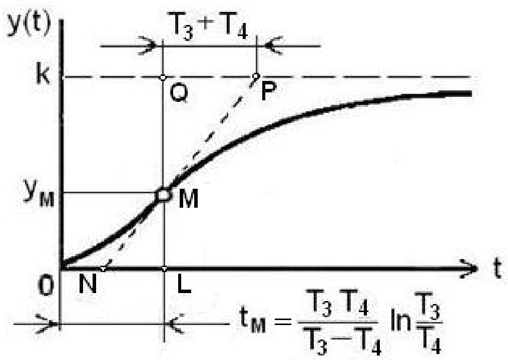


Fig. 5. Determination the time constants T3 and T4 using graphic measurement

Figure 6 shows the transfer function (2) constructed by computer simulation. Above mentioned points of the graph are indicated in the figure.

The sum of the time constants of T3 and T4, that was determined from the graph, is not very different from the calculated value. This difference depends on the scale of the chart. Graphical way to solve the individual values of T3 and T4 by given T3+T4 is predisposed to make bigger errors caused by inaccurate graphs. For this reason, sometimes researchers prefer to use an analytical way. Algorithm of analytical method for determining the separate values T3 and T4 can contain also a subroutine that takes into account the degree of approximation curve to the experimental data.

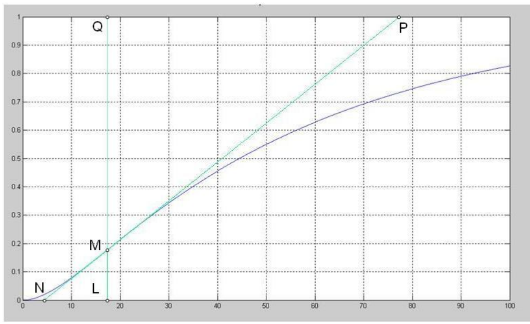


Fig. 6. The transition function for the assumed values of T3 and T4

Block diagram of the program calculate the time constants of T3 and T4 using the graphic data of measurement segments QP and 0L is shown in fig. 7.

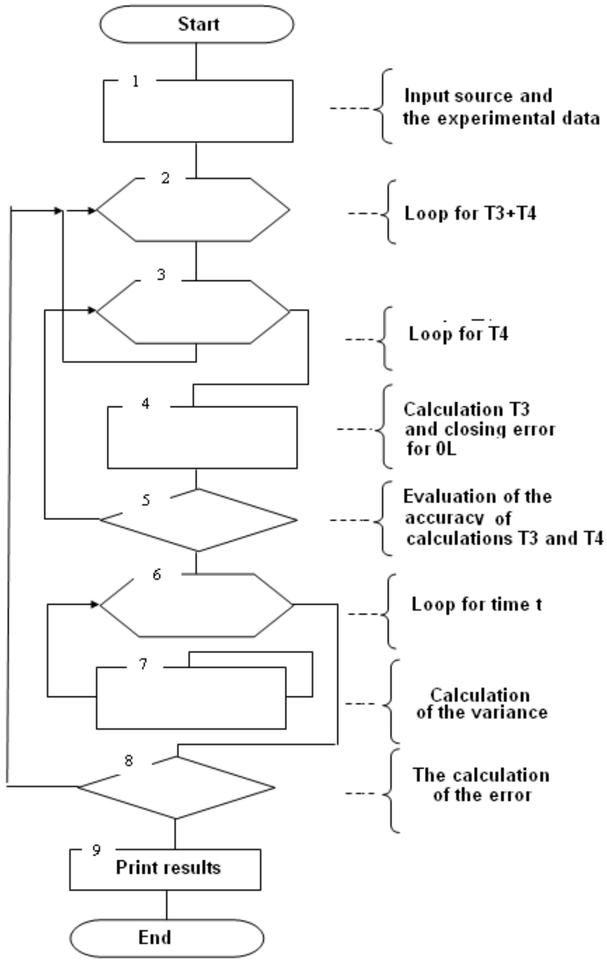


Fig. 7. A block diagram of the program calculate the time constants of T3 and T4

Calculation of time constants with this program gave the following results: T3 = 52.32 (relative error was 0.1%), T4 = 7.68 (relative error is 0.5%).

As the initial data were taken these values:

0L = 17.28 s. and QP = 60.1 s.

In conclusion let's summarize the main steps in determining the parameters of the characteristic equation. The next stages of the work have to be done

1. Perform statistical analysis of experimental data of transfer function. Remove mistakes and errors in the experimental data.

2. Construct the graph with experimental data taking in account the statistical correction.

3. Define the point M (Fig. 6). From point M draw a tangent to this curve. Find segments OL, ML and QP by graphic way.

4. Determine the parameters of the characteristic equation of the object for which there is minimal deviation of the transition process relative to the experimental data (using given algorithm).

CONCLUSIONS

Application of the algorithm to determine the dynamic parameters of the control object which represented by the aperiodic link of second order gives capability for using a smaller amount of experimental data

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ОПРЕДЕЛЕНИЕ ДИНАМИЧЕСКИХ ПАРАМЕТРОВ КОНТРОЛИРУЕМЫХ ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССОВ ОБОГАЩЕНИЯ УГЛЯ С ПОМОЩЬЮ ГРАФОАНАЛИТИЧЕСКОГО МЕТОДА

Олег Лехциер, Виталий Ульшин,
Олег Кильмник, Алексей Писменский

Аннотация. Представлен графоаналитический метод определения динамических параметров процессов обогащения угля с использованием экспериментальных данных. Алгоритм предлагаемого метода основан на графоаналитическим анализом переходной функции объекта, аппроксимированного апериодическим звеном второго порядка. Предлагаемый метод позволяет определить динамические параметры объекта управления при минимальном объеме экспериментальных данных.

Ключевые слова. Обогащение угля, графоаналитический метод, динамические параметры характеристического уравнения