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# RATIONAL APPROACH TO CONSTRUCTING MODELS TO CONTROL AND MANAGE STATICS OF TECHNOLOGICAL PROCESSES

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**Abstract**

The report studies the problem statement of constructing models to control and manage the statics of technological processes. The solution of the problem shall satisfy both the requirements of approximation and the requirements of accuracy of the obtained models.

## I. Introduction

The efficiency of functioning of any control and management system is determined by the level and quality of technical, algorithmic and software support. The level of modern microprocessorbased and computer technologies meets the needs of industrial systems of process control and management such as technical and software too1s for receiving and processing of data obtained with measuring instruments as well as for generating and delivering controlling influences on relevant controlling devices. However the existing conditions of a measuring tools stock does not allow to cover all physical magnitudes with direct and indirect measurements. Therefore every technological process involves parameters which magnitudes are periodically determined in laboratory settings. Given the fact that the frequency of determining these parameters in less that the frequency of modifications of current values on the facility one can understand how efficiency and accuracy of technological process control and management gets reduced when data obtained in laboratory settings is used.

Thus, given the necessity of algorithmic support of control and management system to formulate and implement optimal management of technological process as well as for operational control practical and accurate mathematical models of static processes are required. The development of such models requires an integrated approach that would meet all requirements for systems of control and management of industrial technological processes. The objective of the report is to identify a rational approach to the development of models to control and manage the statics of technological processes.

## II. Problem statement

The construction of control and management models begins with specifying controllable (indirectly controllable) parameters (hereinafter referred to as functions) and control and disturbing influences (hereinafter referred to as arguments) of technological processes through identification and analysis of selected correlations coefficients.

**Problem A.** Let's assume that the statics of a technological process can be described with linear multinomial as follows:

$$\hat{Y} = a_0 + \sum_{i=1}^{m} a_i * x_i \quad ,(1)$$

where $\hat{Y}$ is function; $x_i$ is arguments, which are not correlated, errors in their measurements do not depend on each other and their distributions follow the normal rule of distribution: $a_0$, $a_1$, …., $a_m$ are constant coefficients.

Identification of parameter $\hat{Y}$ by formula (1) is an indirect measurement, therefore, to identify confidence limits of the errors of the confidence probability with P=95 or 99 shall be used [1]. A random error of indirect measurements in case of normal distribution of measurements errors of arguments $\tilde{x}_i$ is determined by [1]:

$$E(Y) = t_q * S(\tilde{Y}) \quad , (2)$$

where $t_q$ is Student coefficient corresponding to confidence probability P=l-q (q - selected significance level) and the number of degrees of freedom $f_{ef}$ :

$$f_{ef} = \frac{\left[\sum_{i=1}^{m} a_1 * S^2(\tilde{x}_i)\right]^2 - 2\left[\sum_{i=1}^{m} \frac{a_i^4 * S^4(\tilde{x}_i)}{(n_i+1)}\right]}{\sum_{i=1}^{m} \frac{a_i^4 * S^4(\tilde{x}_i)}{(n_i+1)}}, \quad (3)$$

where $n_i$ is number of measurements to determine argument $x_i$,

$$S(\tilde{Y}) = \sqrt{\sum_{i=1}^{m} a_i^2 * S^2(\tilde{x})} \quad , (4)$$

is standard deviation of indirect measurement $\tilde{Y}$, $S(\tilde{x})$ is standard deviation of argument measurement $x_i$.

A systematic contributing error of the indirect measurement is calculated as follows [1]:

$$\theta(Y) = k * \sqrt{\sum_{i=1}^{m} a_i^2 * \theta^2(x_i)} \quad , (5)$$

where k is correction factor determined to identify confidence probability (if P=0.95 the correction factor $k$=1,1, and if P = 0,99 then $k \le$ 1,4), $\theta(x_i)$ - non-exceptional systematic error in argument measurements $x_i$. If

$$0.8 \le \theta(Y)/S(\tilde{Y}) \le 8.0 \quad , (6)$$

then the confidence limit of error of indirect measurement $\tilde{Y}$ is calculated as follows:

$$\Delta Y = K * [E(Y) + \theta(Y)] \quad , (7)$$

where $K$ is coefficient determined from Table [1] depending on the value of ration $\theta(Y)/S(\tilde{Y})$ for selected confidence probability - P=0.95 or P=0.99. If $\theta(Y)/S(\tilde{Y})$ < 0.8, then a random component which limits are determined by equation (2) is taken as an error of the indirect measurement and if $\theta(Y)/S(\tilde{Y})$ > 8.0 then a nonexceptional systematic component which limits are calculated by equation (5) is taken as an error.

**Problem B.** Let's assume that the statics of a technological process can be described by a nonlinear equation

$$\tilde{Y} = f(x_i, a_0, a_j) \quad ,(8)$$

and assume that errors of argument measurements $x_i (i = 1,2, \ldots, m)$ are independent and their distribution follows the normal rule of distribution, $a_0, a_1 (j = 1,2, \ldots, l)$ are constant coefficients. If the function $f(x_i, a_0, a_j)$ is differentiable, then

$$S(\tilde{Y}) = \sqrt{\sum_{i=1}^{m} \left(\frac{\partial f}{\partial x_i}\right)^2 * S^2(\tilde{x}_i)} \quad , (9)$$

$$\theta(Y) = k\sqrt{\sum_{i=1}^{m}\left(\frac{\partial f}{\partial x_i}\right)^2 * \theta^2(\bar{x}_i)} \qquad ,(10)$$

where $\frac{\partial f}{\partial x_i}$ is derivative from function $f$ by argument $x_i$. If the equation (4) is compared (9) and the equation (5) with (10), then it is obvious that the results of partial derivatives from function f will depend on the coefficient / coefficients of the relevant variable of the first part of the equation (8).

Thus, is above problems show that the error of the models of technological processes depends on both errors of arguments measurements and coefficients of the models i.e.

$$\Delta(Y) = F\left[S(\bar{x}_i), \theta(x_i), a_j\right] \qquad ,(11)$$

For efficient control and measurement of technological processes the errors of the models shall not exceed legitimate values $\Delta_{leg.}(Y)$.

Therefore coefficients determined while developing the model shall satisfy both the requirements of significance, minimum of residual dispersion and requirements of accuracy of indirect measurements of relevant parameters with obtained models.

Hence, the most rationale way to construct models for control and management of the statics of technological processes may be expressed as follows:

$$\left.\begin{array}{c}\sum_{z=1}^{n}[Y_z - \hat{Y}_z]^2 \to \min \\ if \\ \Delta(Y) \leq \Delta_{add}(Y)\end{array}\right\} \qquad ,(12)$$

where $Y_z, \hat{Y}_z$ are function variables (function of a measured parameter) determined accordingly in z test (by direct measurement or laboratory test) and using the equation (1) or (8) with the results of z measurement of argument $x_i$.

The problem (12) is a problem of parametric optimization with functional limitations which solution is not difficult nowadays.

**References**

1. МИ2083-90. Indirect measurements. Identification of measurement results and calculation of their errors. Collection of normative documents «Measurements».
   Moscow (1997), pp. 105-111.