ARCHIVES of FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 15
Special Issue 2/2015

55 – 58

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

13/2

Improving the Organization of Iron Casts Finishing Processes

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Received 04.05.2015; accepted in revised form 01.06.2015

Abstract

The paper presents issues of production processes improvement in foundries in terms of finishing treatment of iron casts on grinding workstations. Basing on the conducted analysis of work ergonomics on the grinding line and the observation of work at workstations, a range of improvements related to organizing grinding treatment processes was proposed. In order to visualize the production system functioning and estimate its efficiency, a simulation model of a grinding line has been created, on which a simulation experiment was carried out. Due to many factors influencing the effectiveness of processes, it was suggested to use multi-criteria evaluation tools to choose the most rational solution. Three criteria have been assumed, according to which particular improvement variants were evaluated. Also, criteria weights have been set according to the Saaty's method, and particular solution variants have been assessed separately with respect to each criterion. On the basis of the presented course of action, the best solution has been selected from among the analyzed options.

Keywords: Application of Information Technology to the Foundry Industry, Automation and Robotics in Foundries, Multi-criteria variants analysis, Modelling and Simulation of Production Systems, Work ergonomics

1. Introduction

Casting production systems are among the most complex ones due to, among others, difficult, monotonous and dangerous work conditions. Work organization at workstations in foundries needs to be continuously improved, automated and robotized in order to achieve better ergonomics and safety and to eliminate the activities which do not add value to products. Only rational manufacturing processes management basing on a reliable prime costs accounting allows to produce competitive casts [1, 2].

A basic issue of ergonomics is shaping the spatial structure of work, as it should be appropriately adapted to worker's size, his or her physical capacity, body posture, as well as to the type of performed tasks. A worker who is excessively tired, employed not according to his qualifications and predispositions, forced to be active only by financial reasons, exposed to too high or too low temperature, noise, dustiness, inappropriate light or discomfort will always underperform. Design of work space and means should take into consideration the conditionings resulting from the dimensions and posture of human body in relation to work processes. A workstation should be designed to avoid excessive strain on the joints, muscles, ligaments and respiratory and circulatory systems of its operator [3-6].

When improving casting production systems, it is worth applying the modelling and simulation technique. In order to plan and foresee possible results of the introduced changes, we can perform a simulation experiment on a computer model, without having to experiment in production conditions. Thanks to the development of modelling and simulation software, it is easier to rationalize casting production systems basing on universal simulation tools [7-11].

Preparation of variant solutions and their evaluation according to many criteria are key activities in the projects related

to production processes improvement. Choosing one right solution guarantees a successful outcome of a project, so that is why it is more and more common to apply multi-criteria methods which take into account the importance of particular criteria and direct activities in terms of production systems rationalization [12-14].

2. Research object, aim and methodology

The research object is an iron casts grinding line (Figure 1) used for finishing treatment of casts after pouring and clearing them on an automated casting line.

The aim of the realized initial research is to specify ergonomic and organizational problems at the grinding line workstations and to evaluate their influence on work efficiency and comfort.

The aim of the actual research is to improve work on the grinding line in terms of ergonomics and cycle time on the line, which directly translates into direct labour costs at a workstation.

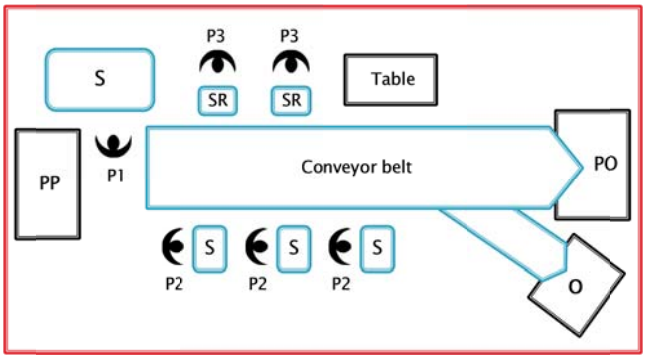

Fig. 1. A schedule of iron casts grinding line: S - grinder, SR - manual grinder, P1, P2, P3 - operators of workstations, PP - area of collecting casts, PO - laying aside area

The second figure presents the stages of project realization. Particular tasks of the finishing treatment were carried out according to point evaluation which takes into consideration 9 ergonomic situations (movement types):

- bending angle at the waist,
- turning angle at the waist,
- height of arm during work,
- angle of bending and straightening knees,
- wrist turn,
- precision, difficulty of moves, concentration,
- range (area) of work,
- number of made steps,
- transporting the treated object considering its weight.

For each of the activities, three ranges have been considered, which are very good (1 point, in green), acceptable (2 points, in yellow), and unacceptable (3 points, in red) in terms of ergonomics. On the basis of these ranges the accuracy of the course of the whole treatment on the grinding line has been evaluated.

A simulation model in the Arena packet was prepared to illustrate the course of casts finishing treatment (Figure 3). A computer model made it possible to check the course of particular variants and to estimate line efficiency on the basis of the generated reports.

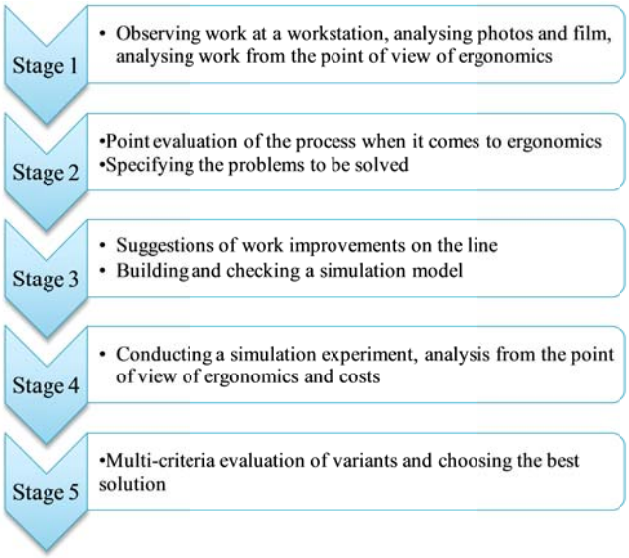

Fig. 2. Stages of Project realization

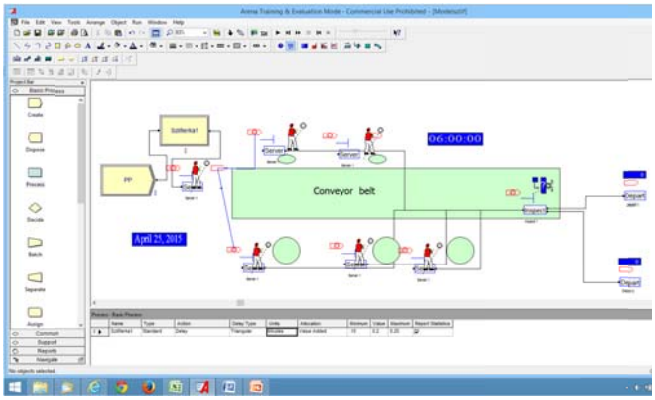

Fig. 3. A production system model made using the Arena software

For the evaluation of particular variants of the production process course, the Yager's method in the point version was used, which has been described in previous papers [15, 16]

According to this method, the first step involved estimating the importance of the assumed criteria on the basis of the Saaty's matrix:

- k_1: work ergonomics at a workstation,
- k_2: cost of the implemented changes,
- k_3: estimated efficiency of the grinding line after the suggested changes.

The fourth figure presents a schedule of multi-criteria evaluation related to the proposed variants of casts finishing treatment improvement on the grinding line.

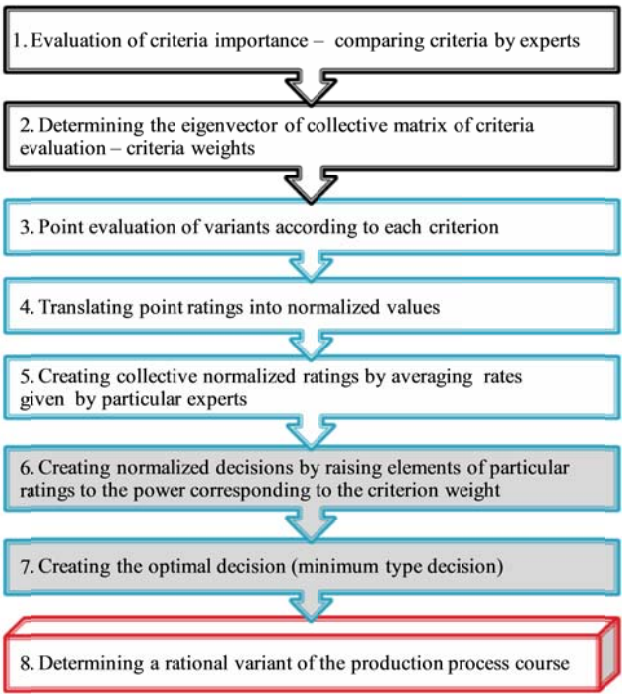

Fig. 4. Multi-criteria variants' evaluation according to Yager's method – choosing the best solution

3. Description of the obtained results

The observation of work at workstations allowed for specifying basic problems and for proposing possible ways of solving them.

For example, it was noticed at the first workstation that the bending angle at the waist and the angle of bending knees during collecting a cast from a container exceed the acceptable values. In order to eliminate this problem, it was suggested to replace the ordinary container by a tiltable one with regulated height. During grinding of the surface on the inlet system it was observed that the posture of the worker was unfavourable and can be relieved by using a regulated grinder stand. Other improvements included changing the location of machines, containers, using local ventilation devices, preparing shelves for putting back tools, using suspended manual grinders, ordering production documentation, using industrial supports for workers, building a sound-proof curtain and changing the conveyor construction.

The next figure (fig. 5) presents a scheme of exemplary combinations of the proposed modifications, according to which the variants of the production system changes have been determined.

Exemplary results of the point evaluation of work ergonomics at a workstation were shown in Figure 6.

	Modification										
	workplace 1					workplace 2			workplace 3		
Variants	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
V1	■		■					■	■		
V2	■		■	■	■			■	■		
V3	■	■	■	■	■	■	■	■	■		
V4	■	■	■	■	■	■	■	■	■	■	
V5	■	■	■	■	■	■	■	■	■	■	■
V6		■	■	■		■		■			
V7	■	■	■	■		■		■	■		
V8	■	■	■		■					■	■
V9											

Fig. 5. Variants of the production system's improvement

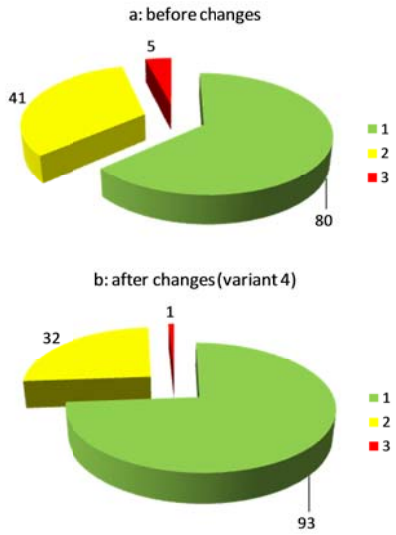

Fig. 6. Exemplary results of ergonomics analysis

The variants have been evaluated taking into consideration the three mentioned criteria. Firstly, experts performed a point assessment of the criteria by comparing them in pairs, and next, the eigenvector of the matrix has been determined on the basis of the collective matrix. (fig. 7).

Expert 1

e_1	k_1	k_2	k_3
k_1	1	0,5	1
k_2	2	1	2
k_3	1	0,5	1

Expert 1

e_2	k_1	k_2	k_3
k_1	1	1	0,5
k_2	1	1	1
k_3	2	1	1

Expert 1

e_3	k_1	k_2	k_3
k_1	1	1	2
k_2	1	1	2
k_3	0,5	0,5	1

Collective matrix

	k_1	k_2	k_3
k_1	1	0,833	1,167
k_2	1,200	1	1,667
k_3	0,857	0,600	1

Weighting of the criteria

$$Y = \begin{bmatrix} 0{,}97358 \\ 1{,}23865 \\ 0{,}78778 \end{bmatrix}$$

Fig. 7. Evaluation of criteria importance according to Saaty's method

On the basis of the performed analysis of work ergonomics at workstations, a computer simulation, cost calculation, point evaluation of the variants was carried out, after which the obtained ratings were translated into values in the range (0,1).

Criterion	Expert	Variants							
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
k_1		0,027	0,108	0,189	0,189	0,216	0,054	0,135	0,081
k_2	e_1	0,194	0,129	0,161	0,032	0,032	0,194	0,129	0,129
	e_2	0,194	0,161	0,129	0,065	0,032	0,161	0,129	0,129
	e_3	0,156	0,125	0,156	0,063	0,031	0,188	0,156	0,125
k_3	e_1	0,077	0,077	0,179	0,179	0,179	0,128	0,128	0,051
	e_2	0,077	0,103	0,179	0,179	0,205	0,103	0,103	0,051
	e_3	0,047	0,070	0,186	0,186	0,209	0,116	0,116	0,070

Fig. 8. Normalized evaluation of variants according to the assumed criteria

The table in figure 9 presents the results of creating normalized decisions reached by raising elements of particular normalized ratings to the power corresponding to appropriate weight.

Criterion	Variants							
	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
k_1	0,029	0,113	0,176	0,194	0,221	0,076	0,140	0,103
k_2	0,120	0,086	0,094	0,026	0,014	0,120	0,086	0,078
k_3	0,119	0,141	0,261	0,261	0,279	0,183	0,183	0,105

Fig. 9. Creating normalized decisions

The last step (fig. 10) included the presentation of the multi-criteria results, which shows that the best scenario is the one corresponding to variant V_3.

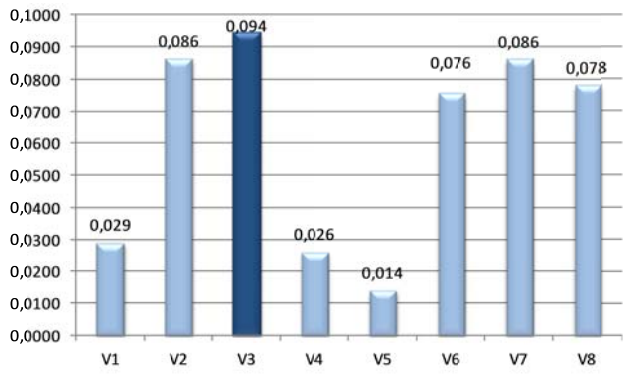

Fig. 10. Creating the optimal decision and ranking variants

4. Conclusions

Thanks to the performed analysis of ergonomics, it was possible to specify the activities which are burdensome and uncomfortable for workers and which often do not add value to products. The modelling and simulation technique allowed to visualize the course of production processes and to estimate the system's parameters after introducing the suggested changes.

Applying the multi-criteria evaluation method allowed to find a compromise in looking for the solution which is advantageous from the point of view of many criteria, taking into consideration their importance.

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