Process Quality Assessment

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Abstract. The work is devoted to the study of procedures for assessing the quality of technological process. It is emphasized that there are significant differences in the parameters for assessing the state of an object and a process. When the technological process proceeds, it most often requires smoothness, the absence of spasmodic changes, since violation of these requirements affects the quality of the final result of the technological process - the finished product. The concepts of process quality and control quality are further divided. To evaluate the latter, there are classical indicators: accuracy, speed, stability margin, and sensitivity. Changes in the quality level of the technological process reflect other characteristics, such as deviations in: synchronization, coordination, stability of technological modes and operational costs.

1. Introduction
Assessment of the quality of management differs significantly depending on whether it relates to an object or process. This is based on differences in the parameters for assessing the state of an object and a process. The condition of the object is usually estimated by the value of various physically measured parameters. During the course of the technological process, it most often requires smoothness, the absence of spasmodic changes, since violation of these requirements affects the quality of the final result of the technological process - the finished product.

On the other hand, to evaluate the quality of the process control, classical indicators should be used: accuracy, speed, margin of stability and sensitivity. Of course, these indicators relate to the management system as a whole. It follows that to assess the quality of the technological process as a whole, a special procedure is needed that tracks a lot of parameters, therefore it is best to implement it in a multidimensional space.

2. Theory
The technological process is usually divided into operations and the coordination of these operations in time (synchronization) comes to the fore, and in order for the mechanically moving elements involved in the implementation of operations to occupy the desired position in space, coordination of their movements is necessary. In addition, it is important that technological regimes are observed for each operation, since deviations of a technological parameter in a previous operation become a disturbing effect for subsequent operations. For example, a shortage or skewed details during heat treatment changes the modes of its further mechanical processing, a change in the thickness of the removed metal layer during roughing affects the further finishing mode. An even greater scatter in technological conditions can be observed if some operations in the production process are performed by a person who can be distracted, forget to take any action, overlook something, and finally, fatigue can prevent him. As a result, the smoothness of the process, and, therefore, the quality of its...
implementation is deteriorating. Of course, deviations in one operation can be eliminated in subsequent ones, but then it becomes important what expenses of energy, materials, raw materials, and, ultimately, finance, we achieve. Summing up this analysis, we conclude that the decrease in the quality level of the process, expressed primarily in the smoothness of its course, can be determined through deviations in synchronization, coordination, technological modes and costs of carrying out its constituent operations.

Synchronization is a classic problem encountered in various fields of human activity [1-5]. Breaks in temporary connections often threaten costly consequences, not to mention spasmodic disturbances introduced by the untimeliness of any actions affecting the quality of products.

The term coordinating management system was proposed by Boychuk L.M. [6], however, coordination as a management function is considered by many researchers [7]. In the latter case, coordination is understood as a coordinated interaction, interconnection, the correspondence (coherence) of any components both in space and in time and even in the dosage of substances or in the state.

Violations of technological conditions are associated primarily with accidents [8], since such consequences are most dangerous. On the other hand, the study of the influence of technological disruptions on the quality of products is also classic [9].

Finally, the important characteristics of the process are the operational costs of energy, materials, raw materials and other resources, which are generally estimated by financial costs. There is even an independent method of Activity-Based Costing (ABC) (cost accounting by type of activity) developed by American scientists R. Cooper and R. Kaplan in the late 80s [10].

The concept of process quality is abstract [11] and has the specifics in that it is possible to evaluate and control its level only indirectly. Usually abstract objects are control objects of the upper hierarchical levels.

We are exploring a two-level quality management system for the technological process. The corresponding composition and the relationship of its elements are presented in Figure 1.

The classical notation is applied here: for vectors of controlled quantities $\tilde{Y}$, control and disturbing actions, respectively - $\tilde{U}, \tilde{F}$. The circuit depicted in Figure 1 can be described by operator equations

$$\tilde{Y}_i = W_i^U \cdot \tilde{U}_i + W_i^F \cdot \tilde{F}_i, \ i = 1, 2.$$  \hspace{1cm} (1)

Here $W_i^U$ and $W_i^F$ are the transfer functions of the control system with respect to control and disturbing actions, respectively.

At the first level, the process is directly controlled, therefore quantities controlling and disturbing influences are most often real, physically measurable and are characteristics of the process flow. At the second level, since direct influences are managed by the process control system at the first level, only indirect influences are possible - parametric, structural or organizational changes, therefore, special operators are needed to form control actions and evaluate the controlled quantity

$$A[\tilde{Y}_1, \tilde{V}] = W_2^U \cdot B[P, S, Org] + W_2^F \cdot C[\tilde{F}_1, \tilde{X}],$$  \hspace{1cm} (2)

Here, respectively, it is indicated: $A[\tilde{Y}_i, \tilde{V}]$ - the operator of forming the level of the quality process ($\tilde{V}$ - additional indicators that affect the quality of the process), $B[P, S, Org]$ - the operator that integrates parametric, structural and organizational changes and impacts in the quality management system, with the goal of increasing its level, $C[\tilde{F}_1, \tilde{X}]$ - the second-level operator, forming disturbing effects on the entire technological system. The components of the vector $\tilde{X}$ reflect the quality of the input raw materials, materials, energy.
From the above formulas it follows the need to identify the features of the formation of impact operators, both control B and disturbing C, as well as the operator of assessing the quality level A.

Parametric, structural and organizational effects by operator B are aimed at eliminating deviations in the smoothness of the process and represent the control actions of the second control level. We can propose a scheme for their integration that defines this operator. Here we need some equivalent for heterogeneous changes, for example, expressed in unit costs of each type of change. Then the control action can be determined by the formula

$$U_2 = \varepsilon_1 \cdot P + \varepsilon_2 \cdot S + \varepsilon_3 \cdot Org. \quad (3)$$

Here $\varepsilon_1, \varepsilon_2, \varepsilon_3$ are dimensional coefficients reflecting the corresponding share of resources allocated to the parametric, structural and organizational impact on material carriers, which are united by the concept of a technological process.

It is important to consider that impacts on the technological process can be both local and global in nature and provide not only the elimination of existing deviations, but also be ahead of new ones.

The quality level of the process can be evaluated in various ways. Examples of such operators can be additive, multiplicative, or combined convolution. For example, you can use additive convolution as the operator A

$$Y_2 = \sum_{i=1}^{N} \alpha_i Z_i \quad , \quad (4)$$

where $\alpha_i$ are weight coefficients, $Z_i$ are values that determine the quality level of parameters.
However, this assessment method does not give zero if any component of the quality management system, even the most important one, is completely out of order and the quality level in this case should be zero. In this case, the multiplicative operator A helps out

\[ Y_2 = \beta \prod_{i=1}^{N} Z_i. \]  

(5)

Here \( \beta \) is the coefficient equalizing the dimension.

You can offer some hybrid operator for quantitative description of the quality level in the form

\[
\begin{align*}
Y_2 &= \nu \sum_{i=1}^{N} \alpha_i Z_i \\
\nu &= 0 \text{ при } Z_i^{\text{min}} > Z_i, Z_i > Z_i^{\text{max}}, (i = 1, \ldots N), S_T \neq S_T^{zd}
\end{align*}
\]

Here \( \nu \) is the coefficient vetoing, \( Z_i^{\text{min}}, Z_i^{\text{max}} \) are the coefficients that describe the acceptable thresholds for the parameters that determine the quality of the process, \( S_T, S_T^{zd} \) is the structure of operational relationships currently available and specified in the technology used. The operator (6) prohibits any changes in the sequence of operations.

3. Model

To test the effectiveness of the proposed assessment, a structural scheme was developed, simulating one operation, shown in Figure 2.

![Figure 2. Structural diagram simulating the operation of a technological process.](image)

On the left side, the diagram represents the operation in the form of an oscillatory link. In parallel, a model of the same operation is launched. To implement the deviation in synchronization, a link of pure delay is introduced. The control is carried out adaptively by deviation from the model behavior, for which the difference of two signals is found.

At the same time, on the right side of the circuit, an evaluation of the output signal is organized using a veto in case the signal exceeds the upper or lower thresholds set by a nonlinear link with the characteristic of a polarized relay and a deadband.

4. Results and discussion

The results are presented in the form of a graph of the transient in Figure 3. Blue shows the transient simulating the operation in which the control subsystem itself tries to cope with the disturbance caused by the delay of the input signal. As you can see, the graph is shifted along the time axis due to the delay.
Figure 3. Transition graph reflecting the operation.

The veto-assessment work schedule is shown in red - zero indicates those places where intervention of the second-level control system is required. As follows from the graph, the transition process twice exceeds the upper threshold and, except for the starting section, only once the excess of the lower threshold is observed.

The results obtained clearly demonstrate the effectiveness of the developed methodology.

5. Conclusion
Thus, the veto-assessment of the quality of the technological process implementation allows to identify the moments where the intervention of a higher level system is necessary. At first, a parametric impact may be sufficient, which is the most mobile, and then, if the situation repeats, it is necessary to attract organizational influence, creating favorable conditions for the technological process, or even apply structural adjustment with the replacement of elements or their interconnections.

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