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Improving Quality and Occupational Safety on Automated Casting Lines

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Abstract

The paper presents a practical example of improving quality and occupational safety on automated casting lines. Working conditions on the line of box moulding with horizontal mould split were analysed due to low degree of automation at the stage of cores or filters installation as well as spheroidizing mortar dosing. A simulation analysis was carried out, which was related to the grounds of introducing an automatic mortar dispenser to the mould. To carry out the research, a simulation model of a line in universal Arena software for modelling and simulation of manufacturing systems by Rockwell Software Inc. was created. A simulation experiment was carried out on a model in order to determine basic parameters of the working system. Organization and working conditions in other sections of the line were also analysed, paying particular attention to quality, ergonomics and occupational safety. Ergonomics analysis was carried out on manual cores installation workplace and filters installation workplace, and changes to these workplaces were suggested in order to eliminate actions being unnecessary and onerous for employees.

Keywords: Quality management, Automation and robotics in a foundry, Application of information technology to the foundry industry, Modelling and simulation of production systems, Work ergonomics

1. Introduction

In the era of continuous innovation and constantly developing management techniques, it is of very high importance to use modern methods and tools thanks to which managing an enterprise brings better results and coordinates work of the whole organization.

The issues related to standardisation of work have recently become a subject of interest in the context of lean manufacturing and world class manufacturing.

Standardization of work is defined as a practice of setting, communicating, respecting and improving methods of implementation of production tasks. An important objective of standardization i to increase the added value offered to customers by eliminating or reducing different types of waste and imperfection of processes.

In case of lean manufacturing approach an important role is played by adding value, it means performing such actions and activities in an enterprise for which a customer is willing to pay. Other actions and activities should be called waste. The main sources of waste include the following: overproduction, excessive inventory, correcting errors and repair of deficiencies, unnecessary treatment, unnecessary circulation, employees experiencing excessive workload, expectation and unused employees' creativity potential. Elimination of activities being waste is a huge possible source of improving performance of an enterprise and improvement of customer service, also in the foundry industry. On the basis of principle of added value, the following breakdown of activities carried out at a workplace can be made:

- Value Added Activities (VAA) - it is a minimum value of activities aiming at manufacturing casting that is in line with a designed process in terms of quality,
- Semi Value Added Activities (SVAA) are such activities as taking and setting elements, as well as necessary controlling,
- Non-Value Added Activities (NVAA) are such activities as walking, transport, waiting, repairing castings, excessive control, production of deficiencies, etc.

Standardization of the concept of lean manufacturing is an important way to fight imperfections, especially in case of manufacturing processes where, for a number of reasons, full automation is not possible or not recommended.

Standardization is not only rules and procedures of conduct to enable the employee safe, effective and efficient realization of manufacturing tasks, but it is also determining the required resources. Standardization of work is related to setting working time standards, staffing standards, number of necessary machines, normative level of inventories of work in progress in order to ensure quality as well as continuity and repeatability in implementation of processes.

Implementation of lean manufacturing is based on five basic principles:

- precise defining of added value from the point of view of a customer,
- arranging all value added activities along so called value stream,
- establishing continuous flow of value through the stream,
- applying the pull system which causes that the value stream responds to current customer's needs,
- implementation of principles of continuous improvement.

One of the methods used in lean manufacturing is the Kaizen method that means continuous improvement. The method assumes an increase of efficiency using low-cost improvements in manufacturing processes and material flows. Kaizen is directed at pursuing the objective with small steps through continuous changes and improvements [1-6].

2. Subject, aim and methodology of research

The object of research in the study is an automated casting line with horizontal mould split. Iron castings are produced on the line on the basis of a three shift rotation pattern for the needs of the automotive industry. The analysis covers a part of the line with low mechanization and automation, where unnecessary and monotonous actions are carried out manually by the operators of this part of the casting line.

The aim of the study is rationalization of work organization and occupational safety, quality of work and repeatability of implemented processes, as well as performance on the analysed workplace.

For visualization of the analysed problem, a technique of modelling and simulation has been used (Figure 1). It is a technique that can be easily used in the foundry industry [7, 8, 9]. Various variants of solutions of functioning of the systems of work can be checked using a computer model. Furthermore, it is possible to evaluate their performance, costs and analyse the possibility of interference without the need to experiment in the production environment [10, 11].

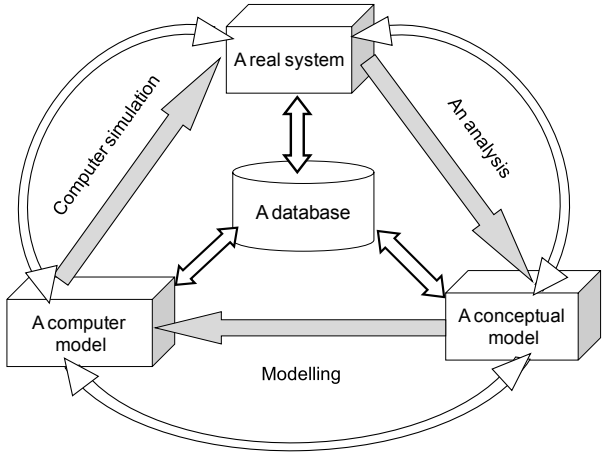

Fig. 1. The use of modelling and simulation in the analysis of foundry production systems [12]

On the basis of a real system, with special attention to efforts made during formation of the lower mould, a line simulation model has been created. The boundaries of the system, production resources and interconnectedness among them have been defined. Using technological data and information of work analysis section, a simulation experiment has been carried out in order to verify the correctness of the model and approve it for further research.

A diagram showing a fragment of the casting line before changes is shown in Figure 2. Rationalization concerned the workplace of manual cores installation, the workplace of manual dosing of modifier and the workplace of filters installation.

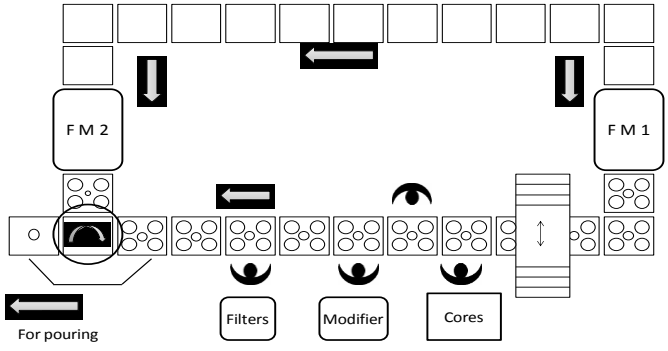

Fig. 2. A fragment of automated casting line before changes

All research was carried out in accordance with the diagram shown in Figure 3. Due to large concentration of monotonous actions and actions uncomfortable for the employees, the analysis of ergonomics of work on a selected workplace was carried out. Description of the results obtained and implemented in a real system has been presented in the subsequent section of the article.

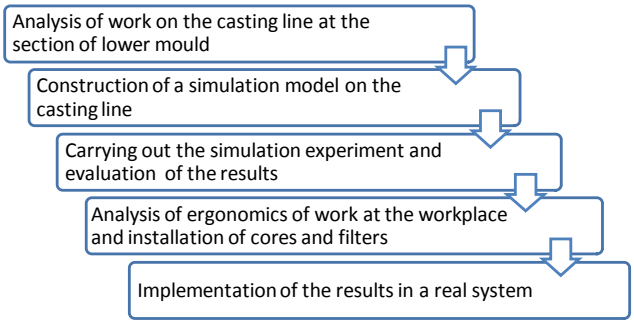

Fig. 3. Project implementation stages

3. A description of the results obtained

In the framework of observation of existing working conditions on automated casting line and due to a large number of castings made of nodular iron through spheroidization, introducing of an automated dispenser of modifying mortar in the mould has been suggested (Fig. 4). Until now, the mortar had been poured manually by an operator with the use of a container with specified volume, which was the source of many errors and led to high labour costs. The use of the dispenser will help to reduce staffing of the line and dosing equal portions of the mortar.

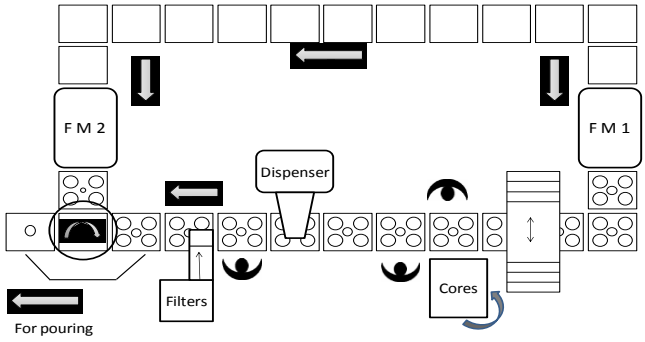

Fig. 4. A fragment of automated casting line after changes

A simulation model of the line, on which the effects of implementation of the suggested solution were analysed, has been created in the Arena software (Fig. 5). Employees' workload was checked and return on investment period was estimated, considering several scenarios related to scheduling of manufacturing on the analysed casting line. An Excel worksheet with cost analysis has been prepared on the basis of reports from simulation in line with a detailed additional calculation, comparing direct labour costs and station costs, taking into account depreciation costs, imputed interest costs, maintenance costs and energy carriers costs. Comparing costs calculation for a variant without a dispenser and with a dispenser, a point in which the costs will become equal to the investment was indicated, where the investment will bring savings of the order of PLN 241/day.

As a result of the analyses, it has been determined that the investment would be returned after 8 months and 7 days. An additional advantage of this solution is the improvement of safety at work by eliminating one monotonous, non-ergonomic and non-automated work stand in whole, and at the same time increasing the space in the area of blowing-down the surface of dividing the form with compressed air and cores installation, which the operators of this area complained about and reported the proposals of changes within Kaizen.

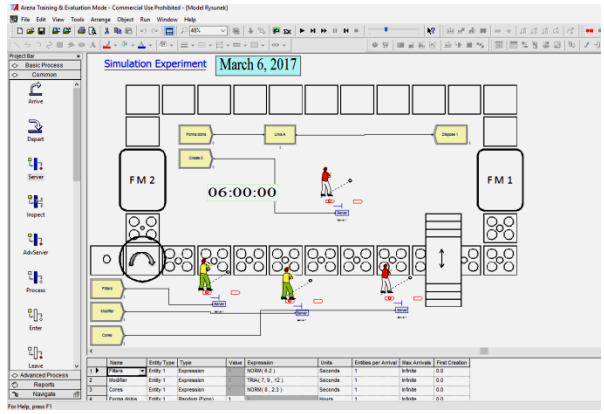

Fig. 5. A model of a casting line in the Arena software

While observing and analysing the work on the workplace of manual cores and filters installation, having regard to the opinions of employees operating these workplaces, the assessment of ergonomics was carried out in line with the rules indicated, among others, in the following works [13, 14, 15]. The research of ergonomics indicated the actions that are unnecessary and do not add value to the castings produced, as well as uncomfortable and onerous for the employees.

Difficult or unnatural actions, which generate onerousness and may cause the risk of an accident, and reduce productivity of work, should be analysed and eliminated.

To eliminate unnecessary movements and improve working conditions on the workplace of manual cores and filters installation, some improvements have been suggested. Using free space left after elimination of the workplace of dosing of mortar for spheroidization, the layout of the workplace of cores installation has been changed. A palette with cores was arranged on the right side of an employee on the adjustable platform (Fig. 6), which allowed to eliminate some unnecessary and uncomfortable actions.

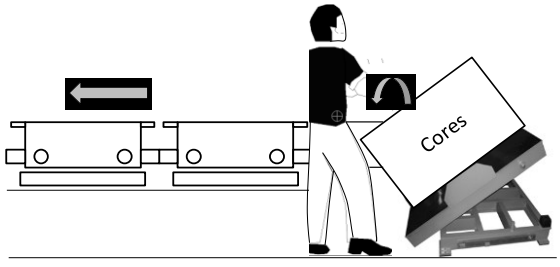

Fig. 6. Reorganization of the workplace of manual cores installation

Furthermore, to improve the working conditions on the workplace of installation of filters, an additional table (boom) with adjustable height and position towards the line was applied. The operator puts small cartons with filters taken from a pallet on it. Thanks to such a modification, each employee may adjust the working space and does not have to rotate by 180^0 to take further filters directly from the palette.

Thanks to actions undertaken, a significant part of actions without added value and uncomfortable actions has been eliminated. Upon the changes made, another evaluation of ergonomics of work was carried out. Precision of movements, bending angle and rotation in a belt, height of arms, bending and straightening angle of knees, rotation of wrists, working area and transport related activities have been assessed. The results of the ergonomic analysis before and after changes has been presented in Figure 7. It was possible to eliminate all activities from the red zone and improve the point-by-point assessment by 3 points at the stand of cores installation, and even by 4 points at the stand of filters installation.

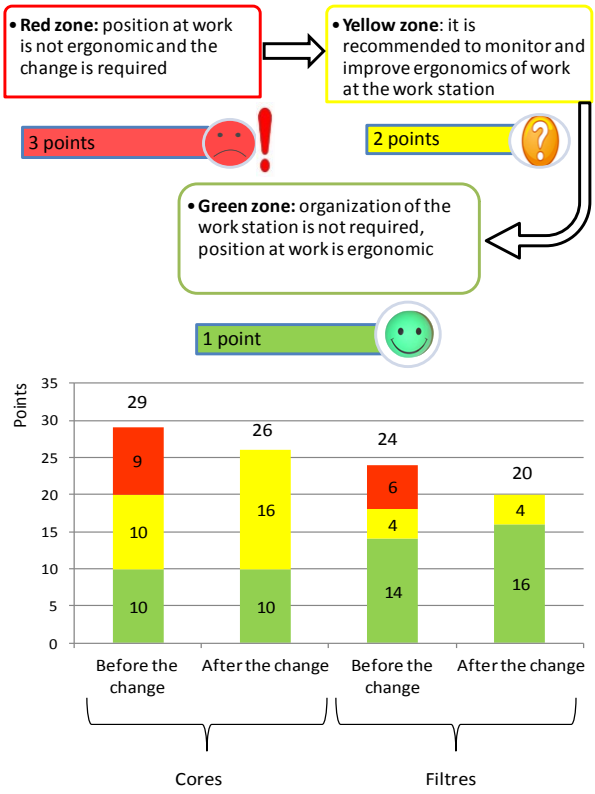

Fig. 7. Comparison of the results of the ergonomic analysis

4. Conclusions

Positive effects in the scope of continuous improvement of production systems in foundries bring the involvement of all employees in continuous improvement of working conditions and quality of processes implemented. Often, small changes of low-cost effectiveness, however, gradually introduced, contribute to a significant improvement in the efficiency of production in the foundry.

Implementation of the principles of lean manufacturing allowed to shorten the production time. Cycle time of the line has not been changed but the number of micro stopovers has decreased by 21%. Furthermore, better quality castings have been achieved thanks to repetition of modifier dosage into the mould. The Overall Equipment Effectiveness indicator has been improved for the analysed line from 90.7% to 91.8%.

Due to difficult working conditions, an important aspect of foundry production is attention to ergonomics and safety of work. Better working conditions are reflected not only in comfort and safety of manufacturing tasks, but also in higher quality of castings and higher culture of processes implemented.

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