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ANALYSIS OF AUTOMATED SYSTEMS FOR ASSESSING PERFORMANCE INDICATORS OF MULTI-NOMENCLATURE MACHINE-BUILDING ENTERPRISES

Abstract. One of the main tasks of technical re-equipment of the enterprise is to ensure compliance of technical capabilities of the created production system of the enterprise with the requirements of technological processes for manufacturing the products of the specified nomenclature and quantity of technological equipment with the requirements of the specified program of product output. Technological solutions, formed within the framework of technical re-equipment, include decisions on the determination of types of additionally acquired technological equipment and calculation of their quantity. It should be taken into account that since in most cases the equipment is very expensive, the exact calculation of the equipment to be purchased is one of the key performance indicators of the entire enterprise. One of the possible ways contributing to the solution of the problem of increasing productivity is the calculation of the production cycle for the manufacture of parts of a given program in the current production system based on the analysis of temporal relationships. In connection with the above, the actual task is to analyze the temporal relationships of the production process, identify unproductive time losses in the manufacture of parts, and develop recommendations for reducing the time of the production cycle and, as a consequence, increasing productivity in the manufacture of parts. To assess the manufacturing process of parts according to productivity indicators in the multi-nomenclature production, automated systems of different classes are used, which allow calculating the labor intensity, machine capacity, and duration of the technological cycle. To solve these problems CAD TPP mainly uses the analytical-calculative method. The most common software and methodological complexes of systems of computer-aided design of technological preparation of production are: "Vertical". T-FLEX Technology, APPIUS, SPRUT-TP.

The paper describes different classes of automated systems used to evaluate the production process of manufacturing parts according to productivity indicators in the multi-nomenclature production: CAD systems of technological preparation of production (CAD TPP), Enterprise Resource Planning (ERP) systems, MPP (Manufacturing Process Planning) systems, MES (Manufacturing Execution Systems), simulation modeling systems etc. The presented systems of assessment of the production process of manufacturing parts by productivity indicators in multi-nomenclature production either do not take into account the time constraints of the production process of parts in multi-nomenclature production, which determine the production cycle of their manufacture, or require a detailed description of production processes, which is absent at the stage of preparation for the technical re-equipment of the enterprise.

Keywords. Productivity, labor intensity, machine capacity, cycle, calculation.

Introduction.

In order to ensure the production of a changing range of mechanical engineering products technical re-equipment of enterprises is carried out. The productivity of machine-building

enterprises is largely determined by the quality of design solutions laid down when carrying out technical re-equipment.

The main tasks of technical re-equipment of machine-building enterprises are to ensure compliance of technical capabilities of the enterprise production system with the requirements of technological processes for manufacturing the specified product range and the quantity of technological equipment with the requirements of the specified production program [1].

Thus, when carrying out technical re-equipment to ensure the specified performance indicators, the main objects of research are technological processes of manufacturing products of the set output program and transportation processes [2].

This approach has proved itself well in large-scale and mass production, for which the main indicator of productivity is the tact (rhythm) of output. The rest of the production processes are aimed at ensuring the specified output beat.

Materials and methods.

In large batch and mass production the critical path of product manufacturing includes technological processes and transportation processes [3].

In the multi-nomenclature small batch and serial types of production, the critical path of product manufacturing of the set production program includes various production processes [4].

As a result, the production cycle exceeds the calculated total value of the technological cycle and transportation cycle. As a consequence, the production system after the technical re-equipment is not able to fulfill the set program.

In practice, one of the directions for solving this problem is to increase the amount of technological equipment, which will be used inefficiently due to unproductive time losses, i.e. have a low load factor [5].

Automated systems of various classes are used to evaluate the production process of manufacturing parts according to productivity indicators in multi-nomenclature production:

- Computer-aided design of technological production preparation (CAD TPP) systems;
- ERP (Enterprise Resource Planning) systems;
- MPP (Manufacturing Process Planning) systems;
- Manufacturing Execution Systems (MES);
- systems of simulation modeling of material flows;
- etc.

Automated systems of design of technological preparation of production allow you to calculate the labor intensity, machine capacity and duration of the technological cycle.

Results.

To solve these problems, CAD TPP mainly uses the analytical and computational method.

The most common software and methodological complexes of systems of computer-aided design of technological preparation of production are: "Vertical". T-FLEX Technology, APPIUS, SPRUT-TP.

The basis of CAD systems is the functional design of technological processes [6], which includes the calculation of cutting modes, rationing operations of technological processes.

Thus, CAD TP has a developed functional for calculating the time of the working period, namely the calculation of piece-calculation time ($T_{st.k}$), time of control operations and time of natural technological processes (T_e).

The time of breaks ($T_{v.ш}$) is set in aggregate.

Automated systems for planning the execution of technological processes are focused on the calculation of the working period time [7].

Automated systems of planning of production processes of MRR class are based on the concept of PPR (process-product-resource), which establishes the relationship between the component parts of the product, operations of the technological process, transportation process and resources for their implementation.

Production operations are represented in the form of a PERT diagram, which takes into account the sequence and time of their execution. The working period time ($T_{v.r.p.}$) is taken equal to the value of the critical path of technological operations and transportation operations (Figure 1), which is calculated automatically [8].

The time of breaks in the systems of MRR class is either not taken into account, or is set normatively. A number of MRR class systems (DELMIA, Technomatics) allow to implement an analytical-calculative method of determining the working period time based on simulation of technological processes and transportation processes.

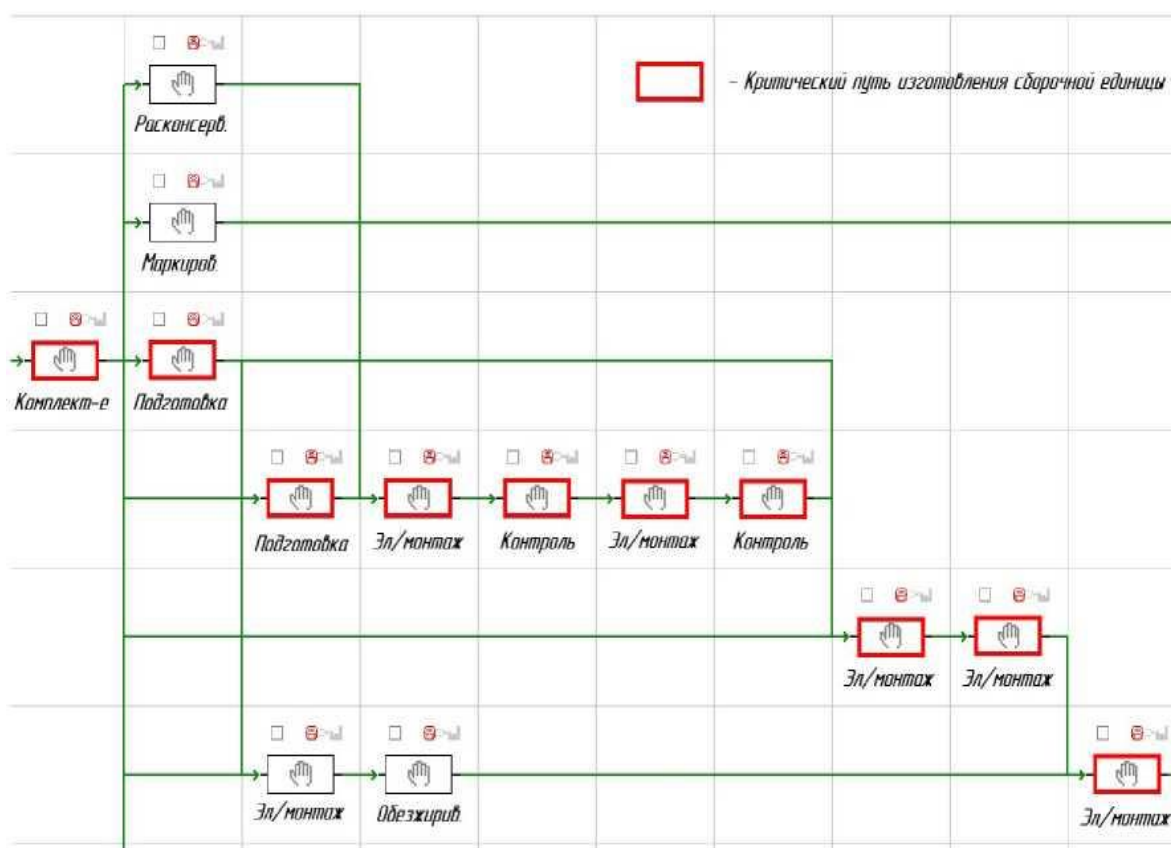


Figure 1 - Graphical representation of the working period time in DELMIA Process Engineer MRR class automated system

Figure 2 shows a graphical representation of the simulation of the manufacturing processes of the ship's bottom section in the system DELMIA V5.

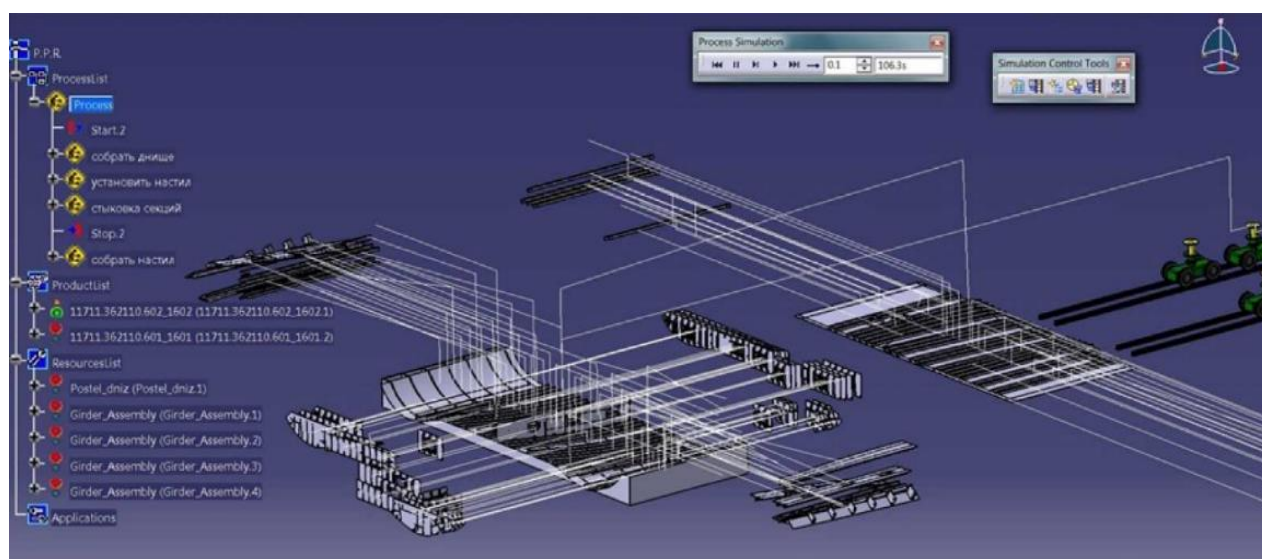


Figure 2 - Graphical representation of the manufacturing process of the ship's bottom

Automated systems of MES class are designed to calculate the production schedule for several shifts, which is formed on the basis of the calculation of the duration of the production cycle [9].

MES-systems are used mainly for operational and scheduling planning and dispatching.

Multi-criteria optimization methods allow to operate with dozens of different partial criteria and constraints, take into account a variety of production situations when constructing equipment schedules. The algorithms used in MES-systems allow scheduling and recalculating them in the dispatching loop in minimum time (from three minutes to 10 seconds for tasks of 2000-5000 operations and 150-200 pieces of technological equipment) [10].

An example of calculating the labor intensity of manufacturing a nomenclature plan, an order, a group of orders, overhaul schedules on the basis of the labor intensity of technological processes of parts manufacturing in the FOBOS operative scheduling system is shown in figure 3 [10].

The main input data for MES-systems are:

- technological processes of manufacturing parts;
- state of technological equipment;
- production schedule obtained as a result of volumetric scheduling.

Input data must contain a complete list of products of the nomenclature manufactured in the planned period of time, as well as a detailed description of technological operations and operations for transportation of products. It is not possible to form the specified amount of input data at the stage of technological preparation of production.

Thus, MES class systems allow to calculate the duration of the cycles of a part of the production process for the whole list of products within a few shifts.

MES-systems are systems that solve operational production tasks. They are not designed to solve the problems of technological preparation of production.

Simulation modeling, which gains more and more popularity in the world, has a great potential for the calculation of the duration of the production cycle

Simulation modeling is a numerical method for the study of the processes of a real system by performing experiments on its model.

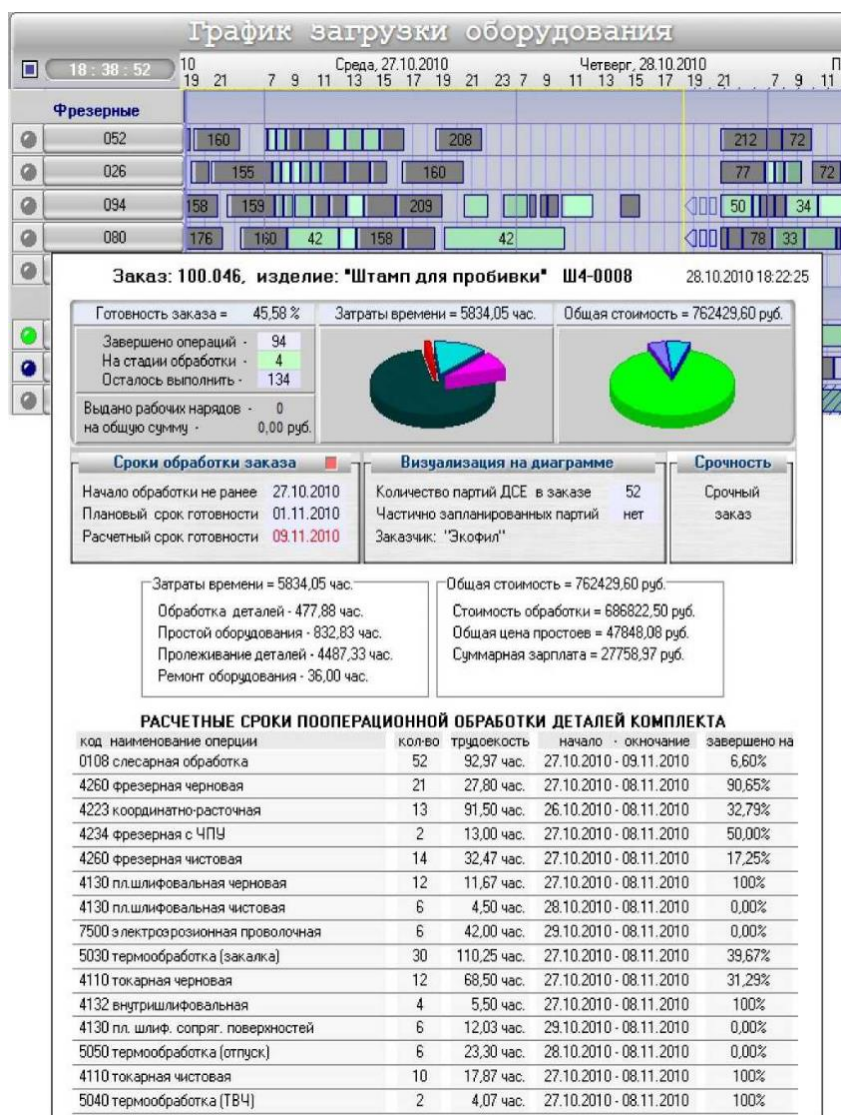


Figure 3 - Example of calculating the labor intensity of manufacturing nomenclature plan

The method of simulation modeling can be used to solve the problems of technological preparation of production, as well as to verify the results obtained by MES-systems. The reliability of the experimental results is largely determined by the degree to which the model corresponds to the real production system.

Simulation modeling is implemented by special software tools, such as DELMIA QUEST, Technomatics Plan Simulation, AnyLogic, etc.

The information model of the production system used in DELMIA QUEST is shown in Figure 4.

The simulation method allows to determine working hours and break times.

An important advantage of the simulation method is the possibility to calculate break times when simulating production processes based on the introduced rules of interaction of elements of the production system, as well as values of the probability of occurrence of events and their duration

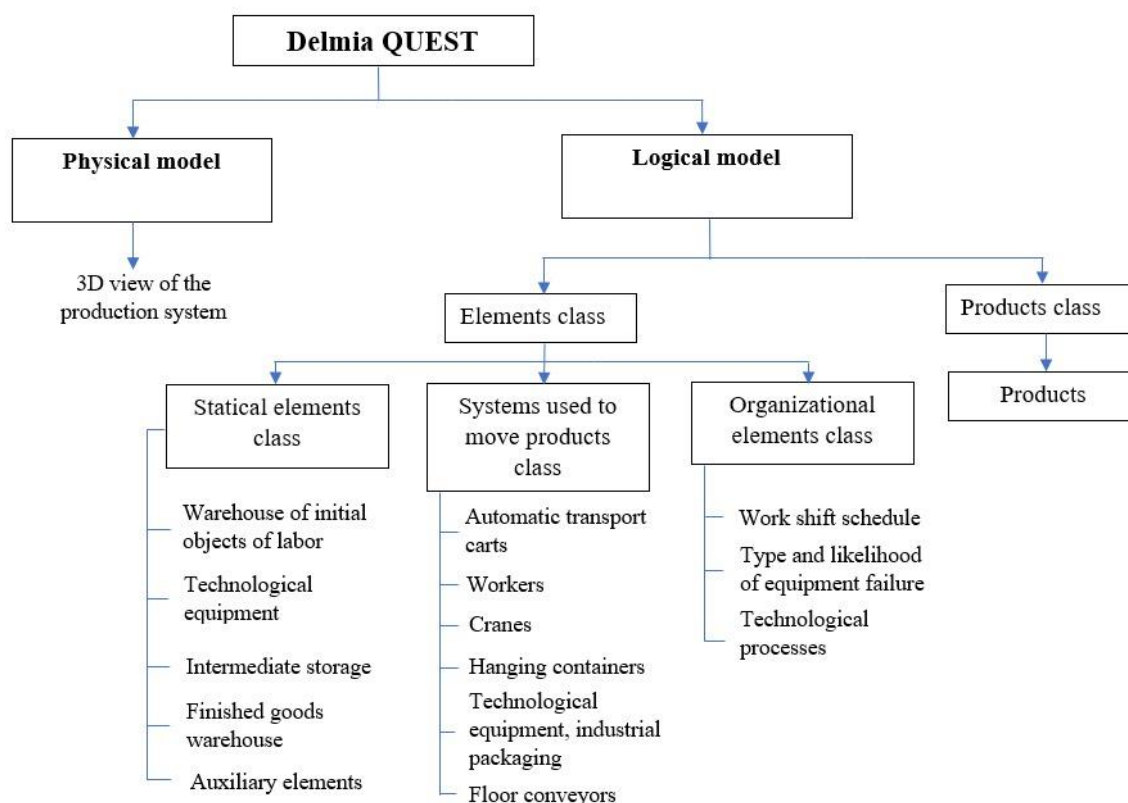


Figure 4 - Information model of the production system used in DELMIA QUEST

Simulation modeling, which is becoming increasingly widespread in the world, has a great potential for calculating the duration of the production cycle [8].

One of the main disadvantages of the simulation modeling method is a large volume of input data, including data on the entire range of manufactured products, which is quite difficult to form at the stage of technological preparation of production.

Table 1 shows a typical report on the results of simulation in the system DELMIA QUEST of the production system of the shop, a graphical representation of which is shown in Figure 5.

Table 1 - Data structure of the typical report on the results of simulation.

Equipment name	Position on the layout	Downtime for organizational reasons, the day	Downtime for technical reasons, day	Working time, day	Number of manufactured products for the year. pcs.	Average operation time, day	Download, (%)
Tile assembly stand	048.1	110.9	18	226,6	3	75,54	0,78
Tile assembly stand	048.2	98,7	36	220,6	3	73,52	0,76

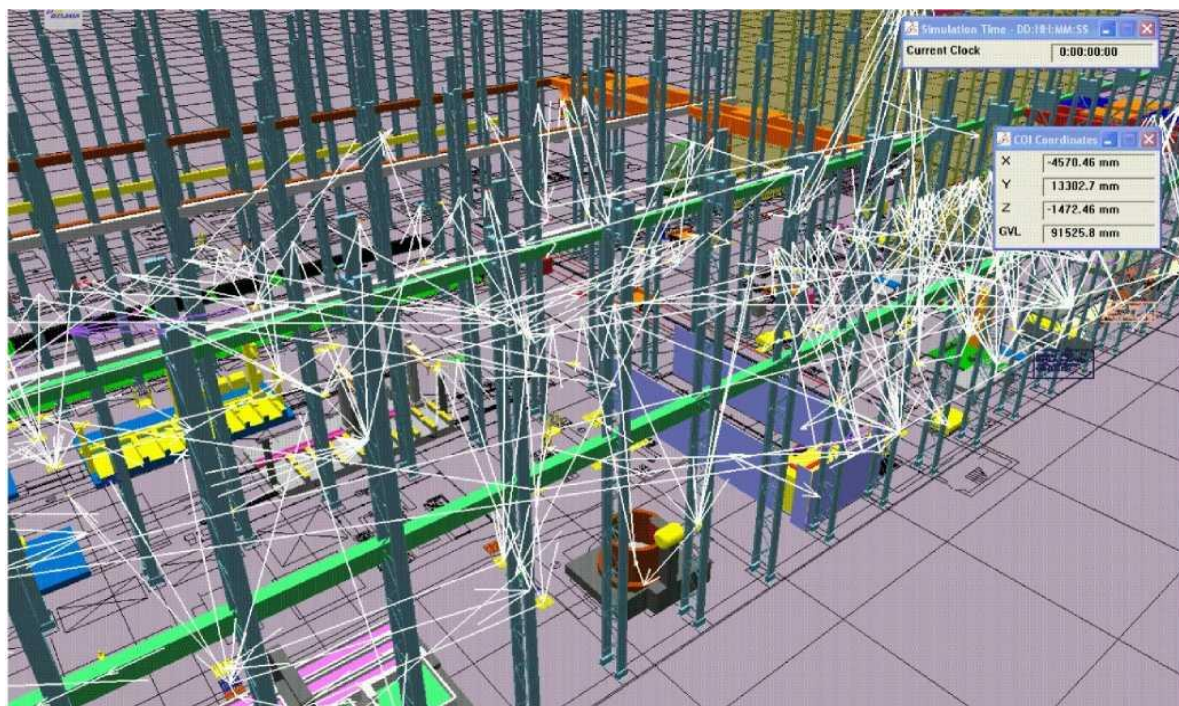


Figure 5 - Graphical representation of the manufacturing system simulation model in DELMIA QUEST (arrows indicate the logistic links between elements of the production system of the shop)

Discussion.

One of the possible ways to contribute to solving the problem of increasing productivity is the calculation of the production cycle for the production of parts of a given program in the current production system based on the analysis of time relationships. In connection with the above, the actual task is to analyze the temporal relationships of the production process, to identify unproductive time losses in the manufacture of parts and to develop recommendations for reducing the time of the production cycle and, as a consequence, to increase the productivity of the manufacture of parts. To assess the manufacturing process of parts according to productivity indicators in the multi-nomenclature production, automated systems of different classes are used, which allow calculating the labor intensity, machine capacity and duration of the technological cycle. To solve these problems CAD TPP mainly uses analytical-calculative method. The most common software and methodological complexes of systems of computer-aided design of technological preparation of production are: "Vertical". T-FLEX Technology, APPIUS, SPRUT-TP. The presented systems of assessment of the production process of manufacturing parts according to productivity indicators in multi-nomenclature production either do not take into account the time relations of the production process of manufacturing parts in multi-nomenclature production, which determine the production cycle of their manufacture, or require a detailed description of production processes, which is absent at the stage of preparation for the technical re-equipment of the enterprise.

Conclusion.

The presented systems of assessment of the production process of manufacturing parts by performance indicators in multi-nomenclature production either do not take into account the time relations of the production process of manufacturing parts in multi-nomenclature production,

which determine the production cycle of their production, or require a detailed description of production processes, which is absent at the stage of preparation for technical re-equipment.

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КӨП МАШИНА ҚҰРЫЛУ КӘСІПОРЫНДАРЫНЫҢ ТИІМДІЛІК КӨРСЕТКІШТЕРІН БАҒАЛАУДЫҢ АВТОМАТТАНДЫРЫЛҒАН ЖҮЙЕЛЕРІН ТАЛДАУ

Андатпа. Кәсіпорынды техникалық қайта жарақтандырудың негізгі міндеттерінің бірі кәсіпорынның құрылатын өндірістік жүйесінің техникалық мүмкіндіктерінің белгіленген номенклатура мен технологиялық жабдықтар санының бұйымдарды шығарудың белгіленген бағдарламасының талаптарына сәйкестігін қамтамасыз ету болып табылады. Техникалық қайта жарақтандыру шеңберінде қалыптастырылатын

технологиялық шешімдер қосымша сатып алынатын технологиялық жабдықтың түрлерін айқындау және олардың санын есептеу жөніндегі шешімдерді қамтиды. Көптеген жағдайларда жабдық өте қымбат болғандықтан, сатып алуға қажетті жабдықты дәл есептеу бүкіл кәсіпорынның тиімділігінің негізгі көрсеткіштерінің бірі екенін есте ұстаған жөн. Өнімділікті арттыру мәселесін шешуге ықпал ететін мүмкін жолдардың бірі уақытша байланыстарды талдау негізінде қолданыстағы өндірістік жүйеде берілген бағдарламаның бөлшектерін өндірудің өндірістік циклін есептеу болып табылады. Жоғарыда айтылғандарға байланысты өндіріс процесінің уақытша байланыстарын талдау, бөлшектерді өндірудегі нәтижесіз шығындарды анықтау және өндірістік цикл уақытын қысқарту және нәтижесінде бөлшектерді өндірудің өнімділігін арттыру бойынша ұсыныстар әзірлеу өзекті міндет болып табылады. Бөлшектерді өндірудің өндірістік процесін өнімділік көрсеткіштері бойынша бағалау үшін әр түрлі кластағы автоматтандырылған жүйелер қолданылады, бұл Сізге еңбек сыйымдылығын, станоктың сыйымдылығы мен технологиялық циклдің ұзақтығын есептеуге мүмкіндік береді. Осы мәселелерді шешу үшін СӨП негізінен аналитикалық және есептеу әдісін қолданады. Өндірісті технологиялық дайындауды автоматтандырылған жобалау жүйелерінің ең көп таралған бағдарламалық-әдістемелік кешендері: "Вертикаль", T-FLEX технологиясы, APPIUS, sprut-TP.

Мақалада көп қабатты өндірістегі өнімділік көрсеткіштері бойынша бөлшектерді өндірудің өндірістік процесін бағалау үшін қолданылатын әр түрлі кластағы автоматтандырылған жүйелер қарастырылған: өндірісті технологиялық дайындауды автоматтандырылған жобалау жүйелері (СӨП АЖЖ), ERP (Enterprise Resource Planning) кәсіпорынның ресурстарын басқару жүйелері, MPP (Manufacturing Process Planning) өндірістік процестерді жоспарлау жүйелері, MES өндірістік процестерін басқару жүйелері (Manufacturing Execution Systems), материалдық ағындарды Имитациялық модельдеу жүйелері. Ұсынылған бөлшектерді өндірудің өндірістік процесін бағалау жүйелері оларды өндірудің өндірістік циклын анықтайтын миллипедті өндірістегі бөлшектерді өндірудің өндірістік процесінің уақытша байланыстарын ескермейді немесе өндірістік процестерді егжей-тегжейлі сипаттауды талап етеді. Кәсіпорынды техникалық қайта жарақтандыруға дайындық кезеңінде жоқ.

Түйінді сөздер. Өнімділік, еңбек шығыны, станоктың қарқындылығы, цикл, есептеу.

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АНАЛИЗ АВТОМАТИЗИРОВАННЫХ СИСТЕМ ДЛЯ ОЦЕНКИ ПОКАЗАТЕЛЕЙ ПРОИЗВОДИТЕЛЬНОСТИ МНОГОНОМЕНКЛАТУРНЫХ МАШИНОСТРОИТЕЛЬНЫХ ПРЕДПРИЯТИЙ

Аннотация. Одной из основных задач технического перевооружения предприятия является обеспечение соответствия технических возможностей создаваемой

производственной системы предприятия требованиям технологических процессов изготовления изделий установленной номенклатуры и количества технологического оборудования требованиям заданной программы выпуска изделий. Технологические решения, формируемые в рамках технического перевооружения, включают решения по определению типов дополнительно приобретаемого технологического оборудования и расчета их количества. При этом надо учитывать, что поскольку в большинстве случаев оборудование очень дорогостоящее, то точный расчет необходимого к покупке оборудования является одним из основных показателей эффективности работы всего предприятия. Одним из возможных путей, вносящих вклад в решение проблемы повышения производительности, является расчет производственного цикла изготовления деталей заданной программы в действующей производственной системе на основе анализа временных связей. В связи с вышесказанным актуальной задачей является анализ временных связей производственного процесса, выявление непродуктивных потерь времени при изготовлении деталей и выработка рекомендаций по сокращению времени производственного цикла и, как следствие, повышению производительности изготовления деталей. Для оценки производственного процесса изготовления деталей по показателям производительности в многономенклатурном производстве применяются автоматизированные системы различных классов, которые позволяют рассчитать трудоёмкость, станкоёмкость и длительность технологического цикла. Для решения этих задач САПР ТПП в основном используют аналитическо- расчётный метод. Самыми распространёнными программно-методическими комплексами систем автоматизированного проектирования технологической подготовки производства являются: «Вертикаль», T-FLEX Технология, APPIUS, СПРУТ-ТП.

В статье рассмотрены автоматизированные системы различных классов, применяемые для оценки производственного процесса изготовления деталей по показателям производительности в многономенклатурном производстве: системы автоматизированного проектирования технологической подготовки производства (САПР ТПП), системы управления ресурсами предприятия ERP (Enterprise Resource Planning), системы планирования производственных процессов MPP (Manufacturing Process Planning), системы управления производственными процессами MES (Manufacturing Execution Systems), системы имитационного моделирования материальных потоков. Представленные системы оценки производственного процесса изготовления деталей по показателям производительности в многономенклатурном производстве либо не учитывают временные связи производственного процесса изготовления деталей в многономенклатурном производстве, определяющие производственный цикл их изготовления, либо требуют подробного описания производственных процессов, которое отсутствует на этапе подготовки к проведению технического перевооружения предприятия.

Ключевые слова. Производительность, трудоёмкость, станкоёмкость, цикл, расчет.
