Methodology for introducing digital technologies into the process of monitoring quality indicators of the technological cycle of electronics manufacturing

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Abstract. Nowadays, industrial enterprises are paying more and more attention to innovations that increase the income of organizations, accelerate growth, which is the basis for creating competitive advantages. Today, one of the most common ways to ensure the effectiveness of production and management of organizations is the implementation of digital technologies. Production and economic processes are actively analyzed in order to identify "weak" points that can be eliminated with the help of intelligent software and hardware systems. In view of the increasing requirements for the quality of manufactured products, as well as for the competitiveness of the organization as a whole, issues related to the development of methods and means of effective management of the process of monitoring the quality indicators of the technological cycle in the production of radio electronic products are of particular importance.

1. Introduction
Intellectualization and automation of most of the processes in industrial enterprises will lead to an increase in the efficiency and quality of manufactured products and services provided.

Continuous improvement of the radio electronics production process, improving the quality of technological processes require an increase in the density of printed wiring, the development of innovative technologies for assembly and assembly production, and an increase in technological reliability [1, 2].

At the same time, improving the quality of technologies, designs and production conditions is one of the priority tasks of the domestic industry (figure 1).

Trends in the development of technologies for the production of radio-electronic products associated with the increased dependence of product quality on a number of non-stationary parameters affecting the production process is an objective reality of high-tech industrial complexes. This circumstance necessitates a transition to expanding the range and parameters of the environment subject to continuous monitoring and control.
Reasons for the lag of the domestic radio-electronic industry

Insufficiently high level of technological efficiency of the designed equipment, the degree of its unification and standardization

Insufficient level of electronic component base

The low level of miniaturization

Poor suitability of devices for the conditions of automated assembly processes in small-scale and mass production

Low level of existing control systems for the design of electronic products

Lack of innovative scientific and technological centers focused on automated production

A small number of developed, technically equipped, specialized production facilities

Figure 1. The main disadvantages of domestic industrial enterprises.

2. Features of managing the quality characteristics of the production process in the context of digital transformation

To date, there has been a positive trend towards the reconstruction of Russian enterprises of the radio-electronic industry and its focus on the creation of high-tech production facilities of small and medium series in order to create healthy competition for foreign manufacturers.

The production of radio electronics is the most complex in terms of the variety of physical and chemical processes used in it, requiring highly professional personnel with versatile specialization.

Figure 2 shows the possible consequences of non-compliance with technological standards for the production process [3, 4].

Easing requirements for process engineering

Reduction of the percentage of the output of serviceable products

Reducing the level of reliability because of the inevitable passage of defects

Large labor costs for detecting and correcting defects

Figure 2. Consequences of non-compliance with technological standards of electronics production.

Monitoring and diagnostics occurring in the process of manufacturing parameters under conditions of unpredictable disturbances does not allow reaching an optimal solution within the framework of
traditional control principles, however, the inclusion of some digitalization elements in the control loop leads to an increase in the quality characteristics of the production process.

Operational monitoring makes it possible to assess the validity of a priori preferences and make an adaptive correction to the mechanism of current state control of a dynamic system [1].

3. Methods for introducing digital technologies into the process of monitoring quality indicators of the technological cycle of electronics manufacturing

To ensure high-quality control of the production process of manufacturing radio-electronic products, it is necessary to implement a system of measures, the most important of which is detailed monitoring of the finding of controlled parameters in the tolerances specified by GOST and other regulatory documents and the prompt restoration of the required values in the event of one or more parameters going beyond certain boundary values [5].

To solve this problem, the authors propose the development of a set of hardware and software tools, including a monitoring system (tracking) and automatic maintenance of the required values of the set parameters within the specified limits. The software, on the basis of which the control algorithm is developed, must meet, first of all, the requirements for the reliability of automatic control of the restoration of the established norms of the system characteristics in case of their abnormal deviation from the standard. We are not talking about trivial cases of switching to a backup set of equipment when fixing the fact of failure of one or another hardware device, but about the synthesis of procedures for restoring the norm of an individual characteristic, which guarantee that the norms of values of other elements of the vector of controlled parameters are not violated and the quality of the production process is preserved during the manufacture of microelectronic products.

Ensuring the effectiveness of the technological process in the conditions described above is achieved through the digital transformation of the monitoring process of qualitative and quantitative indicators of the production cycle [6].

Such indicators can be, for example, the line downtime indicator, the probability of loading per operation, the probability of inconsistency at each stage of the production process.

\[
\begin{align*}
-\lambda p_0 + y p_1 &= 0 \\
\vdots \\
\lambda p_{k-1} - (\lambda + k y) p_k + (k + 1) y p_{k+1} &= 0, k = 2, m - 1 \\
\vdots \\
\lambda p_{n-1} - (i + n y) p_n + n y p_{n+1} &= 0 \\
\vdots \\
\lambda p_{n+k-1} - (\lambda + n y) p_{n+k} + n y p_{n+k+1} &= 0, k = 1, m - 1 \\
\vdots \\
\lambda p_{n+m-1} - n y p_{n+m} &= 0
\end{align*}
\]

where \( p_0 \) – is the probability of downtime for the automatic assembly line,
\( p_k \) – is the probability of loading for one operation,
\( i \) – transition probability,
\( \lambda \) – intensity of equipment loading,
\( y \) – time of the operation,
\( m \) – number of products,
\( k \) – stage (operation).

The second criterion can be the load indicator for one stage (2):
\[ \beta = \frac{\alpha}{n} = \frac{\lambda}{ny}. \]  

(2)

The third indicator is the likelihood of system downtime \( P_0 \) (3):

\[
P_0 = \begin{cases} \left(\frac{n^k}{k!}\right)^\beta p_0, k = 1, n \\ \left(\frac{n^k}{n!}\right)^\beta p_0, k = n + 1, n + m \end{cases}.
\]

(3)

One of the key indicators is the probability of the occurrence of a marriage – this is the probability that the system is in a state \( S_{n+m} \). The probability of marriage is calculated by the formula (4):

\[ P_{\text{defect}} = p_{n+m} = p_0 \beta^{n+m} \frac{n^n}{n!} \]

(4)

An example of a possible criterial assessment of the parameters of the operability of an automatic assembly line is shown in figure 3 [7].

**Figure 3.** An example of a possible criterional assessment of the parameters of the operability state of an automatic assembly line.

The developed methodology is designed to regulate the speed of equipment and inspections, control and comply with the specified criteria for product quality, and also allows you to determine the probabilities of the appearance of defective products at each stage of the production process and all probabilities of states as a function of time.

The methodology analyzes the types of checks performed at each stage, conditions and probabilities of moving to the next stage or sending products for disposal. In addition, at each stage, it is possible to predict the probability of system downtime, the probable completion time of certain work operations,
determine the intensity of the equipment load, the reliability of control, the degree of proximity of the parameter to the tolerance field.

The introduction of digital technologies in the process of monitoring the quality indicators of the technological cycle of electronics manufacturing implies the use of intelligent solutions, new methods and equipment provided by the concept of the CPU in the form of design for manufacturing (DFM), machine-to-machine interaction (M2M), identifiers (ID), Internet of things (IoT), 2D and 3D inspections. Technical re-equipping is aimed at improving the consumer properties of the manufactured products, which, in aggregate, determine its quality, as well as at increasing the technological flexibility of the PP.

The assessment of the qualitative indicators of the functioning of the technological process is based on the analysis of the characteristics of transient processes and is carried out according to the following main quality indicators:

- regulation time $t_{reg}$, s;
- overshoot $\gamma$, %;
- vibration frequency $\omega$;
- the number of oscillations $n$.

So the control system, when introducing digitalization elements, provides the time for regulating the transient process is less than traditional systems (advantage is 62.5%), and the transient process is also characterized by lower values of overshoot (35%), frequency (16%), number of oscillations (60%).

4. Conclusion

Thus, in the course of research, the authors made an attempt to create a model of a management system with an optimal structure, available for external additions and capable of implementing the features of an intelligent system of the cybernetic level.

Taking into account the specifics of control, when the parrying of perturbations of one of the parameters should not lead to critical changes in the characteristics of other parameters, it is proposed to carry out cognitive control, that is, a real assessment of the current values of the parameters, their prediction and comparison will be provided, as a result of which a value will be formulated for the value of which correction.

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