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VIRTUAL ANALYSER OF QUALITY OF LIQUID PRODUCTS

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***Abstract**: The conceptual foundations of the construction of virtual analysers and their application in systems for monitoring the state of continuous technological processes are considered. A parametric model of process control is proposed, allowing to structure a multitude of virtual analysers and determine the types of their functionality. An approach to the problem of building a unified virtual monitoring system based on a matrix of typical virtual analysers has been studied.*
Keywords: *virtual analyser, virtual monitoring,*

One of the most important tasks of industrial enterprises is the modernization and development of methods and technical means of analytical measuring equipment in order to increase the production of high-quality products at the lowest cost. To ensure the required quality, it is necessary to maintain the main technological parameters - such as viscosity, density, flow rate, etc. Their values come from sensors located on the technological object. Maintaining the required parameters of products is complicated by the need to ensure high sensitivity to the violation of a given mode, as well as a large number of control points and management, systematic errors in the testimony of instrumentation [1]. Currently, special attention is paid to the production of instrumentation that improves product quality. The purpose of this work is to consider the development of virtual analysers for the study of rheological properties in the quality control of products manufactured by enterprises.

When assessing the composition of raw materials and the quality of the output products of various installations, laboratory measuring devices are used. However, the results of analyses obtained in factory laboratories do not always have the necessary level of completeness and efficiency and cannot be used for operational quality management. The technological process periodically deviates from the optimal operating parameters, which requires its adjustment. The operation of the installation is supported not only by the general parameters of the process, but by the composition of the streams. It is necessary to ensure the invariance of the properties of the products obtained, determined by laboratory analysis [2]. As an alternative, it is proposed to use virtual analysers, which determine the current properties of raw materials and products according to a mathematical model and are characterized by data obtained by already existing instrumentation.

When creating virtual analyzers (VA), hybrid neural networks, the least squares method, the method of group accounting of arguments (MGUA), ridge regression, etc. are used. The main sources of information for virtual analysis are:

- the hidden redundancy contained in the physic-chemical measurements of existing systems of instrumentation and instrumentation and the results of the work of the factory laboratory;
- retrospective technological knowledge accumulated in the process control process and stored in a database.

In most practical cases, operational control of technological processes is carried out on the basis of using the results of monitoring the production situation, which in turn is implemented through the collection and primary processing of data, including the results of the use of measuring tools and complexes ((usually included in the structure of automated process control systems (ACS TP)), as well as laboratory analyses of intermediate and commercial products. In the broadest sense, a virtual sensor can be interpreted as an observer who estimates from known state variables those that are not directly measured. In fig. 1 shows a block diagram of a virtual analyser. Since it is impossible to create a model of a virtual sensor without errors, a filter is introduced for error correction, with which you can reduce the effect of interference.

Using the least squares method, we construct a regression model of the virtual analyser:

$$\hat{Y} = a_0 + \sum_{i=1}^{k} a_i X_i + \sum_{i<j} a_{ij} X_i X_j + \sum_{i=1}^{k} a_{ii} X_i^2 + \ldots \quad (1)$$

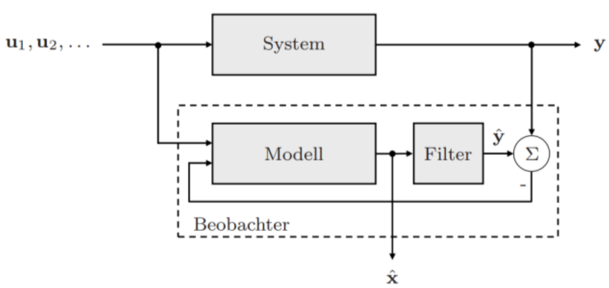

Fig. 1 ***Block diagram of the virtual analyser*.**

By the formula (1), all the elements of the experimental data are first determined, and then the regression coefficients are calculated from them.

To assess the quality of the model obtained, the coefficient of multiple correlation is determined:

$$R = \sqrt{1 - \frac{(N-k)S_{ocm}^2}{(N-1)S_y^2}} = \sqrt{1 - \frac{\sum_{k=0}^{N-1}(y_k - \hat{y}_k)^2}{\sum_{k=0}^{N-1}(y_k - \bar{y}_k)^2}} \quad (2)$$

where the residual dispersion is equal to:

$$S_y^2 = \frac{1}{N-1}\sum_{k=0}^{n-1}(y_k - \bar{y})^2$$

When creating a VA model, neural network models are used. From a mathematical point of view, neural networks (NN) map the vector of input variables to the output vector. The properties of this mapping are determined by the topological structure of the NA: the number of levels, the number of elements at each level, the values of synoptic connections. The learning algorithm means a procedure that uses the rules for learning and calculating a virtual analyser.

The learning process of the neural network model is implemented using a unidirectional network that is trained using the back-propagation error algorithm. The simulation is carried out using the MatLab software package.

1. The traditional cybernetic model of the "black box" is used as the initial structure for the analysis of the technological process. In accordance with the SADT (Structured Analysis and Design Technique) methodology used to form and present structural models, the "black box" of the technological process will look like Figure 2.

Abstraction SATD Formalization TP

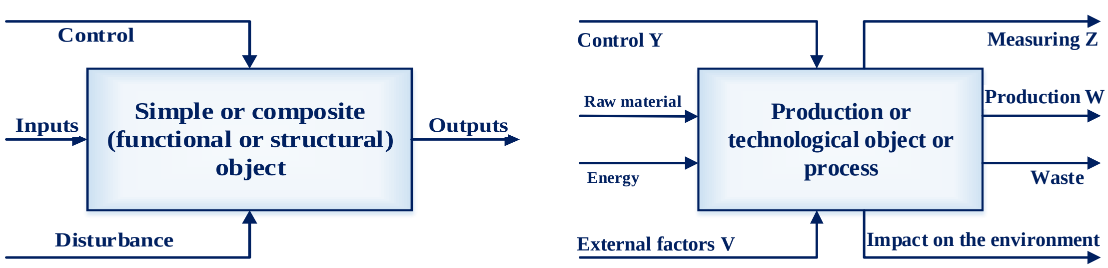

Fig 2. ***Scheme of formalization of a single object of the structural model diagram***

The description of the object being studied is given in the form of a triad of sets

$$y = f(x, u, y') \quad (3)$$

where U = {u1, u2, ...} is the set of control input actions, X = {x1, x2, ...} is the set of input states of the technological process, Y ’= {y1, y2, ...} is the set of state processes.

In the problems of synthesis, the most important role is played by the structure of the system, which is to be determined. In this connection, the generalized model of the object becomes complicated and takes the form

$$y = f(x, u, y, A, R, G) \quad (4)$$

where A is the set of system elements; R is the matrix of relations between the elements of the system given on A; G is the relationship matrix between sets A and X.

The component part of the system {A, R} is called its structure, and {U, X, Y} is the program of its functioning. Thus, the system is the union of these two components, and its unity is determined by the emergence relation G.

When developing a virtual analyser, it is extremely difficult to determine in advance the most rational mathematical platform, which makes it possible to synthesize an effectively functioning process analysis system. The choice of the mathematical core of the virtual analyser is associated with the used measuring equipment, the specifics of the implementation of the technological process, its management, statistical and dynamic structures of the initial data, the nature of uncertainty and other factors unknown in advance. In this regard, it is advisable to build a matrix of virtual analysers, the elements of which are a virtual process analyser built on different mathematical cores. Note that the standard analysers included in the matrix, it is advisable to build for some basic set of technological processes. This is due to the fact that complex technological processes, as a rule, consist of a set of typical processes that are repeated for different tasks.

VA significantly expands the possibilities of monitoring the process. However, this is not always sufficient to optimize management, since requires the implementation of a number of additional functions. The most important of these is the search for optimal control Y * = У*= $\{y_1, y_2, \ldots, y_\chi\}^*$, ensuring the achievement of the extreme value of the selected quality indicator Ψ[U, X, Y]=extr{У}, subject to the fulfilment of a set, in the general case non-linear constraints. Expansion of the VA functionality to control tasks leads to the class of DSS-systems (decision support systems). In this case, the matrix VA is transformed into a three-dimensional functional structure (cubic matrix), the elements of which are variants of constructing DSS for various optimality criteria and technological processes.

With a uniform mode of fluid flow, the viscosity value is calculated by the following formula:

$$\mu = \frac{\pi D_g^3 \Delta P \left(2D_{2cp} - D_g\right)}{192Ql}, \quad (5)$$

where D_g is the hydraulic diameter, Q is the volumetric flow rate of the fluid, ΔP is the pressure drop at the ends of the capillary, l is the length of the capillary.

The value of the hydraulic diameter is determined by the microcontroller according to the data obtained using the position sensor S:

$$D_g = C_1 S. \quad (6)$$

The length of the capillary is constant (in our case it is equal to 20 cm). The values of pressure drops microcontroller receives from the output of the differential pressure gauge.

The flow rate of the fluid flowing through the capillary is regulated by a servo and is determined as follows:

$$Q \leq \frac{500\mu D г}{\rho}. \quad (7)$$

The speed of rotation of the servo is regulated depending on the viscosity value and the working section Dg. The value of density ρ is calculated by the microcontroller in accordance with the functional dependency inherent in it

$$\rho = \frac{m}{V}, \quad (8)$$

where m is the mass of the test medium, (the value of which is obtained using strain gauges installed on the device); V is the volume of the device (V = const).

Using data from technological sensors of different physical nature, it is possible to construct a majority voting algorithm, that is, using the majority element, you can perform a voting function to evaluate the technological features of the pumping mode. The majority element is called the logical element (switch), which operates according to the majority principle. The principle of the majority is that if the majority of input signals is 1 or 0, then the output signal will be respectively 1 and 0. It always has an odd number of inputs. The algorithm of the majority element for building a virtual analyser is shown in Figure 3, where the technological parameters of the flow, pressure and vibration of the pumping pipeline are involved in the majority assessment.

Thus, when evaluating the quality of products in industrial production, the use of virtual analysers makes it possible to calculate the value of viscosity at various volumes of fluid flow. It should be noted that virtual analysers are the most accessible means of monitoring the state of the technological process in enterprises.

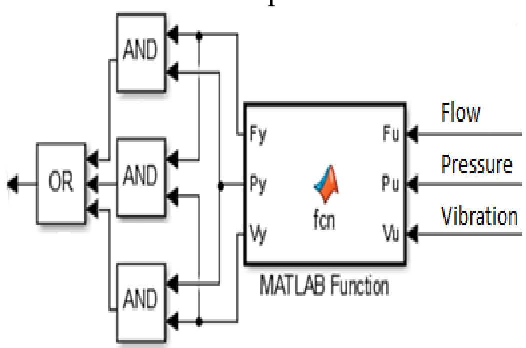

Fig 3. ***The structure of the element of majority voting***

Their main advantages are the availability in use and use, the relatively low cost of obtaining models and the speed of updating data.

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