Optimization of the Production Process of Product Quality Control Using Simulation Methods

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Abstract: A modern industrial enterprise operates in a highly competitive environment. In such a situation, the optimal use of all enterprise resources - personnel, equipment, materials - becomes extremely important. The effect of the use of a particular piece of equipment depends on many factors, among which are the qualifications of operators, the quality of raw materials and workpieces, and timely maintenance. However, most of all, the effect depends on how efficiently the equipment is used. The problem of increasing the efficiency of the use of equipment and target resources at the enterprise for quality control of products is being solved. The purpose of this work is to develop software for simulating the production processes of an enterprise, which will help optimize the production process, collect and analyse the data obtained by the model.

1 INTRODUCTION

Currently, simulation modeling is one of the powerful tools for analysing various social, military, technical, economic and other systems. Under simulation, modelling it is customary to understand the process of conducting an experiment by means of a computer based on mathematical models of real world systems.

The main advantage of using simulation modeling is the analysis of the organization's activities. Modeling the work of an organization allows you to see its structure and activities in order to see the leading qualities and weaknesses in the technological process.

In addition, the simulation model of the enterprise allows you to answer questions regarding the main mechanisms of the organization. The ability to display the processed data on graphs allows you to visually see the entire situation in the organization and quickly make decisions to eliminate shortcomings in technological processes.

One of the main directions of modeling the activities of the organization is the analysis of the work of the enterprise at each individual workplace and the enterprise as a whole.

Problem solving is an obvious internal reserve for improving the efficiency of the organization. That is why the construction of an information model with the help of software products for simulation modeling comes to the rescue in this situation.

Modeling is a method of solving problems, when using which a simpler object that describes the real system and is called a model replaces the system under study. Simulation is used in cases where it is impossible or impractical to conduct experiments on a real system.

Modern modeling systems support the entire set of information technology tools, including graphical shells for the purpose of constructing models and interpreting the output results of modeling, multimedia tools, real-time animation, and object-oriented programming.

One of the simulation systems is Anylogic.

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The AnyLogic software tool is based on an object-oriented concept. Another basic concept is to represent a model as a set of interacting, parallel activities. The graphic modeling environment supports the design, development, documentation of the model, the execution of computer experiments, and the optimization of parameters relative to some criterion.

When developing a model, you can use elements of visual graphics: state diagrams, signals, events, ports, etc. A user-friendly interface and numerous support tools for developing models in AnyLogic make not only the use, but also the creation of computer simulation models in this modeling environment accessible even for beginners. When developing a model on AnyLogic, you can use concepts and tools from several classical areas of simulation modeling: dynamic systems, discrete event modeling, and system dynamics, agent-based modeling (Grigoriev, 2016).

At the moment, there are a number of similar simulation systems that solve the problem.

For example, Hysys software is designed to simulate a chemical process to optimize circuit design. In addition to static simulation of technological schemes, the program allows, in the same environment, to perform dynamic simulation of individual processes and the entire technological chain, as well as to develop and debug process control schemes. It is possible to perform calculations of the main design characteristics of equipment.

Another similar system, Aspen Plus, is designed for stationary simulation, design of chemical-technological production, equipment performance monitoring, optimization and business planning in the field of production and processing of hydrocarbons and petrochemistry.

However, the limitations of the capabilities of such systems became obvious: a small functionality of debuggers, a small number of typical models, the absence of structural modeling, and a large error in calculations.

Thus, to solve the problem, it was decided to use Anylogic. This system has a number of advantages among analogues, namely:

1. Allows you to create models: continuous, discrete, hybrid, deterministic, stochastic;

2. Supports all stages of simulation modeling: creation and verification of the model, its study, parametric analysis and optimization;

3. Has a powerful 2D and 3D animation system;

4. Allows you to enjoy all the advantages of an object-oriented approach: inheritance, polymorphism and nesting.

Thus, the use of this system for modeling the production process in this work will allow you to build a simulation model as efficiently as possible, as it has a rich set of functions, a strong experimental base and better visual design compared to analogues.

2 METHODS

The tasks set in this work put forward a number of requirements for the tools for implementing the company's simulation model, including the simulation environment used to build it and conduct experiments. The software tool used must necessarily implement the functionality for developing models using a discrete-event approach. The AnyLogic modeling package was chosen as a tool for developing a simulation model in the framework of this work. It supports all three simulation-modeling paradigms: discrete-event approach, agent-based modeling, and system dynamics.

A simulation model is a computer program that describes the structure and reproduces the behaviour of a real system in time (Devyatkov, 2011).

Simulation modeling is the development of computer models and setting up an experiment on them (Qing, 2023).

Various varieties or directions respectively can conditionally represent simulation modeling, having their own methodologies (Figure 1).

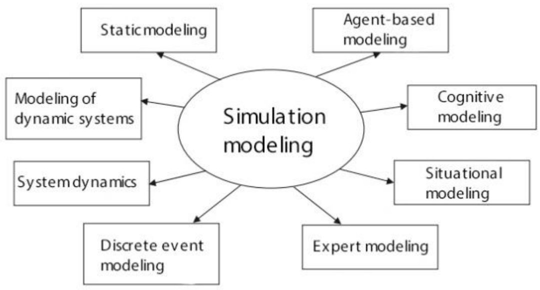

Figure 1: Types of simulation modeling.

To work with the system, one type of user is provided - a modeling specialist. The Modeling Specialist user can:

- To create new technological lines;
- To model their work;
- Save the structure of technological lines and simulation results;
- Load previously saved technological lines.

The model consists of a set of objects (processes). Each object models functions or decomposition elements of the system being modelled. Each object has a set of attributes and methods.

The simulated system is presented as a model of the quality control line system for manufactured products, the block diagram of which is shown in Figure 2.

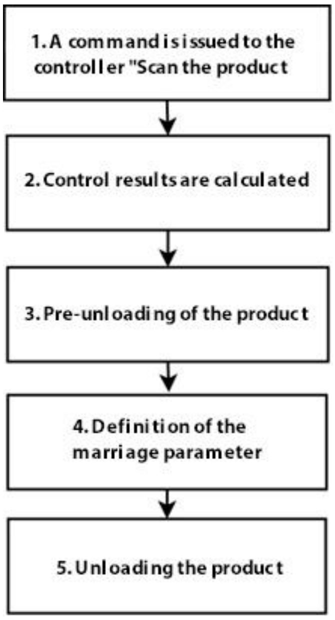

Figure 2: Structural diagram of the quality control line.

The input information in the simulation model is information about the main resources used in production, as well as the use of auxiliary resources by the type of power consumption and compressed air of the product control line, the planned volume, date and time of the start of the model, as well as entering the time for each of the operations in the technological process (Figure 3).

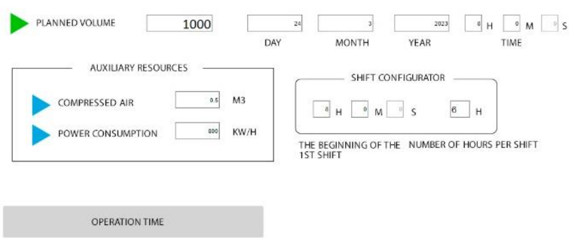

Figure 3: Input data.

The output information includes the results of data processing, in this case, time schedules for checking products, the number of products that passed the test, the planned volume, the amount of power consumption and compressed air in real time (Averill, 2007).

3 RESULTS

As a result of the work done, a model of the technological process of the product quality control line in production was developed using the Anylogic simulation system.

Figure 4 shows the main menu of the simulation model. The main menu allows you to set the planned volume of products to be checked, as well as the initial amount of production resources used. In the main menu of the model, you can set the start time and date for starting the simulation model (Malikov, 2013).

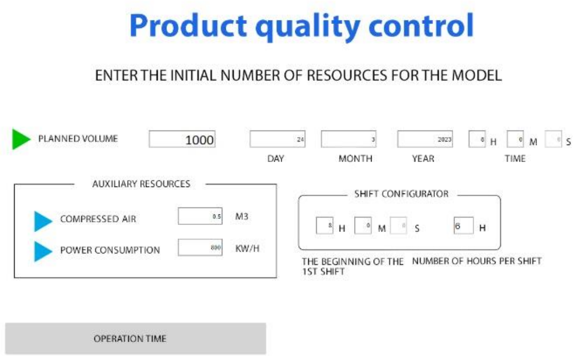

Figure 4: The main menu of the simulation model.

To display the output data collected by the model, an interactive panel was designed with important information grouped on one screen (Karpov, 2019). The interactive panel displays the consumption of the main production resources: power consumption and compressed air. The panel also displays a bar chart with the number of successfully passed product checks and the number of defects (Mourtzis, 2021) (Figure 5).

Figure 5: Fragment of a window with an interactive panel.

4 CONCLUSIONS

In the course of the work performed, a simulation model of the fuel assembly production process was developed, which will improve the efficiency and optimize the technological process, as well as generate an analytical report on the experiments performed for evaluation and recommendations on the stages of the technological process.

This simulation model system will make it much easier to analyse the situation and make decisions regarding production processes.

There is a possibility of modifying the simulation model, according to which the calculations are again made, and then a comparative analysis of the new results with those obtained earlier is carried out. Simulation methods, although they do not lead to optimal solutions, such as linear programming methods, however, allow you to develop policy directions that lead to better results.

In the future, it is planned to create wider functionality and the ability for users to customize the system for themselves: adding the cost of resources to calculate the amount of resource costs, importing and exporting data to tables, building a 3D model.

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