DEVELOPMENT OF A PREDICTIVE MODEL OF A MULTI-PARAMETER FORMALIN PRODUCTION PROCESS UNDER THE INFLUENCE OF DEVIATIONS

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Annotation . Currently, the quality of the output product in the production of formalin is determined in laboratory conditions, which is an expensive, complex process and takes a long period of time. The article discusses the analysis of methods for constructing predictive models of an industrial technological facility. using ordinary least squares (OLS) and regressions to improve the efficiency of safe process control. An approach to constructing predictive models of product quality based on regression models is presented. It is shown that the results obtained do not contradict existing methods for selecting regression modeling methods for constructing predictive models. An approach to constructing a predictive model for making decisions on the operational management of multi-stage and multi-dimensional continuous formaldehyde processes is described.

Keywords. automated control , technological processes , multiparameter model, virtual analyzer, least squares methods, control systems

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INTRODUCTION: Currently, the economy is striving for innovative development based on the restructuring of the oil and gas industry, the development of petrochemical and chemical production, as well as the use of complex and energy-intensive technological processes . The management of such production facilities, characterized by multi-stage and complex processes, requires mathematical models that correspond to real conditions, as well as effective automated control systems. a large number of parameters and variability of conditions [1,2]. The category of such multi-stage and complex processes includes technological processes for the production of formalin [3,5].

In order to improve the control system for multi-parameter technological processes in multi-stage production, it has been proposed and implemented in some control systems to monitor the state of the technological process by a number of parameters and add forecasting functions that allow predicting possible deviations [7,8].

Dispatcher control uses forecasting and modeling methods. The ability to monitor the results of forecast calculations of the production regime allows the dispatcher to take timely measures to correct them, while assessing the trends of the current regime and minimizing possible control errors.

POST A PROBLEM AND A QUESTION THAT NEEDS TO BE SOLVED: For a multi-parameter technological process for the production of formaldehyde, it would be advisable to predict the concentration of formaldehyde and use a specific mathematical model for the development of optimal control models for this indicator.

When choosing this mathematical model, an analysis is carried out at different stages of the formaldehyde production process, as well as modeling of the mechanisms of various technological processes. In our opinion, in this case you can make the best choice. using the division of the production process into certain stages, the synthesis of modeling mechanisms for these stages.

MATHEMATICS (FIRST LEVEL GUIDE) : When developing a model for predicting the formalin production process, first of all, we focus on the process in the S-2 alcohol blocker as the main technological process and the main technological parameters associated with it (axial variables). Here the methanol consumption M C , fresh air (oxygen) consumption A C , concentration of alcohol-air mixture AAM C , temperature of the alcohol-air mixture - AAMT (temperature of the alcohol-air mixture). Based on the values of these technological parameters, obtained (measured) and ordered chronologically using a SCADA system that directly controls the production complex in real processes (these data were not presented in the article due to the large volume), a forecasting model for the formaldehyde production process was built developed under the influence of the unrest. .

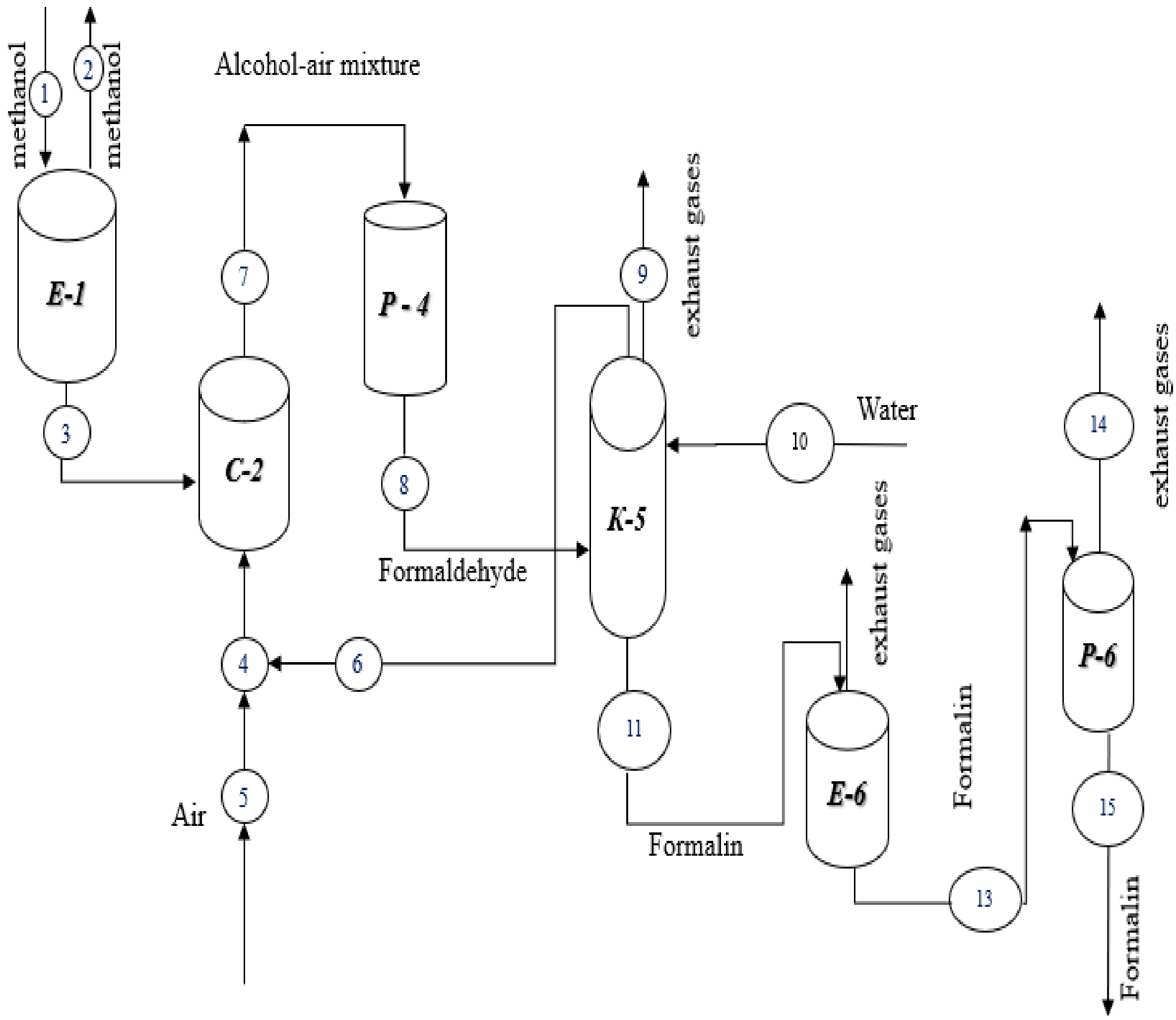

FIGURE 1. 1-reception of raw materials for methanol production; 2-release of return methanol; 3-transfer of methanol to an alcohol evaporator by filtration;4,6 - air blowing, 5-air blowing, 7-alcohol-air mixture; 8-Formaldehyde; 9,12,14 - neutralized exhaust gases; 11,13 - weak formalin; 15 - ready-made formalin; E -1 - methanol collection tank; C -2 - alcohol evaporator; P–4 – contact device (reactor); K-5 - formaldehyde and water saturation column (absorption column); E-6 – formaldehyde collection container; P-6 - formalin quality standardization reactor;

RESULTS AND DISCUSSION : A mathematical model of a technical object is a set of mathematical objects and connections between them, adequately reflecting the properties of the object under study that are of interest to the researcher (engineer). Building black box models involves intensive use of experimental data. A formalized description of technological systems is carried out on the basis of model approximating assumptions. The least squares method is used as a mathematical approximation tool.

Taking into account all the listed factors in the formaldehyde production process and the influence of shocks affecting the course of technological processes, we present the following mathematical model of the formaldehyde production process, which has the required quality (concentration:

$$FC_k = \widehat{FC}\big(I_k, U_k, \varepsilon(\varphi)\big) + e(1)$$

Here, the following variables are described as elements of a generalized mathematical model: k- a set of key technological factors directly related to technological processes in Ik − kthe -cycle, ε- a set of control actions in Uk − kthe -cycle, ε - disturbance function φ, Factors that have the largest share in the synergy of influencing factors (main disturbances) eare the model error.

(1) putting into the empirical model the values of the factors (parameters) involved in the technological process and included in the structure of the conceptual model, we write this model as follows:

$$\widehat{FC}_k = 41801{,}6 + 0{,}5242 \cdot \varepsilon_1(\varphi) + 0{,}111 \cdot MC_k - 0{,}014 \cdot AC_k +$$
$$-0{,}1578 \cdot WC_k + 1{,}3088 \cdot TK_k - 21355 \cdot U_{1_k} - 591{,}348 \cdot U_{2_k}(2)$$

The results of the regression analysis of the parameters of this model are presented in Table 1 below.

From the data in table (2) it is clear that the conditions for the adequacy of the model are met. Indeed, the coefficient of determinism of the model accuracy is 0.795, and the 80% variance of the resulting value follows from the regression equation. Considering that the tabular value of z-statistics is equal to 1.986 with the number of degrees of freedom at the significance level a=0.05 v=99, when analyzing the significance (values) of the model coefficients based on the hypothesis of their insignificant deviation from zero depending on the nature of the randomness of factors, concentration alcohol-air mixture AAMS, average temperature in the reactor zone RT (average temperature in the reactor zone), temperature of the reagent gas released in the reactor RGT (temperature of the reagent gas released in the reactor) and the values of the coefficients in front of the water consumption variables WC (water consumption) become insignificant according to criterion for comparing their values with random error.

(1) we re-run the regression analysis excluding the synergy share from the model. Substituting the corresponding coefficients in table. 2 variables into the empirical model of representation (1), we obtain a model with other parameters different from the next representation, i.e. (1)

$$FC_k = 11911{,}6 + 0{,}5492 \cdot \varepsilon_2(\varphi) + 0{,}0632 \cdot MC_k - 0{,}0056 \cdot AC_k +$$
$$-0{,}0718 \cdot WC_k + 0{,}4774 \cdot TK_k - 6074{,}26 \cdot U_{1_k} - 371{,}553 \cdot U_{2_k} (3)$$

This newly constructed (3) Model (1) fully satisfies the requirements of monandality (adequacy) for the model. In fact, if we pay attention to the sum of deviations calculated for both models, presented in Table 3, the root mean square error - RMSE test (Root Mean Square Error) is -0.79 and the mean absolute error - MAE (Mean Absolute Error) test is 0. 64, mean relative error - MPE test (mean percentage error) -0.05, mean absolute relative error - MAPE test (mean absolute percentage error) is 1.63, test (Theil's U) is 1.15. It is important here that the approximation error for both models does not exceed 1.7, i.e. $\sigma_1 \approx 1{,}63,\ \sigma_2 \approx 1{,}64$.

To get a general idea of the quality of the model based on the relative deviations of each observation, the average error of approximation is defined as the simple arithmetic mean error as follows:

$$A = \frac{1}{k}\sum_{i=1}^{k}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \cdot 100\%$$

An approximation error in the range of 5-7% indicates that the model fits (fits) well to the original data. Typically, the approximation error, i.e., the permissible limit of a ni values, does not exceed 8–10% (8–15% is allowed) [9].

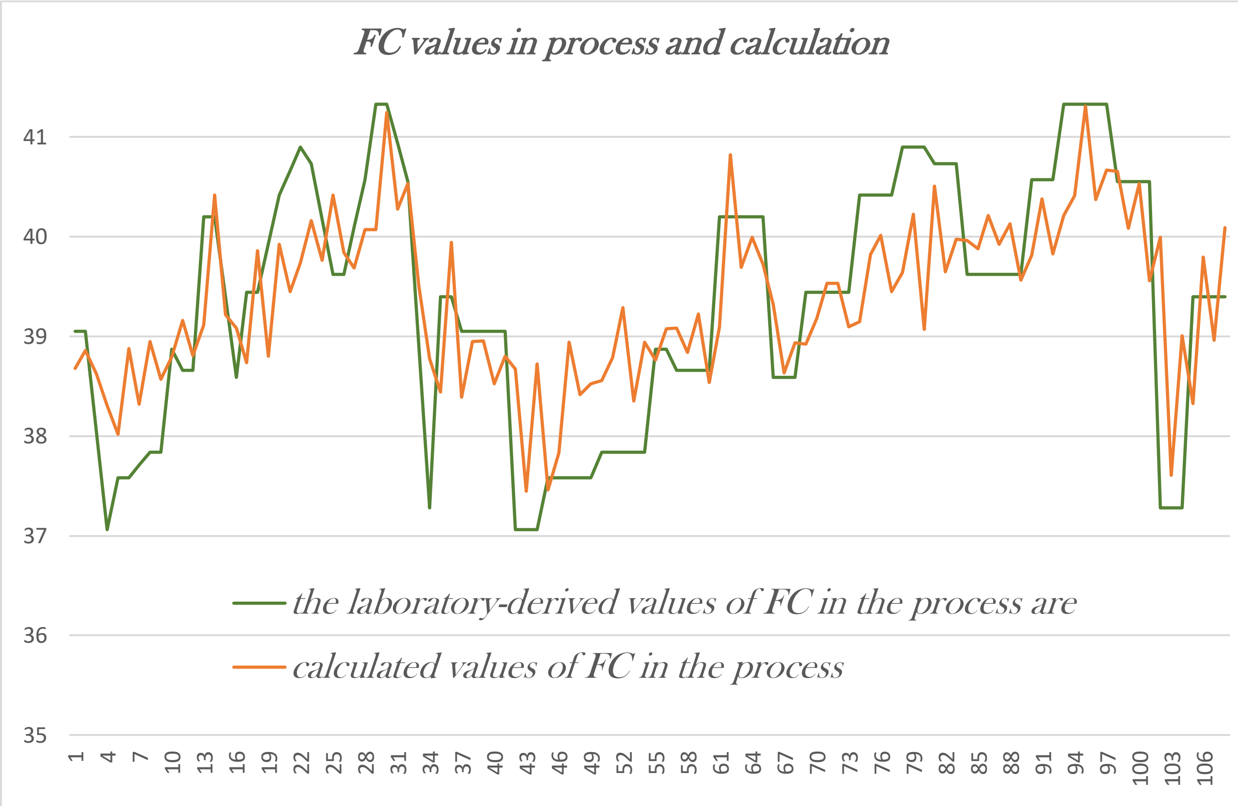

Figure 1a. (2)-graph of model values

The difference between these errors was 5-7 percent, although the model is considered good, and with its value of 8-10 percent it is considered satisfactory. Sometimes, depending on the nature of the complexity of the object being studied, this difference is expanded. up to 15 percent are also observed [9].

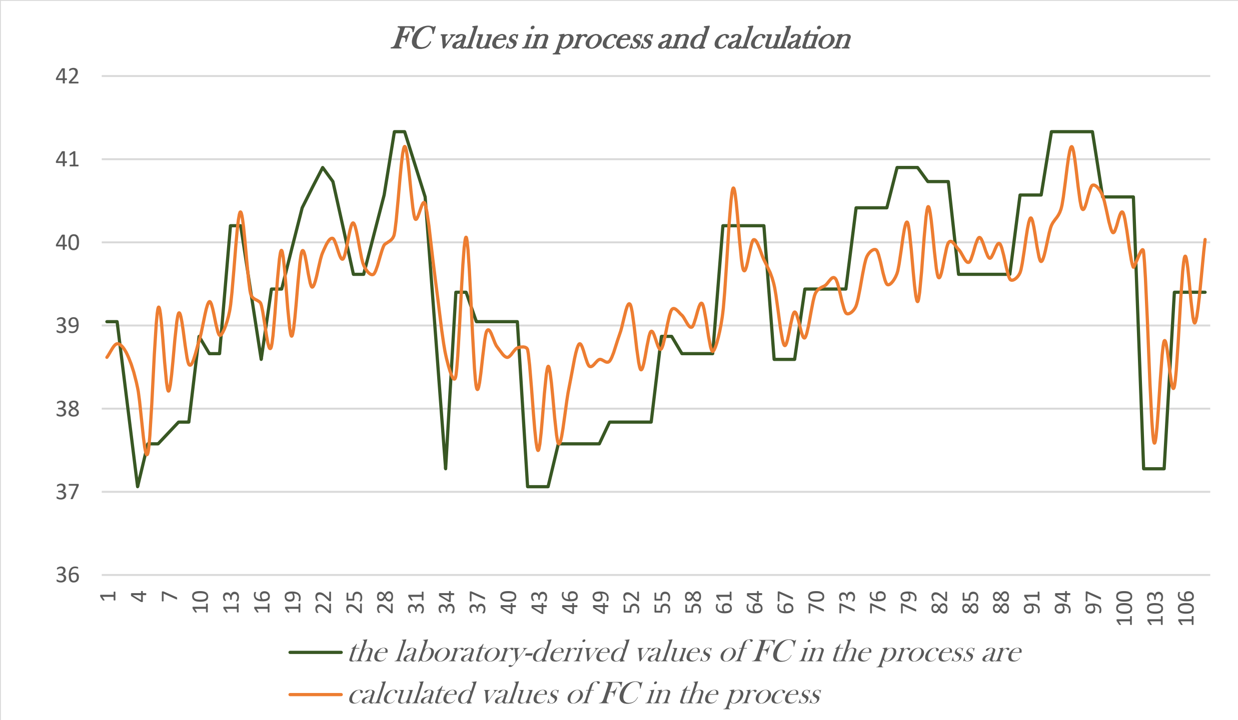

Figure 1b. (3)-graph of model values

In our opinion, modeling justifies the fact that the probability that each parameter has the property of a decisive factor when it is carried out for a multi-parameter technological process is a narrow-limit method for studying this approach. Step by object, carried out with the right to choose each parameter, remains completely irrelevant for identifying the Zion model. This may lead to the approach described above being taken in the same context as the identification question that is being built for the model. and the objection of an inexperienced researcher. These axiomatic considerations highlight the importance of using a wide range of adequacy criteria in the modeling process.

The graph of the values of the empirical model built for the formalin production process under the influence of disturbances is presented in Figures 1a, b below.

It is quite obvious that the practice of using the above adequate models requires the construction of response functions that allow assessing the impact of a riot, where this is one of the main tasks. For this reason, to evaluate hidden fluctuations in the system by factors, we carry out the analysis as follows . To do this, we first build a graph of the transformation of the riot factor (hidden fluctuations in the system) (Figure

2).

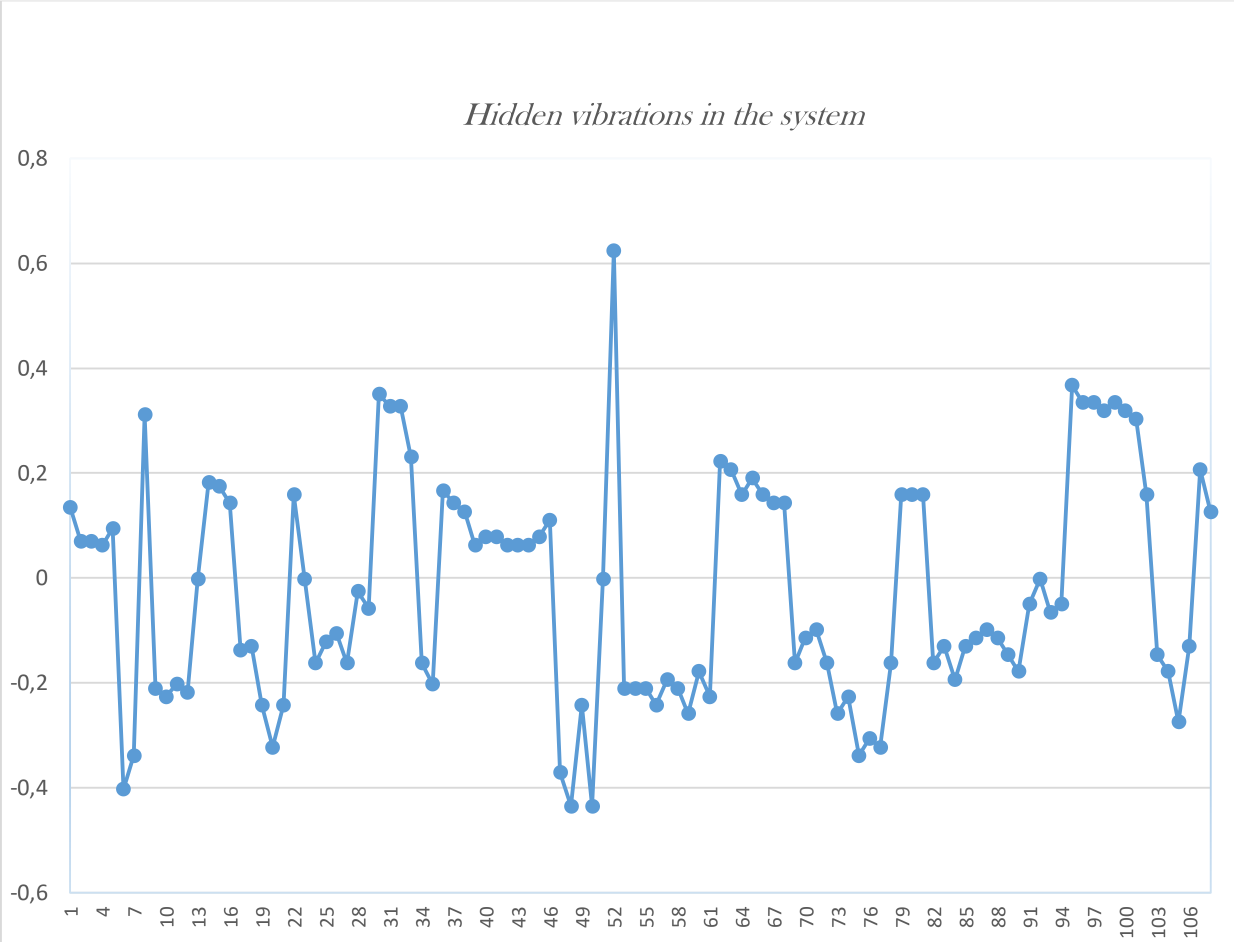

Figure 2. Change values in the selected riot component control regulation

CONCLUSION : Currently, the quality of the output product in the production of formaldehyde is determined in laboratory conditions, which is an expensive, complex process and takes a long period of time. In order to improve the efficiency of safe process control, a setup was implemented using least squares (OLS) and regression methods. An approach has been applied to constructing predictive models of product quality based on regression models. An approach to constructing a predictive model for making decisions on the operational management of multi-stage and multi-dimensional continuous formaldehyde processes is described.

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