

# Modelling and Optimization of Organization of Workplaces in a Foundry

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## Abstract

The paper presents a practical example of improvement of foundry production systems in terms of post-finishing of nodular iron castings produced in the conditions of bulk production for automotive industry. The attention was paid to high labour-intensive efforts, which are difficult to be subjected to mechanization and automation. The times of actions related to grinding processing of castings in three grinding positions connected with a belt conveyor were estimated with the use of a time study method. A bottleneck as well as limiting factors were specified in a system. A number of improvements were proposed, aimed at improving work organization on the castings post-finishing line. An analysis of work ergonomics at the workplace was made in order to eliminate unnecessary and onerous for the employee actions. A model of production system using the Arena software, on which a simulation experiment was conducted, was drawn up in order to visualize the analysed phenomena. The effects of the project were shown on graphs comparing times, costs, work ergonomics and overall efficiency of production equipment indicator.

**Keywords:** Application of information technology to the foundry industry, Automation and robotics in foundries, Overall equipment effectiveness, Modelling and simulation of production systems, Work ergonomics

## 1. Introduction

Increasing complexity of manufactured castings, processes of their production and rapid technological advances have caused that all founding enterprises aim to develop an effective way of managing founding production. The problem is becoming more relevant in the environment where an enterprise has to make decisions, tailored to the market, more often and faster. An important aspect is to reduce production costs while maintaining quality of produced castings [1,2].

In the analysis and optimization of founding production systems, a computer simulation is used increasingly often. The simulation is one of the methods of visualization and supports management of production systems. Simulation methods are based on creating an experimental model of a system which

is represented in the form of production resources combined with mutual relations. Modelling and simulation of production systems are based on creating a computer model of a real production system on which simulation experiments are carried out. As a result of simulation, the report in the form of statistics, graphs and indicators of using production resources is obtained, under which a program of further action is developed. Development of the programme of the experiment allows to check, in a short time, a number of variants of solutions to improve the existing production system. Simulation tests are also used at planning new workplaces [3,4,5].

A popular approach for the improvement of material flows in enterprises becomes so called "lean manufacturing". Lean Management, Lean Production, Lean Manufacturing are the notions which become about restructuring of production processes towards their simplification, slimming by combining

and reducing functions and resources, minimizing inventories and delegating tasks by managerial units to teams of employees dealing directly with manufacturing processes. A free explanation of the word "to lean" is "to slim down", i.e. introducing major changes in the business in relation to ways of organization and management, assets structure as well as in the scope of vocational training and shaping employees' attitudes [6,7,8].

KAIZEN is a Japanese system of production rationalization oriented to continuous improvement of processes and removal of waste. KAIZEN is committed to continuous improvement of processes in an enterprise through small improvements that are made by all the employees [9].

One of the indicators for assessing effectiveness of resources of an enterprise is OEE (Overall Equipment Effectiveness). The overall equipment effectiveness indicator is a tool for determining the level of implementation of objectives in line with the TPM concept. The OEE is the result of three other sub-indicators: availability, performance, and quality. The availability is defined as the percentage of time in which a machine is used in the production process, that is, time of real use of the device in relation to planned time of its operation in the production process. The performance is the quantity determining production capacity of a machine at a nominal speed of the manufacturing process. The quality is defined as the percentage of time during which the machine produces products of adequate quality in the manufacturing process. Losses of quality include, among others, castings which require re-treatment as well as castings returning to a warehouse of input materials [10,11].

Formerly, taking into account evaluation of functioning of work systems, an important aspect was primarily productivity of employees. Over the years this approach has changed. Improving the quality of manufactured products began to be considered, and then the focus on working conditions of workplaces in terms of safety, hygiene and ergonomics of work was improved [12,13,14]. Improving working conditions allows to reduce actions without added value, operations that are difficult and dangerous for an employee, which often has an influence on time, costs and quality of implemented processes, also in the foundry industry.

## 2. Subject, aim and methodology of research

The subject of the research in the work is a post-finishing line of a selected group of castings for automotive industry. The aim is optimization of work organization and improvement of performance on the analysed position.

The post-finishing line of castings (Fig. 1) consists of three processing stations (grinding machines) and a belt conveyor. The line is operated by three employees. The castings for post-finishing are delivered in containers transported with forklifts. After post-finishing on the line, the castings are handed over to a one-hundred quality control.

The project of work rationalization has been carried out as shown in Figure 2. First, the time of individual actions with the use of time study method was assessed based on 100 measurements carried out for various employees and on various

shifts. Further, a simulation model of post-finishing line was made, on which a simulation experiment was conducted (Fig. 3).

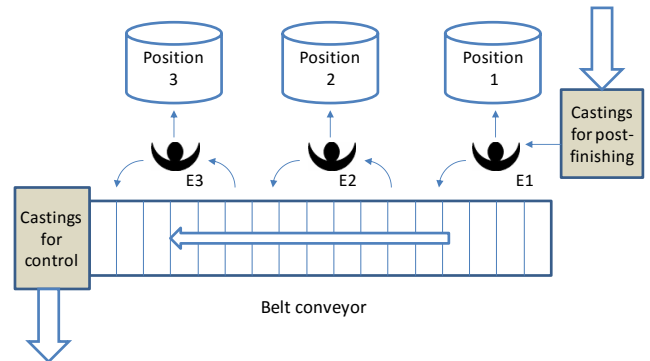


Fig. 1. A diagram of grinding line for iron castings

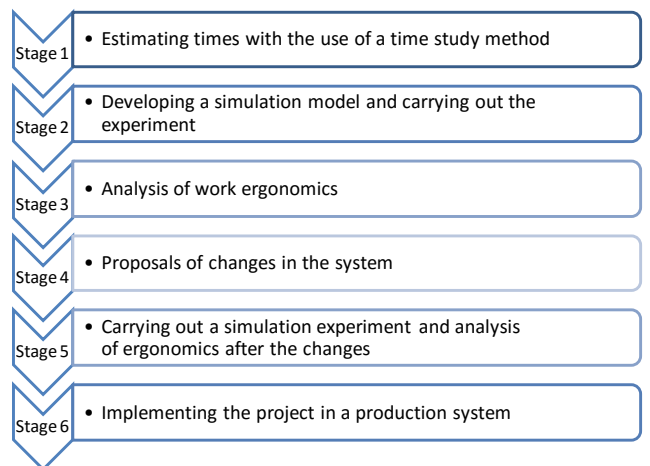


Fig. 2. Project implementation stages

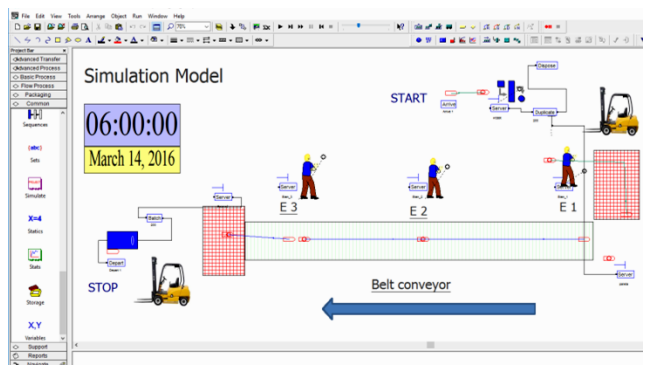


Fig. 3. A model of manufacturing system in the Arena programme

Based on observation of current status as well as on the results of simulation experiment, the following factors limiting manufacturing capacities on this post were indicated:

- problems with work ergonomics on the positions,
- longer time of collecting a casting to post-finishing, including the necessity of raising it from a deep container positioned on the floor.

- limiting continuity of production related to waiting time for a new container with castings delivered with forklifts.

The ergonomics analysis was carried out for a bottleneck. In accordance with the assumptions of the World Class Manufacturing, described in the author's earlier works [15, 16], the assessment of individual ergonomic situation in a three-point scale was carried out.

A number of improvements were suggested, and their impact on functioning of the production system was checked on a computer simulation model. The assessment of ergonomics was carried out once more and compared with a base model. The results of the project were implemented in a real system.

### 3. Description of the results obtained

In the framework of the follow-up of previous conditions on the post-finishing line, the average times of implementation of individual actions were determined with the use of a time study method, and summarized in Table 1.

Table 1. Average times of actions determined with a time study method

	Collecting a casting (s)		Post-finishing of a casting (s)		Handing over a casting (s)		Total time (s)	
	average value	standard deviation	average value	standard deviation	average value	standard deviation	average value	standard deviation
Position 1	5,98	0,39	4,34	0,27	2,82	0,26	13,14	0,55
Position 2	3,16	0,31	4,45	0,24	2,8	0,25	10,41	0,47
Position 3	3,12	0,30	4,51	0,23	2,84	0,27	10,47	0,38

After carrying out the simulation experiment and work ergonomics analysis, a few improvements were suggested. To eliminate the need of bending down an employee while collecting castings on position No. 1 a table was introduced, where a container with elements for post-finishing was placed. Furthermore, the table was designed in such a way that a container is directed towards an employee, which minimizes a distance between objects to be post-finished and an employee. In addition, a work organization change on position No. 1 included also positioning a table with a table grinding machine, and hence a change of employee's position in relation to a belt conveyor. The organization of post-finished position No. 1 after introducing the changes was presented in Figure 4.

Thanks to the implemented changes, the time of manipulating castings on the first position was significantly reduced, which was previously a bottleneck in a system (Fig. 5).

Based on the ergonomics analysis, the position was reconstructed in such a way that apart from reducing times of execution of individual actions, the movements in the third zone were eliminated, and part of actions were transferred from the second zone to the first one (Fig. 6). By eliminating movements that were uncomfortable and onerous for the employees, comfort and safety of work were improved, which should result in a quality of performed actions.

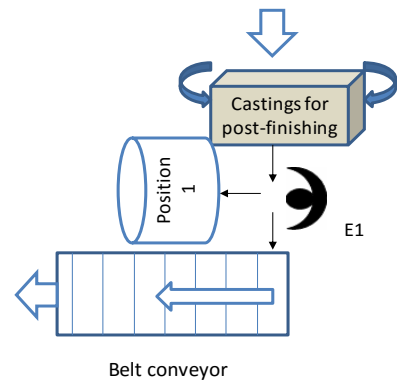


Fig. 4. Organization of position No. 1 after introducing the changes

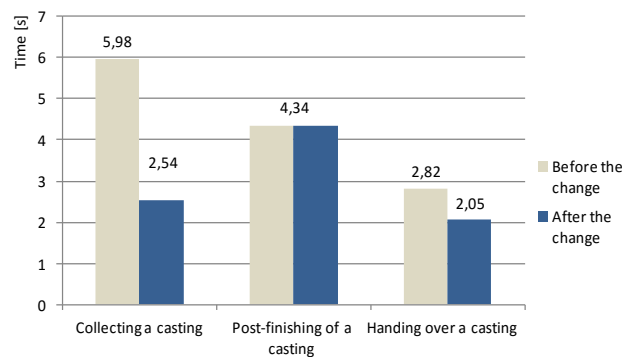


Fig. 5. Times of actions implemented on position No. 1 before and after the change

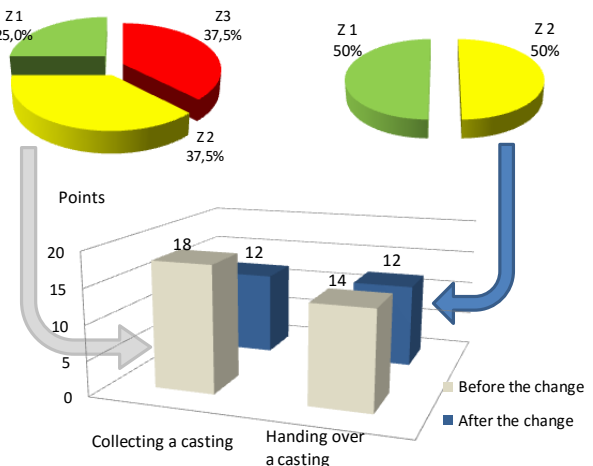


Fig. 6. Comparison of the results of the ergonomic analysis

In order to visualize the proposed solutions, the simulation model was modified and the experiment was conducted again.

Thanks to the implemented changes, a loss arising from waiting time for providing elements for treatment of a post-finishing line was also minimized.

A significant number of actions without the added value was eliminated. Thanks to these actions, a portion of time of post-

finishing of castings during the shift increased, which also has an influence on direct labour costs. Savings resulting from a reduction of direct labour costs were estimated, which declined by approximately 32% for the analysed post-finishing line and the selected group of castings.

To sum up the effects of implementing the project, the OEE indicator and its components were used, as shown in Figure 7.

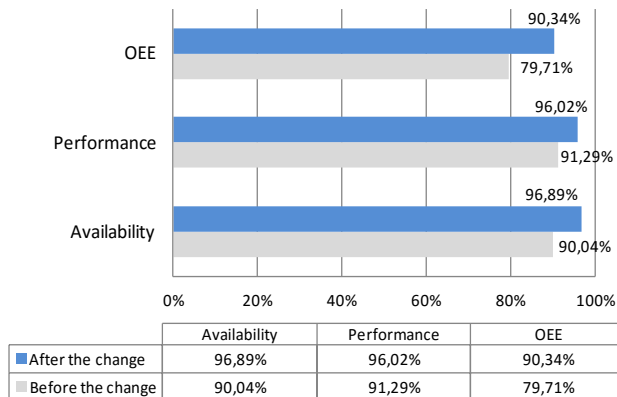


Fig. 7. Overall Equipment Effectiveness for a grinding line for iron castings

## 4. Conclusions

The best way for continuous improvement of production systems in foundries is involving all the employees of an enterprise in a continuous enhancement of the conditions and the methods of work. A programme of minor changes, introduced gradually, might cause a significant improvement of effectiveness of foundry production.

In case of serial and bulk production for automotive industry, one should produce castings in a way in which they meet the requirements of customers, they are produced in a specified number and exactly on time. All signs of wastage resulting from poor organization of production, emerging disruptions in implementation of processes, or quality errors should be eliminated.

The use of simulation techniques in case of foundry production systems may be an effective tool in optimizing of organization of post-finishing of castings. An important aspect in terms of foundry production is also attention to ergonomics

and safety of work, and improvement of working conditions often results in a higher quality of castings and better work culture.

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