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Simulation of a discrete event system for process control of robotic casting

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Simulation of a discrete event system for process control of robotic casting

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Abstract. The article is focused on the study of the principles of discrete-event control and methods of simulation modeling of automatic control systems of production processes. The capacity expansion and cost-saving require introduction of automation into different standard production processes. The production process of the mid-tech casting of workpieces of different forms is considered a controlled process. It is characterized by the complete and long physical process behavior during processing operations, as well as an overly risky maintenance environment. It is proved that a decline in the human factor influence on the production process causes the reduction of production operation downtime, as well as the decreased amount of waste and rejected products.

1. Introduction

Nowadays, different models of robots including manipulators are used as automated lines in modern enterprises. Such robotic systems with greater mobility and maneuverability are much smaller than most stationary systems. However, when the control system is being set up, the variety of parameters matters for the production process (PP) efficiency of production lines. Various heuristic algorithms related to a combinatorial optimization solver are considered to solve the problem of production PP control and implementation model [1-5]. The presented algorithms are based on the Internet of Things (IoT). This approach is not widely used in the extremes of hyper-focused (highly targeted) production, although it is Industry 4.0-related. Thus, based on the research [1-5] and the objects described with the modes of a discrete-event simulation [6], the article provides a comparative analysis of two production lines, one with the classical solvers and significant human labor input, and another a robotics-based computer-integrated flexible manufacturing system (CIFMS).

The simulation results obtained in the presented research allow for efficiency evaluation of robotics introduction during automation of process lines and production processes in an iron and steel company.

2. Materials and methods

At present, most enterprises focused on mass component production are trying to integrate CIFMS into the production processes. This kind of manufacturing improvements allows for enlarging product variety list, reducing the number of scraps, increasing the production efficiency due to the advantages of the introduced robotic systems [7], a well-managed control system and the decreasing influence of human factor.

A class of mathematical models called queuing systems (service systems) can be used to test the efficiency of functioning of a robotic line [8] and the formalization quality of production process objects operating under extreme conditions in a foundry. The functioning of such complicated systems can be characterized by significant non-linear production processes with many mutually dependent operations, queues and request orders formed by them. Classically, the tasks of planning production processes are solved using some standard approaches. They are characterized by statically defined time intervals for the implementation of a given operation and a required process line shutdown for rebalancing for new products.

3. Research of foundry processes using simulation

Simulink environment of *Matlab* [9] was used to keep track of workers' activities and operations scheduling, workpieces and products, as well as to control a flexible automated production system, a simulation model of the production process of iron and steel founding. The classical algorithm for the sequence control of technological cycles can be represented by the production line model shown in Figure 1. However, it should be noted that *SimEvents* software is used to generate the discrete event part of the model of the system-of-interest [10]. The distribution of requests and workpieces is described based on the modes of queues (waiting lists). The model of the production process of iron and steel founding (PPISF) observes the key technological operations [11] as subsystem units (packages) and is linear, while each product life cycle operation includes the essentials of available principles of physics [12].

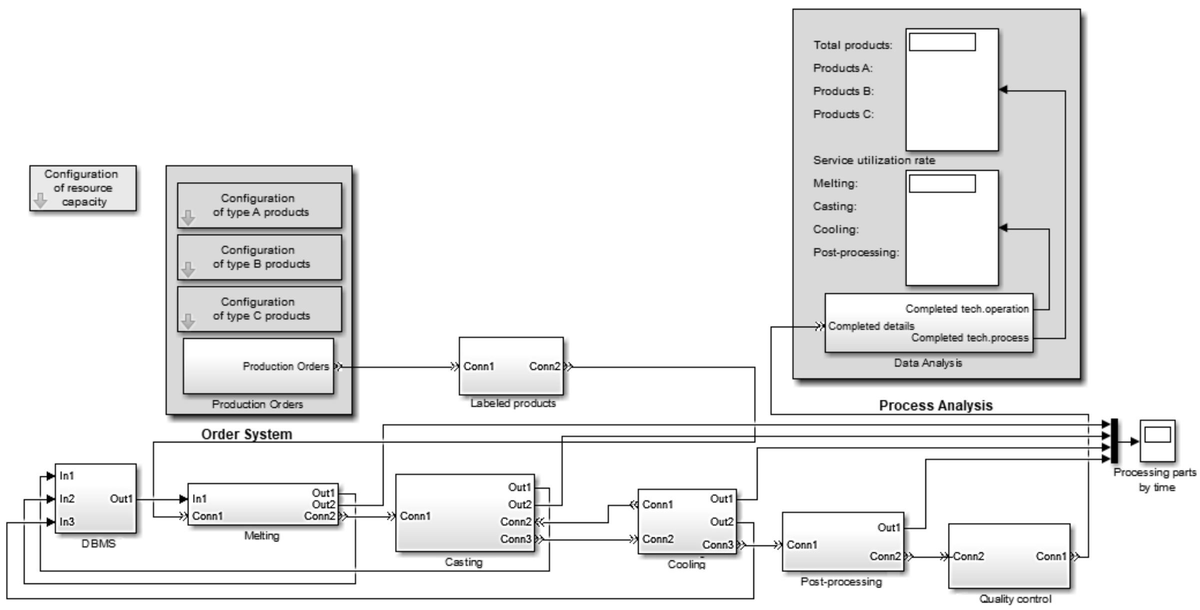

Figure 1. Integrated simulation model of the production process.

The production process modeled in its original condition is based on the integrated simulation model (Figure 1). It does not contain the suggested automation aids. The peculiarity of it is a human element in the loop. Figure 2 shows a simulation model of PPISF, where the human-generated interference is included using the Server unit.

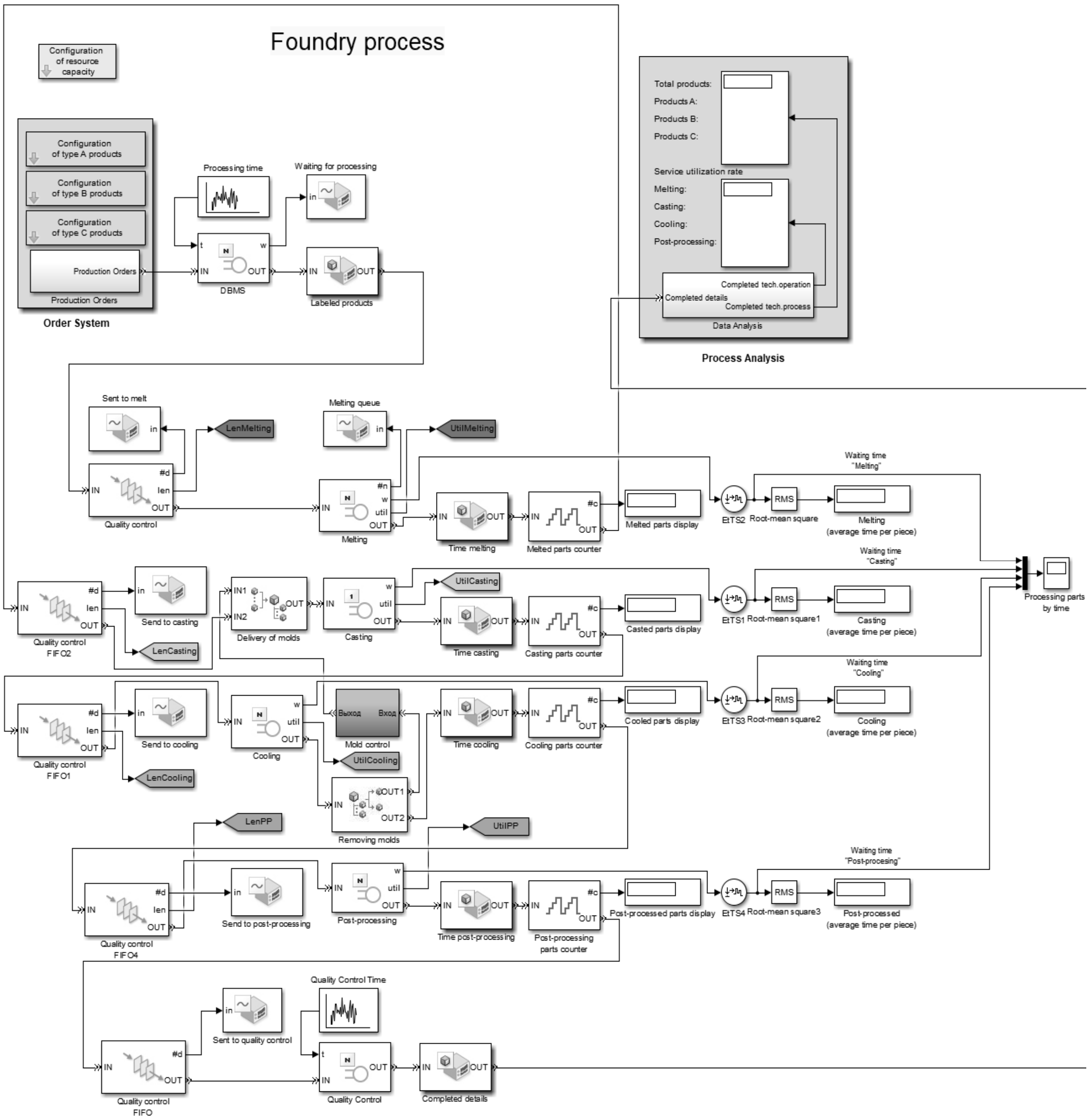

Figure 2. Simulation model of the production process.

A simulation model shown in Figure 3 was developed according to the flowchart of the production process. The operations that had been done in a manual mode were replaced by a robotic station. The multi-loop control system implemented in this model allows the user to control the workpieces at each stage of the product life cycle, based on the time intervals and parameters of each type of product.

The setting signal for the systems shown in Figures 2 and 3 is composed by order processing for each type of manufactured products

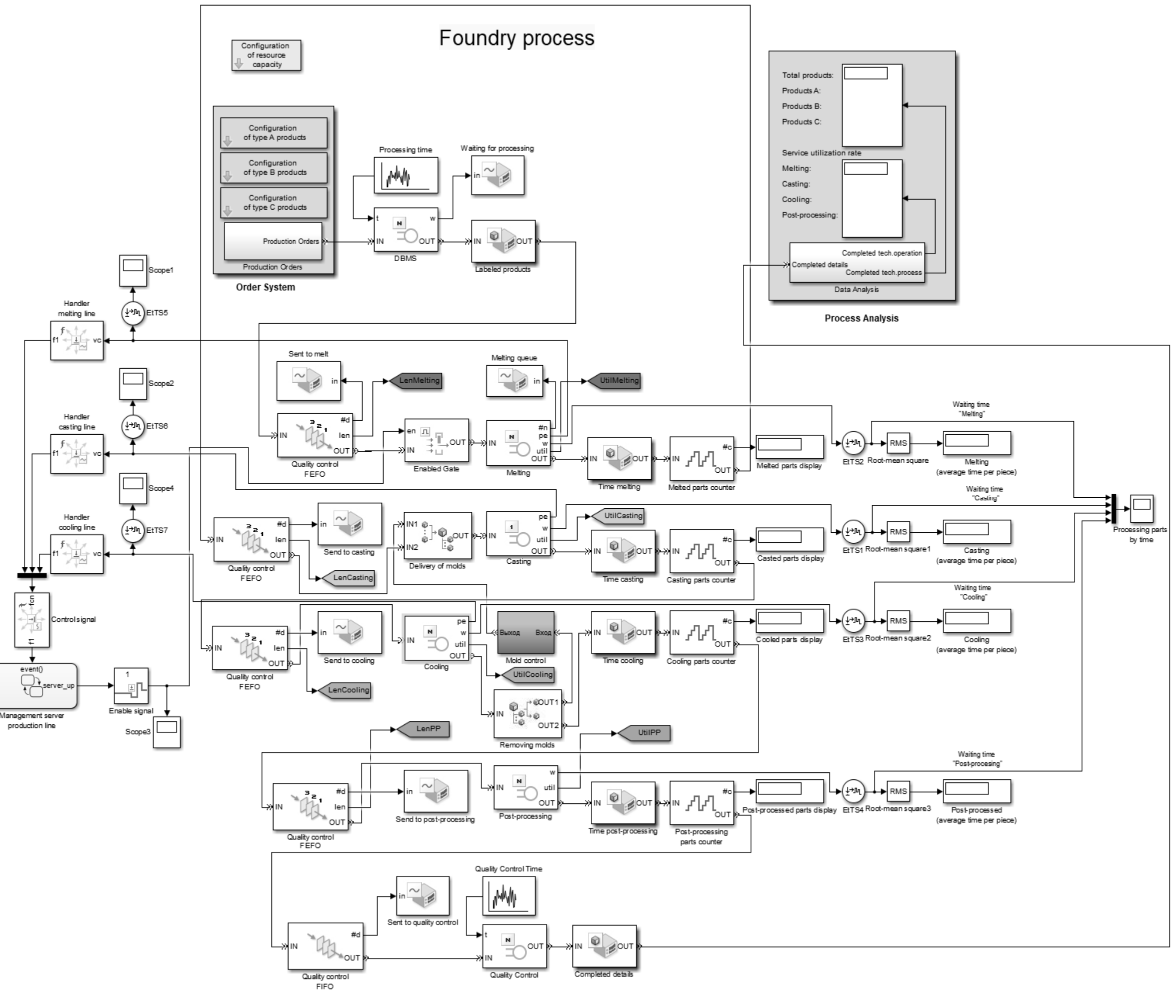

Figure 3. Simulation model of a robotic production process.

The typical process of manufacturing parts [13] in the described PPISF models is regulated for the operations of melting, casting and cooling of the material using a few casting forms. If the condition for the absence of molds in a particular operation is met, the service discontinues the casting.

The output of the data collection subsystem of the above models is graphs illustrating such technological parameters as PP operation workload, the equipment performance in each operation for each type of product. Figures 4 and 5 shows the total transient behavior of the production cycles.

When products received for every process are dynamically controlled, the automated control system [14] allows one to increase the number of parts produced by optimizing the timeout of each service. Figure 5 shows that the established procedure for the production of each set of products has increased and run out at considerably more than the original threshold by one product of each type per unit time.

Analyzing the data presented in the diagrams (Figures 4, 5), the authors can conclude that there is an opportunity to optimize its performance for timing when using the automation aids in the production process [14]. Thus, the significant productivity growth will reduce the production time of each product and, as a result, increase the company' income.

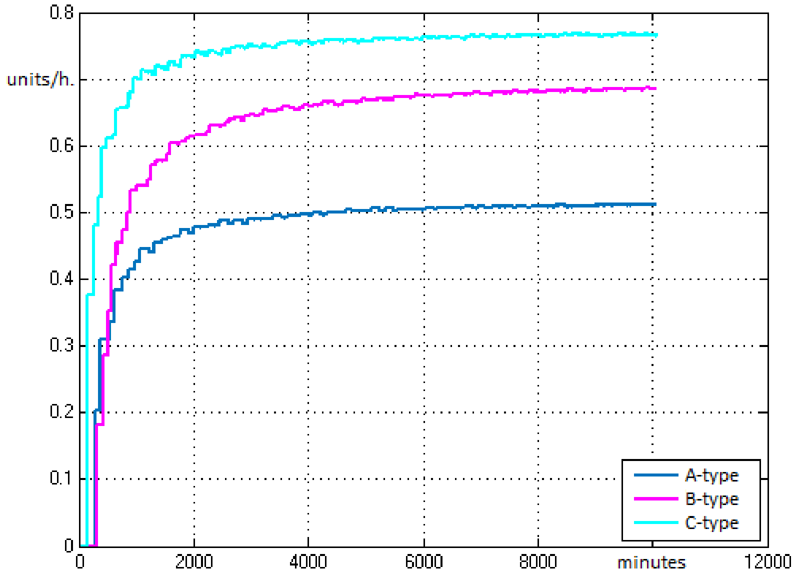

Figure 4. Processing capacity of production item run in a manual mode.

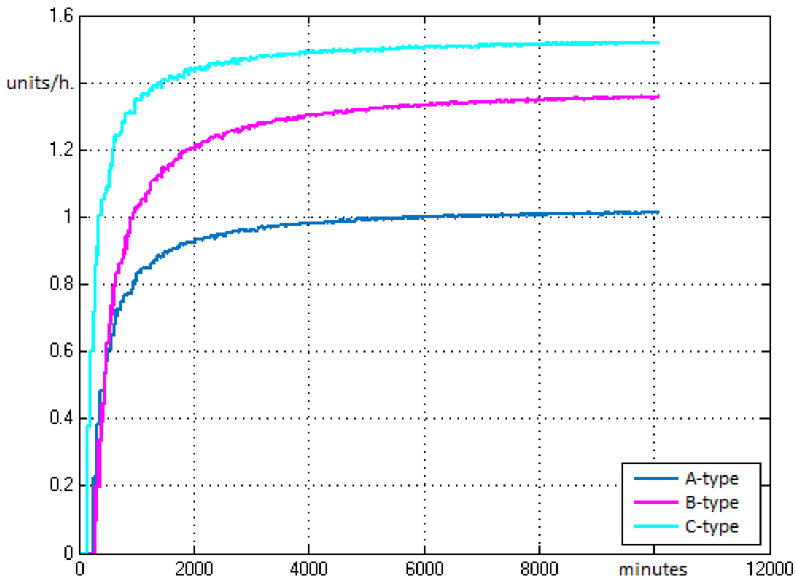

Figure 5. Processing capacity of production item run in the automated production.

4. Conclusion

The findings presented in the mentioned simulation experiment allow the researchers to conclude the following:

- the suggested control system provides productivity enhancement in terms of the number of articles produced by optimizing the production operation time;
- the implemented data collection subsystem analyzes the workload of processes that need optimization;

- the developed and implemented simulation model of the production flow line is a way to improve the technology, which prevents the reasons of errors in the configuration of production processes, improving the technology efficiency as a whole.

Further development of the simulation model will be aimed at improving the control system of the robotic system through intelligent technologies. This will make it possible to modify the processes running in production operations in dynamics by controlling the time intervals.

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