Optimization of the work of the blank production of a machine-building enterprise with the use of simulation

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Abstract. The use of information technology in machine-building enterprises has become an integral part of the entire production process. An analysis of the literature has shown that the topic of optimization of blank production using modern information technologies has not been sufficiently disclosed. In this paper, it is proposed to use simulation modelling to optimize the work of blank production. The use of a genetic algorithm is proposed as an optimization algorithm. Practical testing of the proposed solution showed a good result.

1. Introduction
The modern development of technology and computer engineering provides a solution to various production problems arising in machine-building enterprises. One of these tasks is to meet production deadlines without loss of quality of the finished product. The deadline of finished product release can be provided only if the terms of delivery of materials, possible intersections of material flows, the available production resources and stocks are considered at planning of production processes.

The production units associated with the procurement of products are one of the most difficult to plan production processes. This is explained primarily by the fact that the blank production is located at the beginning of the technological chain of any product. In the manufacture of products it is necessary to build the work of procurement production so that the blanks are coming to the right time. In the case of advanced work of procurement production, a situation may arise when a large number of blanks are accumulated in intermediate warehouses. This situation is complicated by their search and further processing. In the case of a long schedule of receipt of blanks a situation of downtime of the main process equipment can arise and, as a result, delays in the manufacture of finished products.

The assembly operations can arise additional difficulties in planning the work of the blank production. It is necessary to take into account simultaneously the routes of all parts and all components. It is possible to plan the work of the blank production on the basis of these routes and the timing of finished products.

2. Technical review and work goal
The simulation modeling using for researching and optimizing the production processes has been repeatedly described [1-5]. The blank production is also overviewed in these papers. The whole potential of the application of simulation modeling in optimizing the work of blank production is not disclosed.

The latest papers are mainly devoted to the direction of optimizing the level of stocks of materials [6] and reducing costs in the procurement of materials [7]. The whole, the technological chain of production is not considered, and the features of the work of blank production are also not disclosed.
The analysis of technical literature has shown that the simulation modeling using is widely represented in optimizing production processes [1, 8-11]. However, optimization of blank production is not the main task in these papers, therefore, it is presented only superficially.

It should also be noted that at present considerable attention is paid to the problems of the development of artificial intelligence and robotics in relation to production problems [12-14].

The goal of the paper is to increase the efficiency of the blank production using simulation modeling. To achieve this goal, the following tasks are solved: formalization of optimization criteria, development of a simulation model of a blank production, optimization of blank production using genetic algorithms.

3. Formulation of the problem

The blank production consists of 6 types of equipment. 4 pieces of equipment are represented by sheet metal cutting devices. 2 pieces of equipment are represented by band saws. All this equipment form blanks for further processing from the semi-finished products. According to the technological routes, the part of the blank production immediately is coming to the assembly points. However, most of the blanks, before joining the assembly, are undergone by a number of technological operations.

Qualitatively planned work of the blank production ensures that all parts used in one assembly unit are delivered to the assembly point with a minimum being in intermediate warehouses. The good indicator of the work of the blank production is manifested by the minimum waiting time of missing parts when performing assembly operations. The total time spent on the part being in intermediate warehouses and the waiting for parts during assembly of product can be calculated as:

$$T_s = \sum_{i=1}^{n} T_{d_i} + \sum_{i=1}^{n} T_{o_i}$$

where $T_s$ – the total time spent on the part being in intermediate warehouses and the waiting for parts during assembly of one product, $T_{d_i}$ – time spent in the intermediate warehouse, $T_{o_i}$ – time wait for parts during assembly of product, $n$ – total number of parts in an assembly.

The main difficulty in planning the work and ensuring the minimize of finding the part in the intermediate warehouse and waiting for the part to be assembled is the fact that blanks for different assembly units can be obtained from one semi-finished product. However, if, when planning, purposefully try to minimize the being of parts and workpieces in the intermediate warehouse, then the equipment may be idle. The total downtime of the process equipment in the blank production can be calculated as:

$$T_n = \sum_{i=1}^{m} T_{n_i}$$

where $T_n$ – planned equipment downtime, $T_{n_i}$ – planned downtime of $i$-th equipment, $m$ – number of equipment on site.

One of the obvious criteria for optimizing the blank production should be minimization of the execution time of technological operations. However, in this paper, the technology of cutting semi-finished products is not considered; as a result, for the explored production volume, the total time for performing technological operations is not changed. But, with the same time of forming the blanks, the time spent on assembling a single product may be varied. This time difference is explained by the time it takes to collect all the components of the assembly. The assembly time itself is not considered, since the blank production cannot affect it.

Thus, the optimal performance criterion of the blank production can be described as:

$$\sum_{i=1}^{k} T_{s_i} + T_n \rightarrow \min$$

where $T_{s_i}$ – time spent on the part being in intermediate warehouses and the waiting for parts during assembly of the $i$-th Assembly unit, $k$ – total amount of assemblies, $T_n$ – planned equipment downtime of the blank section.
The resulting optimization criterion may vary depending on production conditions. For example, if it is necessary to ensure that the product is ready on time, a weighting factor can be introduced to increase the significance of the waiting time for parts to assemble and locate parts in the intermediate warehouse. This coefficient can apply to all assembly units, as well as to individual representatives. Similarly, weighting can be applied to equipment downtime.

4. Development of a simulation model
One of the main advantages of simulation is to research a complex study of all production processes of an enterprise. When optimization of one site is required, the best solution would be to develop a simulation model of the entire enterprise.

It is possible to assess the effect of optimizing the blank production by analyzing the areas processing the blanks, as well as analyzing the assembly operations. Therefore, the creation of simulation model of the entire enterprise is an important task in the case of optimizing the blank production.

The software package Siemens Plant Simulation was chosen as a simulation tool. When using a software package, the process of creating a simulation model is automated, in order to reduce the complexity of work. Figure 1 presents a general view of the developed simulation model.

The preparation and loading of source data is the first task of creating model. The tabular form is the most convenient format of source data. Therefore, the following tables are used to set and change the initial data of the simulation model:
- the composition of the product contains information on all assembly units of one product;
- the composition of semi-finished products including the list of blanks obtained from each semi-finished product;
- technological routes of manufacture.

The described tables are loaded into the simulation model using the ODBC interface (Open Database Connectivity). The simulation model ensures the reliability of the simulation experiments when using information from the loaded tables.

The software method has been developed providing the movement of imitations of semi-finished products, blanks, parts and assembly units to automate the modeling of production material flows in Plant Simulation. The developed method, based on the information presented in the table with technological routes, determines the path of movement of the blanks and records information regarding the time and place of processing. The recorded information is further used for work planning.
5. Optimization of blank production

The developed simulation model allows optimizing the blank production. The simulation model is regarded as “black box” in the process of optimization. When the simulation model is launched, a variable parameters of optimizing are chosen, a fixed source data set and optimization criterion (3) are set. In our case, the queue of semi-finished products for forming blanks is used for optimizing parameters.

The value of optimizing criterion and the optimal work plan of the site are defined as a result of the execution of simulation experiments. An optimal work plan is an optimized work schedule, which can be represented as a Gantt chart. Figure 2 shows the general scheme of optimization experiments.

The first simulation experiment was carried out with the initial set of parameters to determine the initial value of the optimization criterion. The source data contains information on 2 assemblies. All the equipment of the blank production is involved in the release of these products. As a result of the simulation experiment, a criterion value of 54.28 hours was obtained – it is time spent on the part being in intermediate warehouses and the waiting for parts during assembly and equipment downtime of the blank section.

One of the most obvious ways to present information describing the employment of productive resources is the Gantt chart. The diagram allows to visually assess the work plan of the production unit, and also simplifies the work on monitoring the implementation of the plan. Figure 3 shows the Gantt diagram of the work of the blank production of the source data.
A genetic algorithm is used to optimize the work of the machine-building blank production. The objectives of this exploration did not include the analysis of the work of the genetic algorithm, the description of the work of the genetic algorithm is presented in [15].

The program method of the simulation model is responsible for calculating the adaptability function of the genetic algorithm. The operating parameters of the genetic algorithm are empirically determined. As a result of analytical work with the results of 30 optimizations, it is found that to achieve the minimum value of the optimization criterion, 30 generations with a population size of 40 genotypes are required.

The optimization of the blank production in the simulation model of machine-building production allows to obtain a data set providing optimizing criterion value equal to 39.62 hours – it is time spent on the part being in intermediate warehouses and the waiting for parts during assembly and equipment downtime of the blank section. The improvement is 27% in comparison with the simulation experiment using the initial data. Figure 4 shows the Gantt diagram of the blank production after optimizing queue of semi-finished products.

![Gantt chart after optimizing queue of semi-finished products.](image)

Simulation experiments on other data sets showed similar results. The improvement in optimizing criterion ranged from 22% to 29%.

6. Conclusion

Summing it up, we can say that the main advantages of using simulation to optimize the work of the workpiece are:
- increase the productivity of the workpiece to 29%;
- the ability to analyze the impact of changes on the entire production process, when changing the billet products;
- the possibility of drawing up an optimal production plan, both in clean production and in other production divisions.

The development of a simulation model is a difficult job that requires practical industrial skills and theoretical knowledge. Nevertheless, the complexity of such work is fully justified in the study of diversified industries with a large number of intersecting material flows. A separate production process can be implemented using a mathematical or structural model, but only a simulation model makes it possible to carry out a detailed analysis from the point of view of the systems approach. The simulation model allows you to analyze and optimize any production site in the shortest possible time. In the future, it is planned to focus on the operational preparation of the optimal production plan with the possibility of adjusting in real time.
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