

Method of Parametric Structural Synthesis of the Machine-assembly Departments

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Annotation

Reconstruction and technical re-equipment of enterprises is preferable to the creation of a similar capacity as a result of new construction. Stringent requirements apply to projects of modernization of production, design methods used, duration and quality of the project works. Traditional methods of designing high-tech Assembly areas, based on average calculations are inefficient and weakly correlated with the automated production process. Important research task is to develop a method of automated design of Assembly areas, based on computer modeling of technological processes and automated synthesis of structure and parameters of the production equipment. The article describes the formalized representation of the production process machining industries, including operations of separation and assembly. Developed algorithmic, mathematical and information support of the process simulation of the machining industry, including operations of separation and Assembly. Implemented the lexicographic algorithm generates the best options for production jobs. These options are processed statistically. Developed a method of structural-parametric synthesis of machining industries. The method takes into account changes in production item due to the simulation of a sample optimal replacement jobs that have the highest probability. The use of the developed method will ensure the optimality of the design solutions according to the criteria of efficiency of functioning of the machining industries.

Keywords: Machine-assembly plant, Structural-parametric synthesis, Lexicographic algorithm, Simulation plant

1 Introduction

A reorganization of existing enterprises is most efficient way to adjust for challenging market environment. Return of the reorganization investment is estimated to be 3 times faster comparing to establishment of similar facilities. In the conditions of the formation of a new technological order the tasks of the reconstruction and re-equipment are important for vast majority of machine-building enterprises in the country especially in adopting of new product ramping.

Highly competitive product markets require very efficient organization of manufacturing facilities saving material and human resources. Level of manufacturing automation is most crucial to achieve production efficiency and, therefore, production of the competitive products. In this regard, modernization of manufacturing projects, design styles, timing and quality of a design work are subjected to very demanding requirements.

The traditional averaged calculations methods that used for design of the high-tech machine-assembly plant (MAP) are ineffective with low correlation to the automated manufacturing process. For this reason computer modeling of manufacturing processes is necessary to improve the methods of a computer-aided design of the MAP.

On the basis of this, the improvement of computer-aided design of the MAP based approaches is important scientific challenge that would provide great benefit to the country

economy.

Solution of the specified problem is possible with development of computer modeling of manufacturing processes that provides the automated structural-parametric synthesis of the MAP.

The developed method will provide the optimality of accepted design solutions according to criteria of operational efficiency of the machine-assembly lines.

2 Review of Works on the Subject of Research

A great contribution to the theory of design and optimization of manufacturing processes in the machining production made the researches of [1]-[8] and other authors. The successful solutions for design and optimization of manufacturing processes are offered by the companies who develops the special software such as the Dassault Systems, Siemens PLM Software, Autodesk, AnyLogic Company, MSTU «STANKIN», SPRUT-Technology.

In accordance to numerous analyses in the field of a machining production design, systems of operating scheduling, systems of simulation techniques which implemented on the machine-building enterprises the design-automation systems cannot be developed without connection with the operating scheduling regardless of production seriality. Therefore the leading world companies provide the set of solutions for production design including the package to compose production schedules which are used in the maintenance process of created system. The domestic developments in the field of operating scheduling such as «FOBOS», «SPRUT-OKP» aren't the tools for manufacturing processes modeling that makes difficulties for getting of statistics on the production assortment.

The solutions offered by foreign vendors which are leaders in the field of modeling (Tecnomatix, Delmia) has a wide set of tools but their manufacturing application for domestic enterprises involves the additional costs on adaptation to production standards, purchasing of unused modules and the development of specific subsystems.

Therefore, the development of automated system for design of the machine-assembly departments that include the module for composition of production schedules has a great importance. The mathematical model was based on the method for automated construction of sequence diagrams which was developed in Orenburg State University and described at the works of [5] [9-12].

3 Simulation Algorithm for the Working Process of the MAP that Takes into Account the Separation and Assembly Operations

The technological process of manufacturing of the product named «drill pipe» was used as model object for development of the product structure. This technological process contains the following operations: sawcut the pipe in a predetermined size, cutoff the workpieces for manufacturing of the nipple and coupling, machining of the pipe, nipple and coupling, welding the nipple and coupling with the pipe, machining of the drill pipe.

The product structure in the form of a bi-directional graph (fig. 1) is proposed to account partitioning and assemblage operations. On this figure left to right shown the direction of workpieces flow and right to left – the information about workpieces required for pipe assembly. In the block specified the nodes which are connected with graph according to the technological process of manufacturing and composition of the product. At the first blocks the nodes wherein specified the composition of the product are equal to zero, at the last blocks – on the place of node that indicate the following manufacturing stage, assigned the value «-1», which fix the machining completion.

The operations of partitioning and assemblage of the products introduce significant changes to the work of modeling subsystem. Thus, for example, without the data of operations the user by itself calculates and sets the number of workpieces that start up to manufacturing. In our

modeling case it is necessary to automatically provide the compliance between the number of assembling products, number of assembly units and amount of a raw stock for workpieces production.

Number of machined workpieces in a batch start up depends on whether the product is unit or workpiece and is described by the expression:

$$Z = \begin{cases} V_{PROD} \cdot z, & \text{if } V_{PROD} \text{ include } z \\ V_{PROD} \cdot \text{deved } z, & \text{if } z \text{ taken from } V_{PROD}. \end{cases} \quad (1)$$

where V_{PROD} – number of products to be produced, pcs.;

z – number of assembly units with the same name belonging to the product or number of workpieces produced from raw stock, pcs.

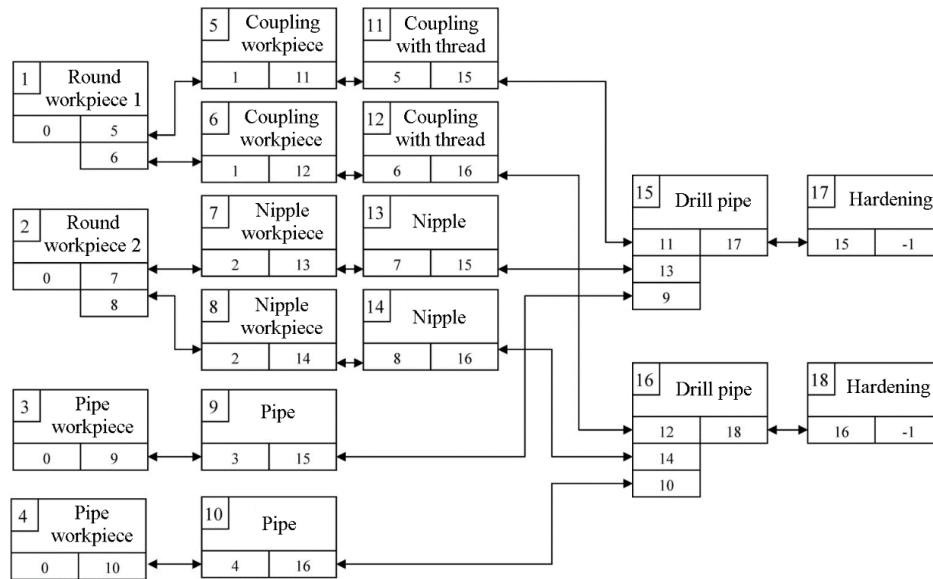


Fig. 1 Bi-directional graph of the product development with account the blanking and assembling operations

The amount of a raw stock (pcs.) required for manufacturing of given number of workpieces can be determined by expression:

$$Z = \begin{cases} V_{PROD} \cdot \text{div } z + 1, & \text{if } V \text{ don't divided on } z \text{ without residue} \\ V_{PROD} \cdot \text{div } z, & \text{if } V_{PROD} \text{ divided on } z \text{ without residue} \end{cases} \quad (2)$$

Thus, this expression takes into account the situation where, for example, the one bar can be sawn to 8 workpieces for nipple. But if required to make ten such workpieces then it is necessary to put the two bars on sawing operation. For the selection of an acceptable variant of the work order (WO) it is necessary to analyze the product composition and distribute the productive time of assembly units (AU) between the equipment groups:

$$F_i - \frac{df \cdot F_i}{100} < T_{i,j} \Sigma < F_i, \text{ at } i=1..G, j=1..N, \quad (3)$$

where F_i – fund of productive time of the equipment group i , min;

$T_{i,j\Sigma}$ – total productive time of the workpieces machining in composition of product j on the equipment group i , min;

G – number of the equipment groups, pcs;

N – assortment of the delivered products, pcs.

Then the total productive time of the workpieces machining in composition of product j on

the equipment group i determines by expression:

$$T_{i,j} = \sum_{j=1}^N T_{PROD,i,j} \cdot V_{PROD,j}, \tag{4}$$

where $T_{PROD,i,j}$ – productive time of product j on the equipment group i with account of product composition (min), determined by equation:

$$T_{PROD,i,j} = \sum_{k=1}^{Kol} T_{AU,i,j,k} \cdot Z_j, \tag{5}$$

where $T_{AU,i,j,k}$ – productive time of assembly unit k of product j on the equipment group i , min; Kol – number of AU in product j , pcs.

The developed structure for describing of the products allows keeping and using the information about assembly units and raw stock in the modeling process. Based on equations above the algorithm for modeling of manufacturing process was developed (fig. 2), the corresponding software was accomplished and estimation of adequacy was performed. The input data are the capabilities of primary and auxiliary equipment and geometrical position of process modules. The output data are the actual duration of work cycle, coefficient of equipment utilization, productivity, utilization by the equipment groups and machine tools, sequence diagram for work of MAP.

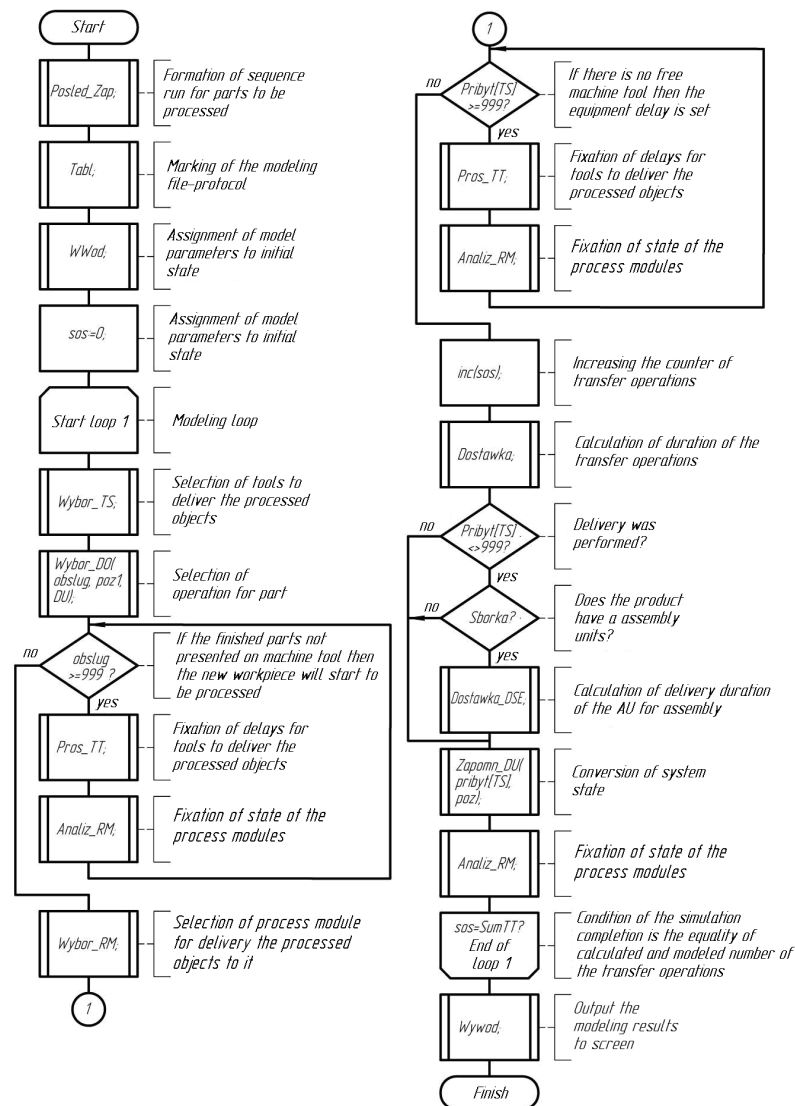


Fig.2 Simulation algorithm for the working process of the MAP that takes into account the separation and assembly operations

4 Synthesis Algorithm for Operating Schedule Based on the Use of the Truncated Lexicographic Algorithm

In the conditions of multiproduct manufacture the multiple passes of manufacturing process on the different variants of WO for collection of statistical data about the productive efficiency, in the dependence of content of the batch run are required. As it is well known, the brute force approach of all possible variants of the batch run has a factorial dependency and cannot be used for real life problems even on the modern highly productive computers. The formation of work orders relates to problems in combinatorial optimization and may be reduced to statement of Knapsack problem.

Let exists the set of items consisting of the M names and L parameters. Then the characteristics of items will defined the by vector $\bar{A}[i]$, which determines the values of each parameter of the item: $\bar{A}[i]=[a_{i,1}, a_{i,2}, \dots, a_{i,L}]$, where $i \in \{1, 2, \dots, M\}$. The number of items of the each name $N[i]$ may be the any integer in the range $N[i] \in \{0, 1, \dots, M_{\max}\}$, where M_{\max} – maximum number of the identical items. Within a predetermined range of constraints $\bar{S}_{\min} = \{S_{\min}[1], S_{\min}[2], \dots, S_{\min}[L]\}$ and $\bar{S}_{\max} = \{S_{\max}[1], S_{\max}[2], \dots, S_{\max}[L]\}$ it is required to find the combinations of packing which meets the specified constraints.

In the mathematical statement the conditions of possibility of the packing for given combination of items are described by the following expressions:

$$\begin{cases} S_{\min}[1] \leq \sum_{i=1}^m a_{1m} N_m \leq S_{\max}[1] \\ S_{\min}[2] \leq \sum_{i=1}^m a_{2m} N_m \leq S_{\max}[2] \\ \dots \\ S_{\min}[L] \leq \sum_{i=1}^m a_{Lm} N_m \leq S_{\max}[L] \end{cases} \quad (6)$$

When the condition (6) meets the constraints for combination k then number of items in the knapsack $N_{\Sigma}[k]$ will be

$$N_{\Sigma}[k] = \sum_{i=1}^m N[i].$$

Subject to the introduced mathematical support the algorithm for generation of the work orders variants based on the branch and bound method was developed

If in a production flow of the processing of the parts from different groups without their interleaving is found a situation when the some machine tools are not active due to the specific of a manufacturing cycle then it may be concluded that the given situation involves the abrupt reduction of the productive efficiency. Therefore, attempt to optimize the operating schedule through interleaving the parts of various groups in a sequence can be engaged. Solution of this problem was realized with truncated lexicographic algorithm (fig. 3).

The number of steps in this algorithm was reduced at the expense of the selection from the sum of all rearrangements of the sequence run the rearrangements with the predefined interval only.

For statistical treatment of the modeling results for sampling of the WO the advanced algorithm was developed that allows to receive the frequency histograms and cumulative probability plots for the various factors of MAP efficiency. Comparison of modeling results of the work orders with and without optimization reveals higher efficiency for optimization with the sequence run.

To account the sensibility of the MAP to alterations of the manufactured product assortment the technique for selection of representative batches based on the estimated probability of higher efficiency of the manufacturing system was realized (fig. 4). Selection of the representative batches that allowed to use in the developed computer model of the MAP in the algorithm of

structural-parametric synthesis of the production equipment is subject to the wide assortment of produced objects.

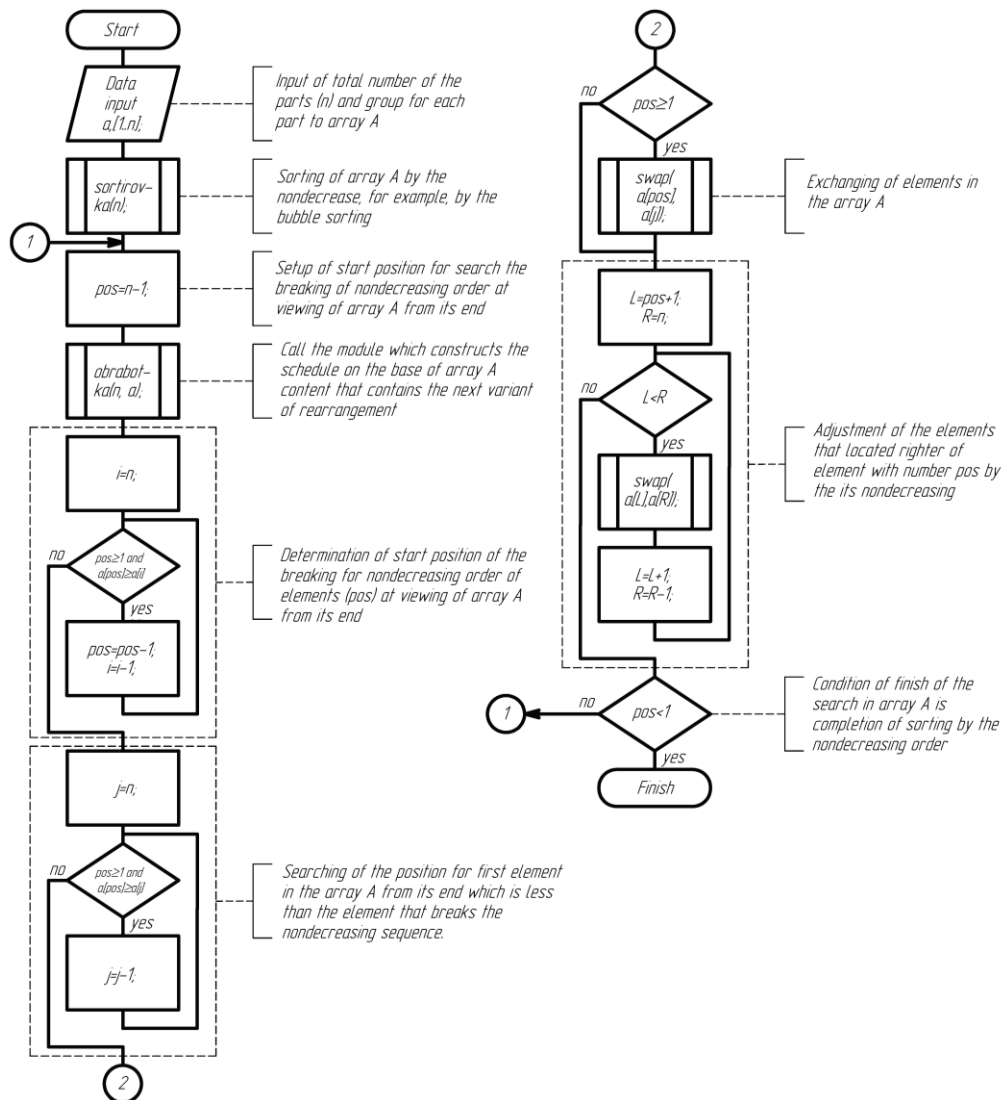


Fig.3 Synthesis algorithm for operating schedule based on the use of the truncated lexicographic algorithm

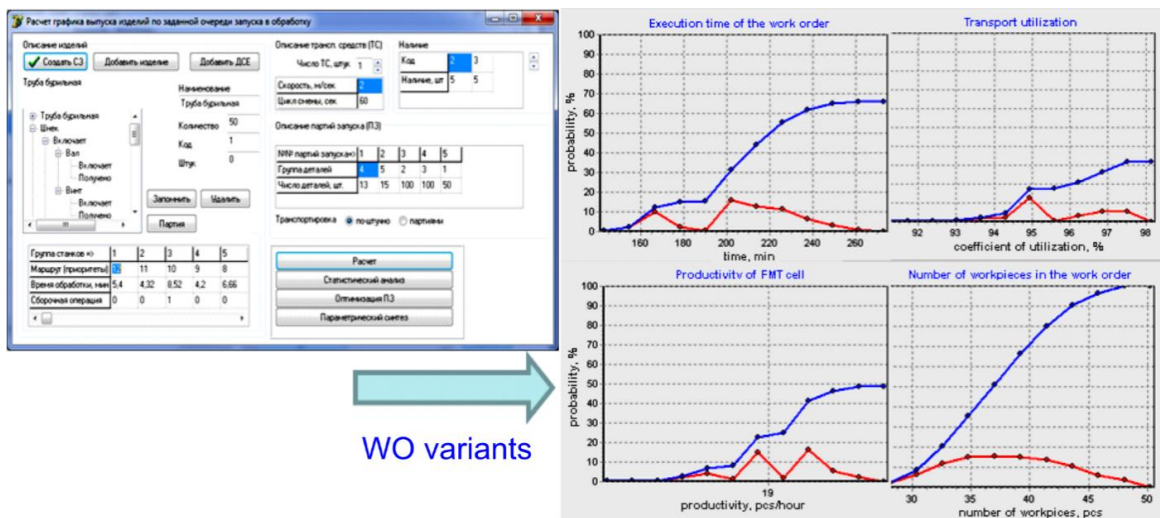


Fig.4 Statistical analysis of the work orders

5 The development of the method of structural-parametric synthesis for machine-assembly plants

The next stage is the development of the method of structural-parametric synthesis for machine-assembly plants. The introduced method uses the three strategies based on using of genetic algorithms, Hooke-Jeeves method and alternating-variable descent method.

In the process of computing experiments the structural-parametric synthesis method is found to be most effective if based on the genetic algorithms. It may be explained by the fact that the two other methods use the same principle of optimization, i.e. here it matches the optimal value of the one parameter when the other parameters are constant. The advantage of the genetic algorithm is the variations of all synthesized values on every iteration step that as the result allows to get the uniform set of parameters that provide the maximum efficiency of the machine-assembly departments.

The other distinctive feature of the algorithm is that algorithm during the execution takes into account all used efficiency indexes: usage and duration of the actual equipment work. This approach allows to avoid the procedure of criteria convolution so as to proceed for the complex efficiency index. Meanwhile, the parameters selection is performed with regard to extreme value from all efficiency indices.

For solution integrity in the problem of structural-parametric synthesis of the machine-assembly departments the algorithm for synthesis of coordinate arrangement of equipment was introduced. In the capacity of synthesis method the genetic algorithm based on the chromosome conception wherein the values of genes not modified but their locations are changing is implemented. This algorithm was realized in the software «Komponovka 1.3».

On the basis of computer model of the manufacturing system the method of structural-parametric synthesis of the machine-assembly departments was developed (fig. 5) that take into account the partitioning and assemblage operations of the produced objects. This method takes into account the change of manufacturing assortment at the expense of modeling the sampling of optimal WO which has a maximum probability of production starting.

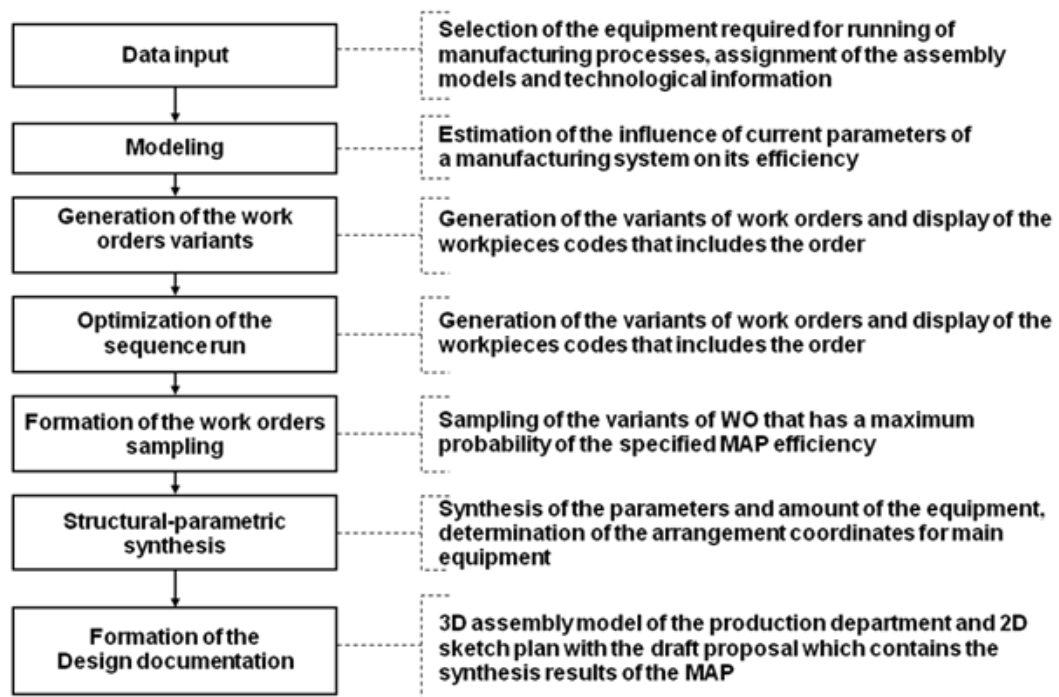


Fig. 5 Method of structural-parametric synthesis of the MAP

On the framework of introduced algorithms the program «Plan3D» was developed which is possible to transfer the generated model of MAP to CAD-system KOMPAS and automatically

construct the layouts of designed machine-assemble department in 2D and 3D formats. On the layout the table with the selected parameters of manufacturing equipment is also displayed (fig. 6).

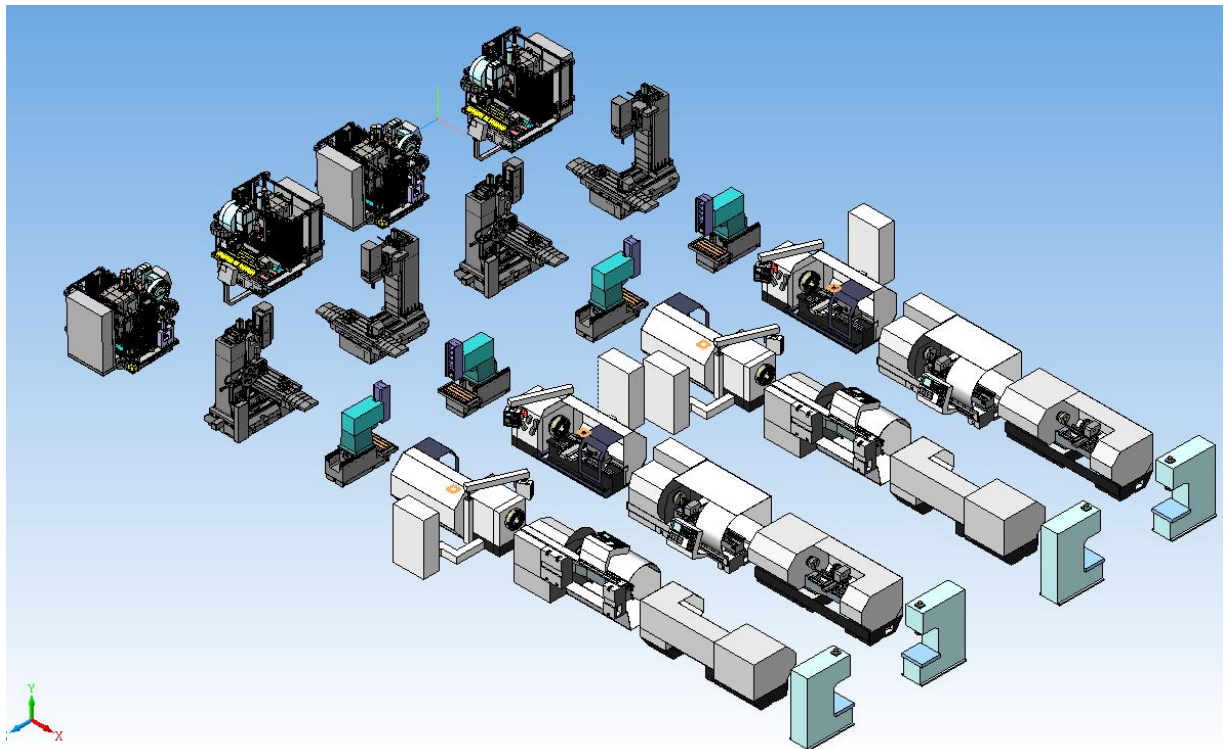


Fig. 6 3D model of equipment arrangement for machine-assemble department

The design data that formed as a result of automated structural-parametric synthesis are easy integrated into uniform information space of enterprise and allow to make changes via tools of CAD-system KOMPAS.

5 Conclusions

In this work it was determined that the modern approach to design the machine-assemble departments is a detailed analysis of the design solutions related to selection of structure and parameters of manufacturing equipment via computer modeling of MAP with the running on multiple manufacturing processes.

The formalized presentation for functioning process of the machine-assemble department was performed. This presentation which describes the dynamics of assembly units manufacturing is based on the diagrammatic work method and may be used for most categories of the machine-building products.

The algorithm for synthesis of optimal operating schedules which allows reducing a turnaround time by 10-15% was developed.

The method for designing of machine-assemble departments which distinctive feature is the usage of operating scheduling procedures and computer modeling of the MAP functioning was developed. It was proved that the inclusion the procedures of an operating scheduling into method for design allows to increase the MAP efficiency on 23%.

The program realization of a developed algorithms and procedures was designed, tested and approved. The developed software allows to form the complex of design solutions realized as 3D model of the equipment arrangement and nomenclature of the equipment parameters on the base of computer simulation of functioning and analysis of structure and parameters of the MAP.

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