Applicability of the reverse engineering model for unification tasks in systems engineering processes of engineering enterprises

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Abstract. The article describes the modernization of consumer characteristics, taking into account the total number of technical characteristics of the product, presented regulatory and technical design documentation for the products being created. The methodological apparatus for assessing the degree of product innovation is used. The task is also to simplify the process of reverse engineering by introducing three-precision 3D scanning, which allows to accelerate the technological stages of reverse engineering until the time of manufacture of the product, as well as simplify the process of fault detection of finished products and simplify the implementation of the principles of unification.

In the modern world, there is a predominance of modern, universally recognized traditional technologies for creating machine parts, products, assembly units, and other component groups of products necessary to ensure the functionality of various assemblies. Such technologies include casting, processes for machining the surface of a part, molding, smelting, and other technologies generally recognized and in use today. The main problems of traditional technologies are long life cycles, specialized equipment features and technological methods within which the required products are manufactured. The high level of defects inherent in heavy industry and the existing labor-intensive control operations not only increase the cost of the product, thereby disrupting the terms of contracts and the rhythm of the production system, but also creates the preconditions for the formation of a negative image among suppliers.

However, modern scientific and technological progress allows for the technological replacement of traditional production processes by introducing modernized equipment, with which it is possible to achieve new indicators. Such decisions should be based on a comprehensive analysis of production capacities and are achieved through the teamwork of all managers who own the main production process and make decisions at their functional places. The application of this approach can be attributed to the analysis of the possibility of modernizing the existing basic structure on the basis of which a complex technical system is produced.

Signs of advanced standardization, laid down with the help of the results of the introduced program of promising standardization in force in the period of the 50s or 80s, have created an in-depth potential for modernization even for those technical systems that are still in use today. The practical value of leading standardization lies in a clear understanding of the nature of systems engineering processes and the sufficiency of indicators that reflect their effectiveness and efficiency. Thus, it becomes possible to use not only traditional technologies in industry to visualize the volumes of a complex
technical system produced as products of market value, but also to use innovative technologies to reflect the organization’s competitive potential as a market participant in the engineering or electronic industry.

Various processes for creating value in the production system have mixed parameters, the stabilization of which leads to the creation of synchronized production. However, the technological features of the equipment and the diverse product range lead to a non-rhythmic production system, therefore, analysis of the possibility of unification of the main technological processes with greater complexity becomes a high priority task to achieve goals in creating synchronized production based on modern technologies.

The unification of those technological operations that cause more temporary losses than the total set of technological operations in the production cycle will lead to a decrease in time costs and physical wear of technological equipment. The peculiarity of such decisions is that it is necessary to use statistical methods of quality control, namely control cards and a checklist to understand the processes of organization of production.

\[
Q_{4_{-\text{level\_unification\_technological\_process}}} = \begin{bmatrix}
I_{41} = \frac{\sum (b_i) P_n - \sum (b_i) P_0}{P_n} \\
I_{42} = \frac{\sum P_{\text{time\_tech\_process\_spec.}}}{\sum P_{\text{time\_tech\_process\_general}}} \cdot 100\%
\end{bmatrix}
\]

(1)

\(P_n\) is the total number of technological operations in the process creating the technical level of the product; \(P_0\) is the total number of specialized technological operations in the process creating the technical level of the products [1]. The study of the production system is as follows: the ratio of the number of specialized technological operations to the total number of all technological operations in the technological process. To understand what resources are involved in creating a product, you need to analyze the product’s technological route using data from the operating map.

Measuring the level of competitiveness as part of the monitoring system for the production system is based on the criteria of industrial applicability [2, 3]

\[
Q_{5_{-\text{industrial\_competitiveness}}} = \begin{bmatrix}
I_{51} = \sum_{a=1}^{d} K_{51a} \times \Theta_{51a} \\
I_{52} = \frac{\sum (K)P_n}{\sum (K)P_e}
\end{bmatrix}
\]

(2)

Where \(\sum_{d=1}^{d} I_{5d}\) is the linear convolution of the industrial applicability criterion, \(K\) is the weight coefficient, and \(e\) is the expert estimate for the estimated characteristic., \(PH\) – technical level of innovation, \(RK\)-technical level of analog [4].
The development curve of system engineering processes consists of the potentials of various parameters that make up the value of the ongoing technological processes. The set of potentials gives a representation in the form of a fragment of the curve of development of system processes presented in figure 1. Different reference points indicate the state of the system-technical processes, the management of which makes it possible to strive for synchronized production. The scheme of development of a single technological process as part of a production system is shown in figure 2. The existing technological restrictions imposed by the level of scientific and technological progress of the enterprise where the technological process is implemented impose a certain framework for the vector of parameters of technological operations that include a common set of indicators that reflect the reference points A0, B0, C1, D1, E2, F2.

Figure 2. Diagram of technological process potential development.

However, the state of the E2 reference point is characterized by technological substitution of traditional methods in creating value, thereby pushing back the restrictions imposed by the equipment. This state is typical for the principles of reverse engineering, when the final product of a technological operation changes without a significant change in the technological modes of the production system.

The similarity of the vector of parameters of the manufactured product with the result of the introduction of replacement technology, first of all, must be evaluated by analyzing the technical specifications for the production of the product and the planned operating environment. Reverse engineering will allow to unify technological processes where the use of specialized equipment creates technological downtime and slows down the overall rhythm of production.

However, there are still several prerequisites for the introduction of reverse engineering - problems of alterations and as a result a high percentage of defective products. When implementing the ideology of synchronized production, you can achieve such indicators as 1% of the total number of defects in
the batch and up to 10 defective products per batch of one million units of production, and such indicators can be achieved in a year and a half [5].

You need to start implementing a synchronized production system through clearly defined goals:

- reduce the production cycle by an order of magnitude;
- reduce the percentage of defects and re-processing to 1 %;
- increase productivity by 100 %.

Of course, these are more than ambitious goals, and to achieve such goals, you need a clear and technological basis in the form of spent production capacity and stable technological processes.

Thus, this goal can be achieved by replacing traditional technologies with reverse engineering.

Reverse engineering is the study of a ready-made device or program, as well as its documentation, to understand how it works; for example, to discover undocumented features (including software bookmarks), to make a change or reproduce a device, program, or other object with similar functions, but without direct copying [6].

Up of various mechanisms and machines with no actual development. Allows you to reproduce a successful design with minimal cost, for example:

- an item is urgently needed, but for certain reasons it has been discontinued, the price of the product is too high, or you will have to wait a long time for its delivery;
- project documentation does not match the device, papers are lost, difficult to obtain, or documents were not originally made;
- it is necessary to analyze the state of the product and perform stress calculations after prolonged use to improve its quality;
- you need to analyze the details or devices of competitors.

Additive manufacturing technologies that allow manufacturing any product based on a 3D computer model can help in this issue.

The reverse engineering process itself includes all stages, starting with scanning and ending with testing of the received part. Reverse engineering is, of course, not just getting drawings. And it's not so much getting drawings as making a specific part based on them and understanding that you have achieved your goal [7].

Figure 3. Stages of reverse engineering.
Cleaned parts are subjected to defects in order to assess their technical condition, identify defects and establish the possibility of further use, the need for repair or replacement. In fault detection reveal: the wear of the working surfaces in the form of changes in the size and shape of the part; the presence of crumbling, cracks, chips, holes, scratches, grooves, burrs, etc.; the residual strain in bending, torsion, warpage, the change of physic-mechanical properties result from the effects of heat or environment [8]. Figure 2 below shows a map of the applicability of changes to the technical system. To solve problems of technical system recovery after serial failures caused by severe environmental factors.

Following the decisions on the modernization of structural elements in accordance with the requirements of the market environment and the requirements of regulatory and technical documents from the strategic factors of advanced standardization in a non-stable competitive environment, it is advisable to apply reverse engineering to reduce the cost of restoration or modernization processes.

In cases where it is necessary to produce a limited batch of small-sized components to replace parts related to the aesthetic form of the product, design or interface element, the system that needs to establish the problem of the existing industry has a sufficiently serious research. The result, which carries out rationalization changes in the organizational structure of those enterprises that have decided to take this difficult step of restructuring in order to achieve efficiency and preventative effectiveness of issues of integration of the ideology of synchronized production.

This can be achieved by implementing 3D scanning of individual elements in the production of hydraulic brake drives, replacing defective parts with printed 3D models. By introducing replacement technologies, such as additive manufacturing, we are able to work not only with them, but also with engineering plastics, composite powders, various types of metals, ceramics, and sand. This simplifies the defect procedure and creates a positive social effect for the introduction of reverse engineering elements.
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