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Simulation Methods in Shipbuilding Process Design

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The paper aims at presenting the use of simulation methods in shipbuilding production process design. The basic design procedure principle is described, the main elements of the designing spiral, flow diagrams and interrelations between individual activities determined. The flow diagram indicates a point in which the simulation results affect the design flow.

A simulation program package was used to create a shipbuilding production process model. An example of possibilities and methods of presentation of the program package outputs is given, and the advantages of using simulation methods in the shipbuilding production process are described in a conclusion.

Keywords: shipbuilding, process design, simulation methods

0 INTRODUCTION

The shipbuilding production is a complex and lengthy process, which demands careful planning and timely decision-making. Characteristic of an intermittent process like shipbuilding is a large number of working activities of different duration. Thus, it is necessary to ensure work-in-process storage areas, which demand an adequate space and a rather intensive use of transport devices. Position of machines, transport equipment and other devices within the process does not change. The major changes in the process are caused by diverse production programs. Products of different purpose and geometries pass through the same production process and incur different work-loads on workshops, equipment and work-in-process storage areas, which might cause interruptions in production [1].

Problems encountered in complex systems are efficiently resolved by simulation methods. Mathematical and statistical analyses do not play a major role in such systems, since they are not realistically described by mathematical equations. The literature does not offer an unequivocal definition of simulation. The term "simulation" would mean imitation, and the simulation procedure, according to one of definitions, is a set of activities ranging from real system modelling to experimenting with a model and analysis of results [2]. The simulation enables prediction of steps taken in real production process and recognition of unfavourable situations, such as interruptions or bottlenecks in production. It is also possible to monitor the effects of parameter changes on overall process before the production in workshop starts, when error corrections are much more difficult and expensive.

Papers about simulation methods in the shipbuilding are scarce. In those very few authors' effort is to present and encourage the use of simulation method as a tool for easier decision making in shipbuilding production process. Medeiros et al. [3] and Williams et al.[4] are presenting their work on systems for modeling and visualization of production process and the importance of the internet as a communication tool. Kiran et al. [5] introduce hierarchical approach to modeling. Overall simulation model of the production process is divided in number of smaller models that are created separately. Smaller simulation models could be then controlled and analyzed easier. Their approach also includes methods that integrate these sub-models into an overall model in order to run different scenaria and identify global performance measures.

Research of McLean and Shao [6] presented overview of the generic simulations of shipbuilding operations. They are concerned to control and follow-up of labour resources and costs in complex system like shipbuilding. Dain et al. [7] present stochastic simulation model for determination, follow-up and control of costs, activity delay or labour resource shortage because they could cause

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huge disturbance in production. Nedess et al. [8] emphasize, among other things, that due to the fact that required space is a resource for time-critical processes with restricted capacities on shipyards and other shipbuilding companies. The space allocation has to be handled as one of the most important tasks in production planning, and this aspect was implemented in the simulation module for space allocation within the Simulation Toolkit Shipbuilding (STS). They also highlight the need for special simulation modules for shipbuilding industry. Steinhauer and Meyer-König [9] present importance of simulation and STS in sub-assembly and assembly stage planning.

1 SHIPBUILDING PROCESS DESIGN

A shipbuilding process design consists of elements each of which has its appropriate requirements and limitations. Elements of the shipbuilding process design are production concept, product analysis, material flows, building dynamics, arrangement of working areas, process flexibility, management, logistics, human resources and investment. Their interrelation is complex, and the ultimate solution is looked for in iteration of several steps [10]. Each next iteration step brings new solutions for the design elements, which affect other design elements. The final result is a compromise design of an overall shipbuilding process, which does not offer the best solution for each individual design element.

The shipbuilding process design procedure may be expanded by application of simulation program packages for modelling, visualisation and experimenting with a model, which enables prediction and avoiding of adverse effects the parameter changes have in a complex production process such as shipbuilding.

When the data obtained by analyses of product, production process and material flow are used, the simulation procedure enables creation of production process and final product model. Performing a large number of experiments with models in a short period of time will create a considerable database for quality and informed decision-making on solutions for the production process.

Figure 1 shows a block diagram with shipbuilding process design elements and their interdependence achieved by two-way relations. Interdependence of elements is complex, and their relations in the design stage are open in both ways until the final solution has been found.

Simulation in the shipbuilding process design consists of a preparatory and executive process.

The preparatory procedure includes calculation of necessary model element and creation of the production process and final product models.

Executive part of the simulation procedure starts with the experiment scenario, which defines a research purpose, input data and analyses parameters, such as the equipment efficiency or experiment duration. The procedure continues with experiment with a model and analysis of output data, which results in conclusions. If the conclusions have determined that the research were to continue with a new experiment, the procedure is repeated, i.e. the changes are made in product analysis, production process and material flow. These changes affect the production process and final product models, which initiate a new experiment. When all the options are researched and final conclusion brought, the results are presented to responsible management, which makes decisions on all the shipbuilding design elements.

2 AN EXAMPLE OF SIMULATION METHOD USE IN SHIPBUILDING WORKSHOP PRODUCTION PROCESS MANAGEMENT

The simulation method use in management of production processes will be shown using an example of situation analysis for a shipbuilding workshop [11]. The data obtained from the shipyard will be used to build a simulation model of the shipbuilding workshop, define the production program and carry out computer-supported experiments. Analysis of results of an individual experiment and comparison of results of a larger number of experiments creates a database facilitating quality decision-making on the production process changes. Taylor ED software is used for modelling, visualization and results analysis.

2.1 Simulation Program Package Taylor ED

Simulation software Taylor ED is object-oriented program package for modeling, visualization and analysis of the production

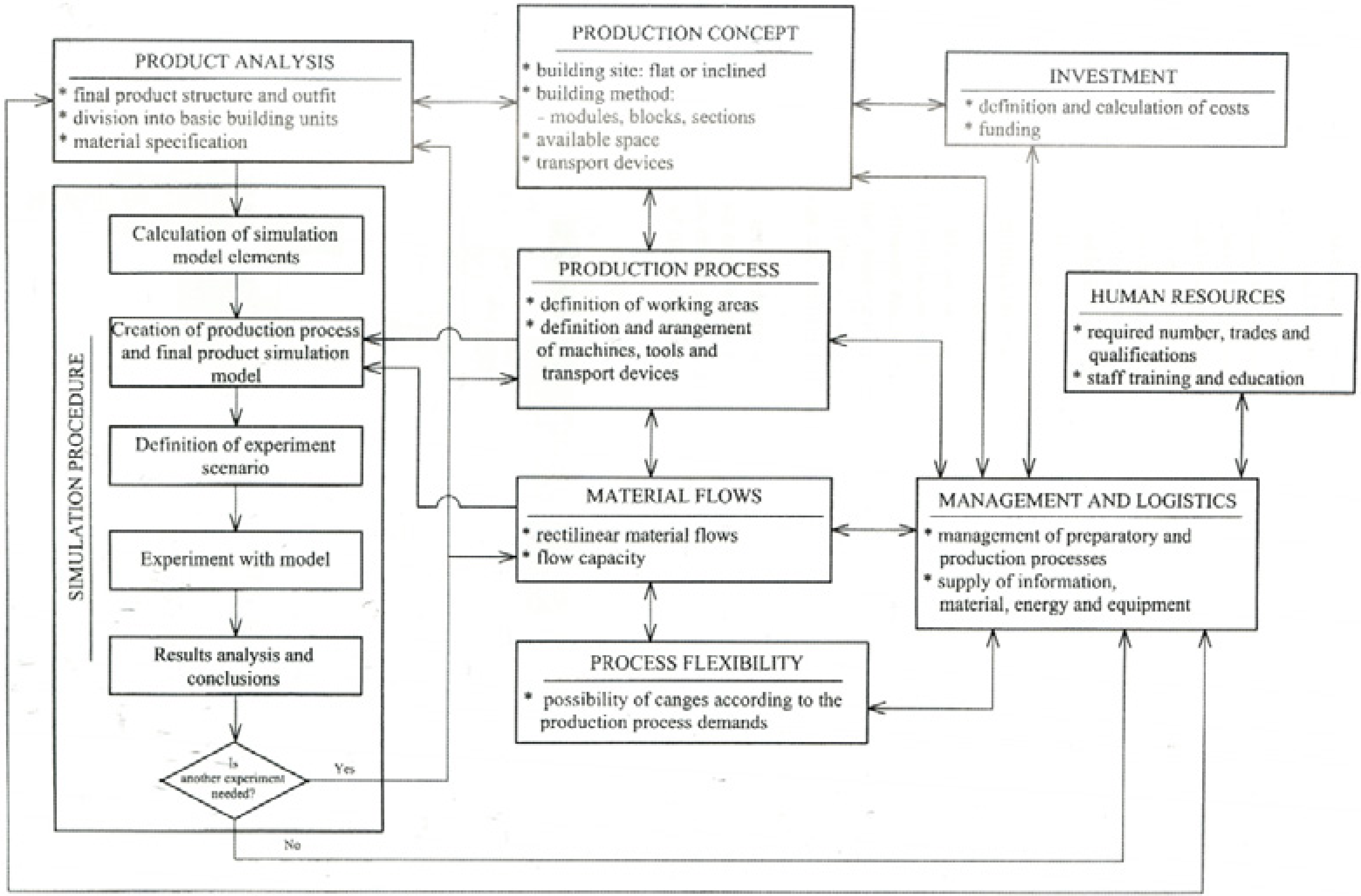

Fig. 1. *Shipbuilding process design elements obtained by simulation procedure*

process. In the program package whole production process and products of the workshop are created. A basic element of the simulation model is an atom. The atom represents single machine, tool, and transport device, necessary areas like interim stores, semi-products and products of the workshop. There are 80 defined and created atoms in the program package.

In the program package atoms are arranged on workshop layout. Their geometric characteristics and functions are defined, as well. Relations between atoms are defined to determine task scheduling in the workshop. Connecting entry and exit channels of atoms define the routing - the flow of the products through production process in a simulation model. Function of the atom is operation that has to be done. It could be set, for example, as duration of machine operation or speed, load and unload time of transport device.

2.2 Shipbuilding Workshop Simulation Model

The simulation program package models the production program with elements that represent equipment, devices and transport devices. Each element is defined by its geometry (sizes of equipment and devices), position in space and operating characteristics (speed of transport devices or fabrication duration on equipment). Figure 2 presents a model layout.

Cut lengths of plates, profiles and bars are defined by their geometrical characteristics and ship structure analysis. Through cutting machines possibilities, duration of cutting is determined for each machine. Analysis of the cutting duration real values is basis for value distribution definition. Log-normal distribution is very close to real values and it is set in cutting machines atoms in the simulation model.

Basic areas are material stockyard and shipbuilding workshop. Plates and profiles are arranged on the material stockyard, which is equipped with a portal crane. Portal crane transports a material on the prefabrication line. After that plates and profiles are going to the shipbuilding workshop.

The shipbuilding workshop consists of 5 naves. The first nave is used for profile cutting on a robotised line, which consists of a line for the profile edge cleaning and a robot station for plasma

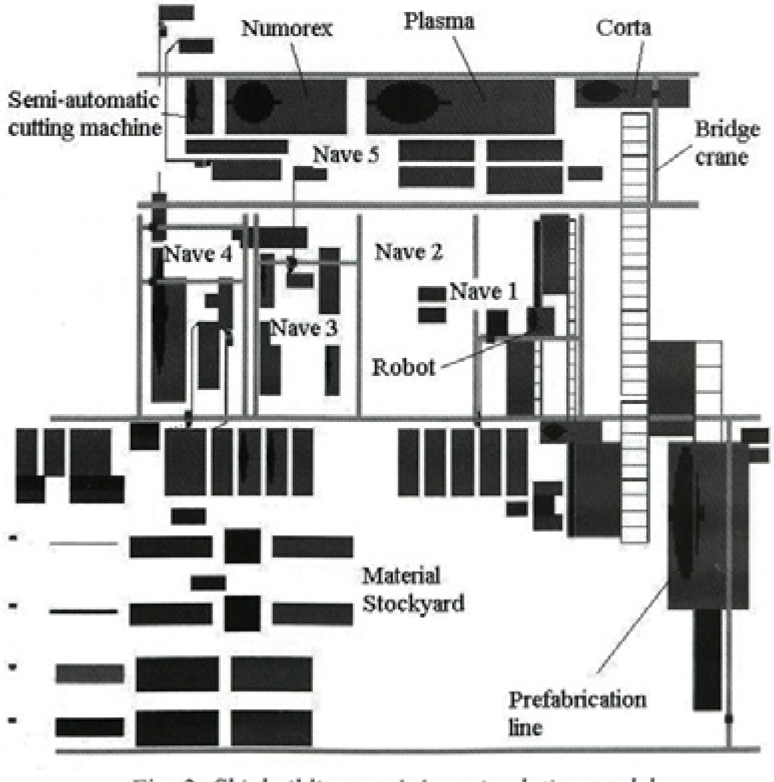

Fig. 2. *Shipbuilding workshop simulation model*

cutting. Profiles are transported in the nave with bridge crane, roller conveyors and transverse chain transport device.

The second nave is used for disposal of tools and as an auxiliary area off the main material flow. Being less important, this area is not modelled in the program package.

The third nave is used for shaping of earlier cut plates. The plates are shaped in press, and transported in the nave with bridge crane and trolley.

In the forth nave, the profiles are bent on bending machines and transported with bridge crane and trolley.

The plates are cut in the fifth nave. Three cutting machines are used, one for plasma and two for gas cutting (Numorex and Corta). The plates are transported with bridge crane and trolley.

2.3 Production Program

To initiate the experiment with the simulation model, it is necessary to define the workshop production program, necessary material quantities, and sequence of fabrication. In this example, the production program includes plates, profiles and bars used for the hull building.

Quantity of material is determined from characteristic sections. The central part double-bottom sections and parts of the double-bottom with bilge of an oil product carrier were selected. Geometry and quantity of plates, profiles and bars was determined from the specification of material, same as the fabrication procedures. These data are used to define the scenario of the material input into the shipbuilding workshop. Figure 3 shows mass percentages of plates, profiles and bars in total quantity of material. In total quantity of material, plates account for 84%, and profiles and bars for 16%.

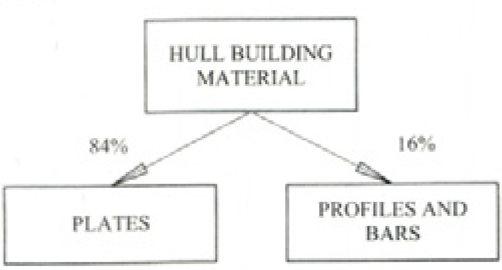

Fig. 3. *Mass percentages of plates, profiles and bars in total quantity of material*

2.4 Experiments with Model

The modelling process is followed by launching of an experiment. The visualisation module used to monitor the experiment progress is started at the same time. It enables monitoring of what is happening with material, semi-products, equipment, devices and transport devices in any part of the process.

The paper describes two experiments with models. Having in mind complexity of the analysis, monitoring of process and results analysis will be limited to the profiles and plates cutting processes. The efficiency of equipment, devices and transport devices, situation at the interim store and quantity of fabricated material are monitored.

The first experiment monitors and evaluates situation in the basic simulation model for the shipbuilding workshop. Based on the analysis results, the changes and improvements are

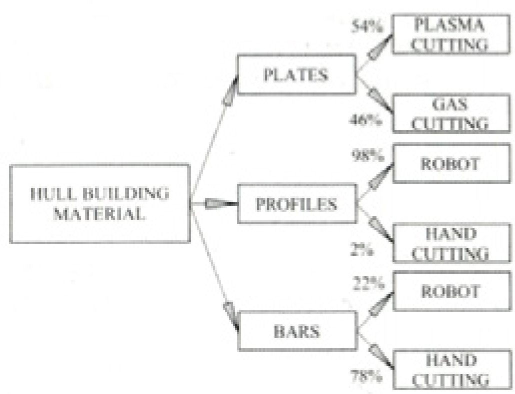

Fig. 4. *Distribution of material according to the working site in the first experiment*

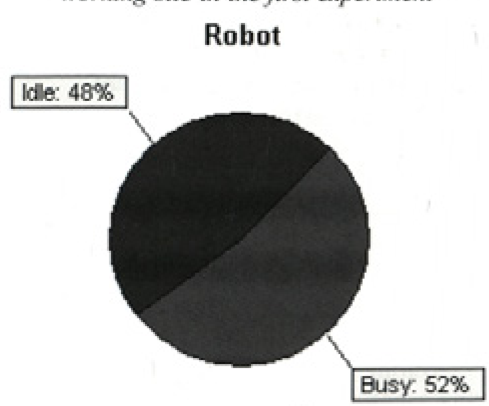

Fig. 5. *Profiles cutting robot status during the first experiment*

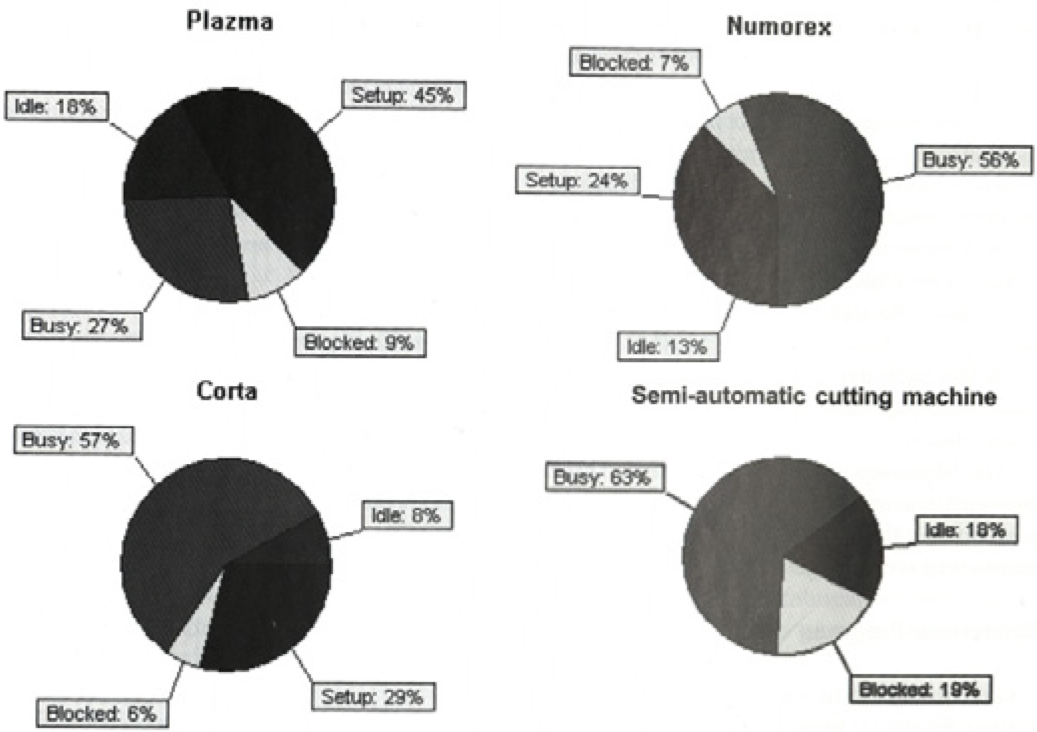

Fig. 6. *Status of cutting machines and plate edge preparation bench during the first experiment*

proposed to be included in the new simulation model.

The second experiment monitors effects of the proposed changes on situation in the nave in which the profiles and plates are cut. The proposed improvements are estimated by comparison of obtained results.

Since an experiment with the simulation model in the program package is running continually and permanently, the experiment duration needs to be limited. The experiment duration is set at 1920 hours, i.e. according to the number of working days and effective working hours, at six months work in a shipyard.

2.4.1 The First Experiment with Model

Figure 4 shows distribution of material according to its fabrication site in the first experiment. Plates are commonly cut by plasma cutting machine because of its cutting speed. Profiles are cut by robot, and bars are usually cut by hand.

During the experiment, profiles and bars cutting robot operation was monitored, and the robot status is presented in Figure 5. The machine was busy 52% and idle 48% of time, and it cuts 8641 profiles and bars. Hence, the machine is not sufficiently busy and it could fabricate an additional quantity of profiles and bars.

In plates cutting workshop (nave 5), all the cutting machines and the bench on which semi-automatic cutting machines are used to prepare the plate edges for welding were monitored. For the experiment, 30% plates were planned to be forwarded after machine cutting to the benches for edge preparation for welding. Number of fabricated plates, profiles and bars are in Table 1. During the experiment, 6403 plates were fabricated at the cutting machines. Figure 6 shows status of machines and bench during the experiment. It is noticed that machines are blocked for quite a long time, which means that the plate is fabricated and waiting for transportation. The transportation in the workshop is done with a bridge crane, which is expected to perform numerous tasks. It is also noticed that in the interim store, near the edge preparation bench, a large quantity of material piles up and that it needs to be released of storage load.

Verification of the simulation model is performed and the model behaves with expectations. Validation of the model is established for 6 months period by comparison of experiments

Table 1. *Number of fabricated plates, profiles and bars in first experiment*

Cutting machine	Plates	Profiles and bars
Robot	-	8641
Plasma	3487	-
Numorex	1807	-
Corta	1109	-
Total	6403	8641
Semi-automatic cutting machine	667	-

results and real number of worked elements. Simulation model expresses real situation in the shipyard workshop very well.

According to the analysis results, the process improvements are proposed which are to be incorporated into the new simulation model and new experiment.

The proposals include:

- Increase in profiles cutting machine efficiency by delivery of a larger quantity of bars for fabrication. In new experiment, the robot is fed with 60% bars compared to 22% from the first experiment.
- Moving the plate edge prepared for welding to one of oxygen cutting machines so that number of plates that go to the edge preparation bench is reduced from 30% to 25%.
- Fitting the plate-cutting workshop with a new bridge crane to share the transportation load with the existing crane.

2.4.2 The Second Experiment with Model

Introduction of changes into the model results in a new scenario of material input into the shipbuilding workshop. New distribution of material according to the working place is shown in Figure 7.

During the experiment, same as in the previous experiment, operation of equipment, devices and transport devices, and quantities of material fabricated in the profiles and plates cutting workshops was monitored.

Figure 8 shows the profiles cutting robot status. The machine was busy 90% of time and it cut 14756 profiles and bars, which is an increase of 38% and 70% respectively compared to the first experiment.

Number of fabricated plates, profiles and bars is given in Table 2. The machines fabricated 7248 plates, which is 13% more compared to the previous experiment. Cutting machines status is shown in Figure 9. Blocked status was reduced by 25%, and efficiency increased because the crane load was reduced and transportation became more efficient.

According to a simulation, suggested improvements result with greater efficiency and performance of the machines in the workshop. Comparison of the data from table 1 and 2 shows that greater quantity of material could be processed on the cutting machines. This is, very important

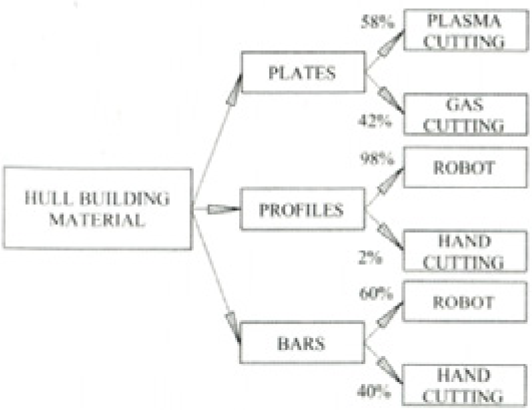

Fig. 7. *Distribution of material according to the working site in the second experiment*

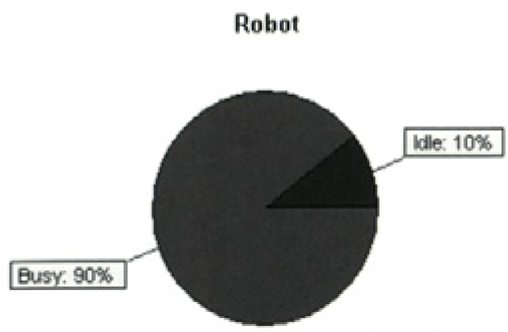

Fig. 8. *Profiles cutting robot status during the second experiment*

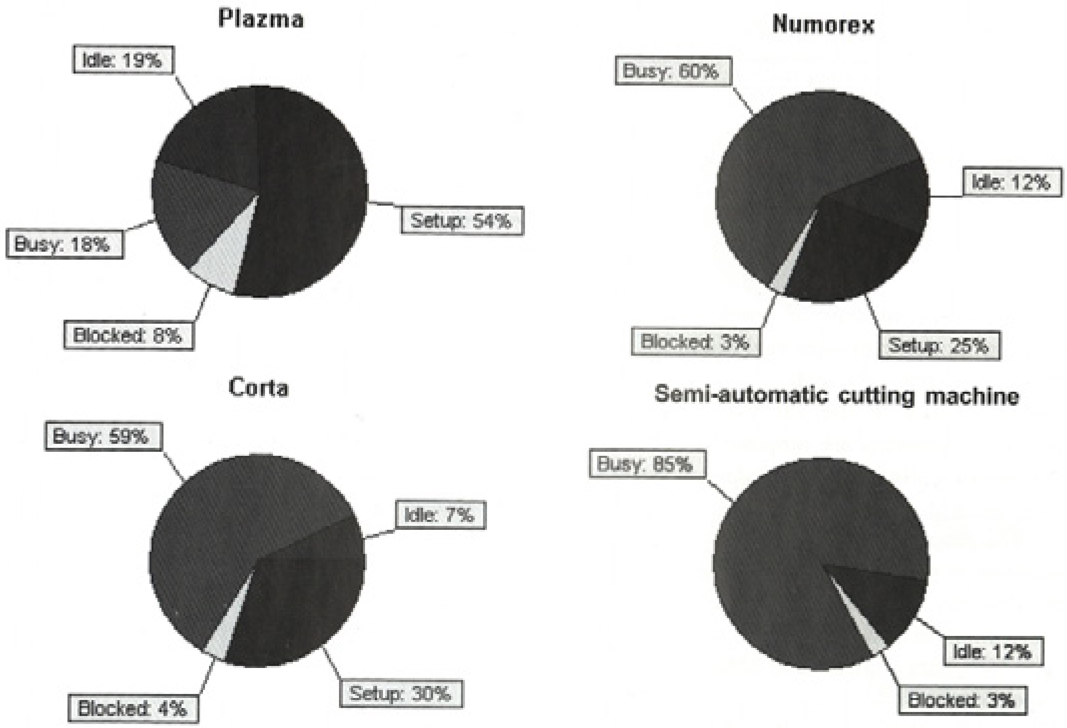

Fig. 9. *Status of cutting machines and plate edge preparation bench during the second experiment*

Table 2. *Number of fabricated plates, profiles and bars in second experiment*

Cutting machine	Plates	Profiles and bars
Robot	-	14756
Plasma	4183	-
Numorex	1923	-
Corta	1142	-
Total	7248	8641
Semi-automatic cutting machine	1638	-

for plasma cutting machine. It could cut about 20% more plates with better transport organization. Improvements influence the quality of the material flows. It is seen that there are not huge quantities of material on work-in-process storage areas, which could cause problems with sorting and control.

The effects of proposed changes in workshops for plates and profiles cutting are positive, so it is necessary to make a technical and economic analysis that would estimate necessary investment and payback period.

3 CONCLUSION

Paper presents the usage of the simulation methods in the shipbuilding production process management. The entire workshop (machines, tools, working areas, transport devices) and products (plates, bars and profiles) was modeled and analyzed by simulation.

Simulation model of the shipyard workshop was verified and validated, ensuring the confidence in suggested improvements of the technological processes.

Experiments with model are used to analyse different technological solutions for a production process, and to anticipate situations in case of investment into new equipment or when alternative production programs are considered which might affect particular stages in the production process. Differently defined experiment scenaria include changes in model parameters, and carrying out of a number of experiments in a short period of time enables a broadly based research, resulting in a database that makes it possible to evaluate status of all the production process stages according to the criteria such as efficiency of equipment and devices, process duration or capacity of interim stores. The analysis conclusions are used for efficient management and decision-making process in a real system.

An advantage of simulation procedure use in production process management is that it enables creation of a realistic model of the production process and final product, and an approximation of situations encountered in a real production system to be used in production process control and management. Complex production processes, such shipbuilding, are too complicated to be resolved by mathematical analysis, and simulation methods have proven better for analysis and understanding of their behaviour. Their application is possible in already defined production processes as well as in those, which are in a design stage.

Application of the state-of-the-art program packages enables a more extensive use of simulation procedures in production process control and management than before. This is certainly due to advancement in computer technology and capacities, primarily in their operation speed and graphic software. Advancement in program packages resulted in their being user-friendlier; the users need not involve in programming, coding and testing of programs. Instead, they may focus on modelling, experiments with model and analysis of results.

An advantage the state-of-the-art program packages have is an option of 2D and 3D visualisation of production process model, which facilitates an experiment monitoring, detection of errors in model creation and pinpointing of interruptions or bottlenecks in the production process.

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