



ARCHIVES of FOUNDRY ENGINEERING

DOI: 10.1515/afe-2016-0019

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences



ISSN (2299-2944)
Volume 16
Issue 2/2016

17 – 20

Quality and Safety Assurance of Iron Casts and Manufacturing Processes

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Received 17.03.2016; accepted in revised form 15.04.2016

Abstract

The scope of this work focuses on the aspects of quality and safety assurance of the iron cast manufacturing processes. Special attention was given to the processes of quality control and after-machining of iron casts manufactured on automatic foundry lines. Due to low level of automation and huge work intensity at this stage of the process, a model area was established which underwent reorganization in accordance with the assumptions of the World Class Manufacturing (WCM). An analysis of work intensity was carried out and the costs were divided in order to identify operations with no value added, particularly at individual manufacturing departments. Also an analysis of ergonomics at work stations was carried out to eliminate activities that are uncomfortable and dangerous to the workers' health. Several solutions were proposed in terms of rationalization of work organization at iron cast after-machining work stations. The proposed solutions were assessed with the use of multi-criteria assessment tools and then the best variant was selected based on the assumed optimization criteria. The summary of the obtained results reflects benefits from implementation of the proposed solutions.

Keywords: Quality Management, Automation and Robotics in Foundry, Transport Systems in Foundry, Workplace Organization, Ergonomics of Work

1. Introduction

Foundry companies facing high costs of work under difficult and dangerous conditions, low liquidity and increasingly saturated outlet, can no longer seek solution in lowering their own costs of production by reducing staff.

Manufacturing oriented to elimination of waste and continuous improvement of manufacturing systems has become increasingly attractive also as it comes to the foundry industry. The Lean Manufacturing concept is aimed at eliminating all activities with no value added to the product. It is a philosophy of skillful and economic management of resources. The term "lean manufacturing" indicates a right path and supports actions related to introduction of changes to organization of manufacturing processes [1,2]. The genesis of this concept

derives from a manufacturing method applied for the first time at Japanese Toyota and it is connected with the kaizen philosophy [3,4]. Kaizen means a continuous improvement of working practices and personal efficiency [5]. Through continuous improvement of manufacturing systems, it is not only the productivity that is increasing, but also the efficiency and quality of work as well as the quality of manufactured products. The lean manufacturing concept creates potential to use less human effort and equipment, spend less time and space and, at the same time, move closer to fulfillment of the assumed goal which is providing a client precisely with what they are expecting. Application of this concept allows for faster manufacturing and achieving higher quality at lower costs in relation to the traditional approach [6,7,8].

An important issue regarding the subject approach is providing employees with constant place for improvement

and acting in a manner that would develop their sense of responsibility for entrusted tasks and efficient functioning of the company [9].

2. Subject, objective and methodology of research

The subject of the research in the working environment is manufacturing of iron casts which, after acceptance from the foundry line, undergo after-machining and 100% quality control [10]. The objective of the research is to reduce work intensity, improve quality of iron cast manufacturing and improve conditions of work at selected manufacturing work stations.

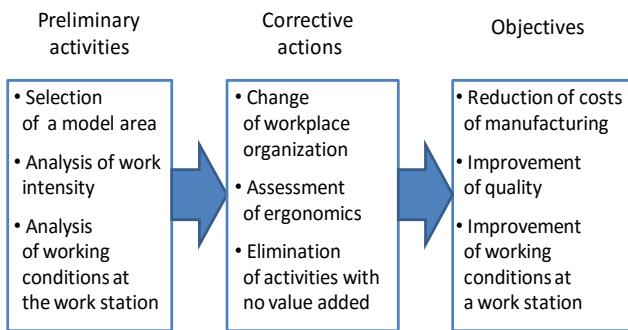


Fig. 1. The concept of research

The project was initiated by appointing a working group and establishing a model research area. The iron casts manufactured in one year were divided into three groups, according to the intensity of work:

- group A in which approx. 20% of elements represent approx. 80% of the accumulated work intensity rate,
- group B in which approx. 30% of iron casts represent approx. 10% of the accumulated work intensity rate,
- group C in which approx. 50% of elements constitute 10% of the accumulated work intensity rate.

On the basis of the analysis, a representative with the highest work intensity was selected from group A. Further on, the work intensity was divided into individual foundry departments and technological operations (fig. 2).

The analysis of work intensity was carried out, according to departments: melting plant, foundry molding plant and after-machining department (fig. 3). The research showed that from the point of view of the work intensity, the greatest rationalization effects can be obtained by improving after-machining processes for the previously-selected group of iron casts. Further actions were focused on optimization of processes, such as: grinding, milling, USG control and acoustic tests. In further considerations the aspect of iron cast cleaning was omitted, since this operation is performed at the foundry line and it was subject to modifications as part of the previous project.

In order to rationalize the iron cast after-machining processes, a team called Workplace Organization was appointed and its aim was to create an optimal work station that would create the condition for obtaining the best quality, maximum safety and

maximum added value (fig. 3). The team supervised by its leader concentrated on division of costs into individual activities and identification of losses measured in pieces, money and wasted working hours [11].

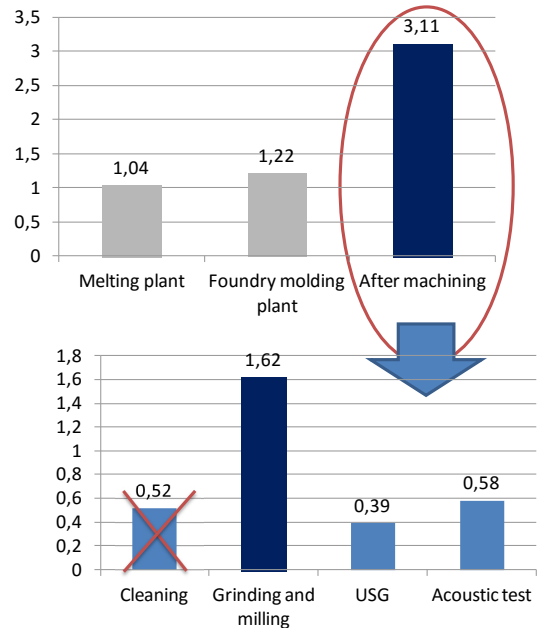


Fig. 2. Work intensity of a selected group of iron casts

The process of improvement of the working conditions at the work station was started from returning order and cleanliness in the work zone, training the employees, analyzing and minimizing distances traveled by the casts during the manufacturing process and establishing delivery terms and conditions.

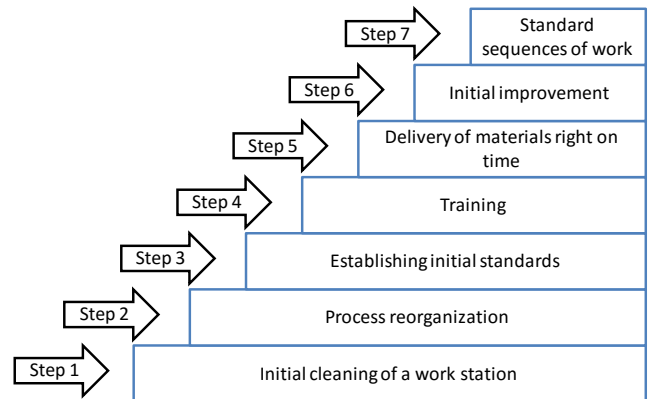


Fig. 3. Seven stages of workplace organization

The aim was to create a work station standard that would guarantee safety and convenience for the employees, improve quality of performed operations and increase efficiency of a work station.

Currently, both the after-machining of iron casts and the quality control are performed in two manufacturing halls. Due to

high level of noise, the control acoustic test must be conducted outside the main hall. The main manufacturing room holds space for operations such as: grinding, milling, USG tests and molding in different parts of after-machining department.

Several variants of after-machining reorganization were proposed, which then underwent multi-criteria assessment in accordance with the Yager method, comparing them with the current condition. The assumed criteria of assessment are as follow:

- work intensity of the after-machining processes,
- distance traveled by iron casts,
- work ergonomics at the work station.

Weights of individual criteria of assessment were set by selected members of the workplace organization team, based on the collective Saaty matrix and power method of determining characteristic vector (fig. 4).

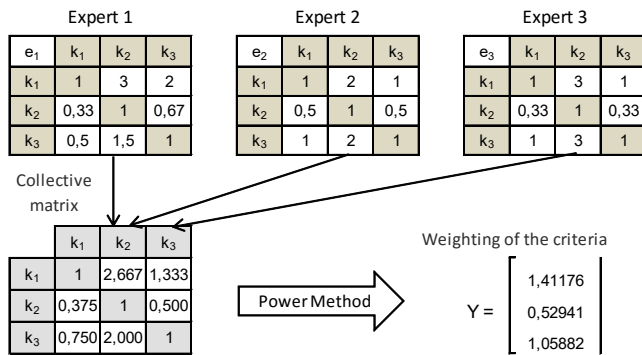


Fig. 4 Saaty matrix

The assessment of work ergonomics was carried out in accordance with a three-step point scale (fig. 5), dividing the operations into elementary activities [12].

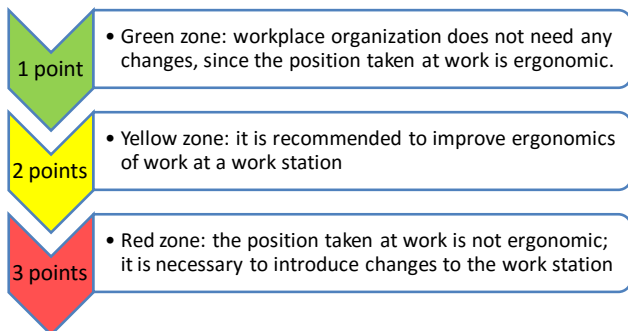


Fig. 5 Points of activities at a work station in accordance with the ergonomics

3. Description of obtained results

Three new solutions were proposed in terms of process organization of after-machining of iron casts, which then were compared with the current condition. As part of improvement activities, there was an attempt to reorganize the process accumulating all operations performed at the main hall in one

work center. Furthermore, it was planned to provide variant V3 and V4 with a sound-insulated cabin and to apply the acoustic test also at the main manufacturing hall. In all three new variants the work stations were connected by means of a belt conveyor to minimize costs of inter-station transport. It was also proposed to introduce improvements related to providing pallets from the after-machining line, accepting machined casts and handing them over to the storage. At designing the work station, particular attention was given to elimination of elementary activities which do not add any value to the manufactured products.

Based on the design documentation of manufacturing halls, with the use of AutoCAD assessments were made in terms of distances that are traveled by iron casts as part of the after-machining processes.

Ergonomics of work was assessed at selected work stations and the final outcome for individual stages was shown in fig. 6.

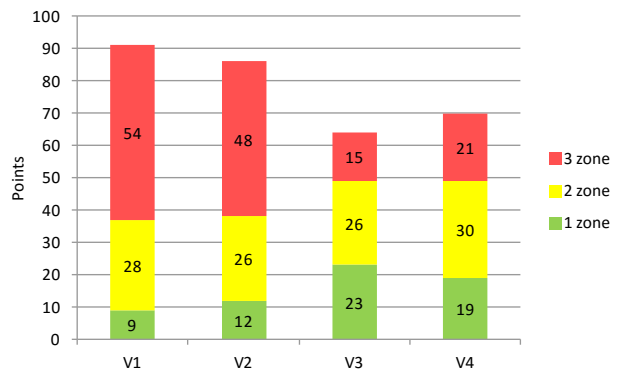


Fig. 6 Work ergonomics at the work station

Further on, work intensity of operations was estimated and compared to the results of measurements taken prior to the changes.

Taking into consideration the weights of individual criteria, a multi-criteria assessment of variants was carried out in accordance with the Yager method. Table in fig.7 presents total notes standardized for individual change proposals compared to the current condition.

$$d_j = \sum_{j=1}^m c_{ij}^{y_j} / a_i$$

	variants			

Fig. 7 Total notes standardized for the variants

As a result of proceedings described in the previous works of the author [13,14], it was decided on the best variant of the

after-machining organization out of the checked options. It turned out that the best solution was the variant marked as V4 (fig. 8).

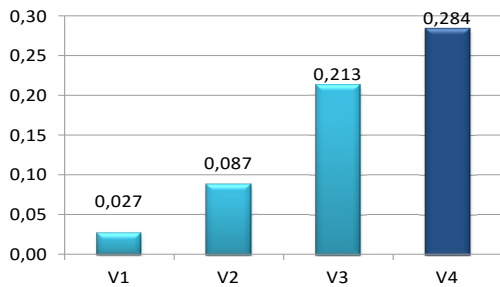


Fig. 8 Results of multi-criteria assessment of the variants

The diagram of the after-machining work center designed in accordance with the assumptions of variant No. 4 is shown in fig. 9.

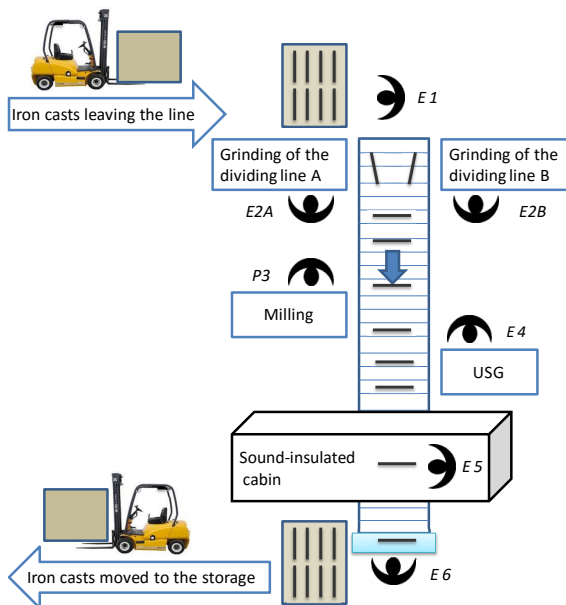


Fig. 9 Diagram of a machining work center for variant No. 4

By designing a compact machining work center located close to the acceptance point of iron casts leaving the line and relocating the acoustic test operation to the main hall, it was possible to reduce the path of iron cast flow nearly by half. The time needed to perform an activity with a value added was reduced by more than 40%. Furthermore, approximately 45% of activities that added no value to the product were eliminated, which has great influence on profitability of the iron cast manufacturing. The carried-out analysis of ergonomics made it possible to improve the convenience and safety of work at a work station through elimination of activities that were inconvenient and difficult for the employees. Such activities affect not only the quality of work but also the quality of manufactured products.

4. Conclusions

Improvement of quality of iron casts and manufacturing processes is a difficult task, yet it is beneficial for the foundry. In order to manufacture casts properly in terms of quality, at the lowest own costs possible, it is necessary to improve the manufacturing systems at all stages of execution of the manufacturing processes, through elimination of waste, as well as inconvenient and dangerous activities. Good organization of a work station is employee-friendly and it eliminates causes of errors and unnecessary costs.

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