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Production system rationalisation on the example of iron foundry

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Abstract

The present paper presents a systemic approach to foundry management. Thanks to production process modelling and simulation techniques, an attempt was made to synthesise many interconnected devices and numerous manufacturing stages into one production system. In the beginning, a factor analysis was carried out of the research object, which is a system of iron castings manufacture on automated foundry lines. On the basis of a simulation experiment, use the accessible production resources and manufacturing own cost of castings were analysed, depending on batch content and melting order, choice of an automatic line and the model of line fed with cast iron, sequence of order realization and the size of production lots. Simulation experiments were carried out on a computer simulation model prepared in the Arena packet produced by Rockwell Automation. Cost was estimated on the basis of additional calculation according to cost centres basing on factory spreadsheet.

Keywords: Application of Information Technology to the Foundry Industry, Automation and Robotics in Foundry, Costs Calculation, Modelling and Simulation of Production Systems

1. Introduction

In today's competition on the market, there is a growing interest in the producers, which are able to accept an order and take binding decisions related to its realization, at the same time keeping the dates and casting quality, offering the lowest possible price. This need results from the tendency of shortening the lifecycle and wide variety of produced casts. This relates also to large-scale production of iron castings for automotive industry needs, which, in turn, causes the need of looking for possibilities of higher production flexibility and precise cost analysis. Flexibility may be understood as a variety of produced goods, possibility of differentiating production size, possibility of setting different sequence of manufactured castings, fast reaction to customer requirements, which constitutes a significant problem in case of iron castings manufactured on automatic lines. There exists a need of systemic approach to solving problems related to production management in an iron foundry [1, 2, 3, 4, 5].

2. Aim and research methodology

The aim of this work is to rationalize iron foundry's operation as a system of iron castings manufacture on automatic lines.

The following conception of research realization was proposed:

- carrying out factor analysis of the research object in order to enumerate input, fixed and disturbing factors, and determine their influence on the output factor, which was assumed as order realization dates and own cots of castings manufacture,
- determining cost centres and preparing a system of production own cost estimation on the basis of a factory spreadsheet,
- working out a spreadsheet of cost optimization of direct material for batch preparation,
- carrying out experiments on simulation models: design of production schedules, checking realization punctuality

of order parts, determination of self costs according to factory spreadsheet and choice of the best considered schedule of cast manufacture [6, 7, 8, 9, 10].

Figure 1 presents factor analysis of the research object with division into input, output, fixed and disturbing factors [11, 12].

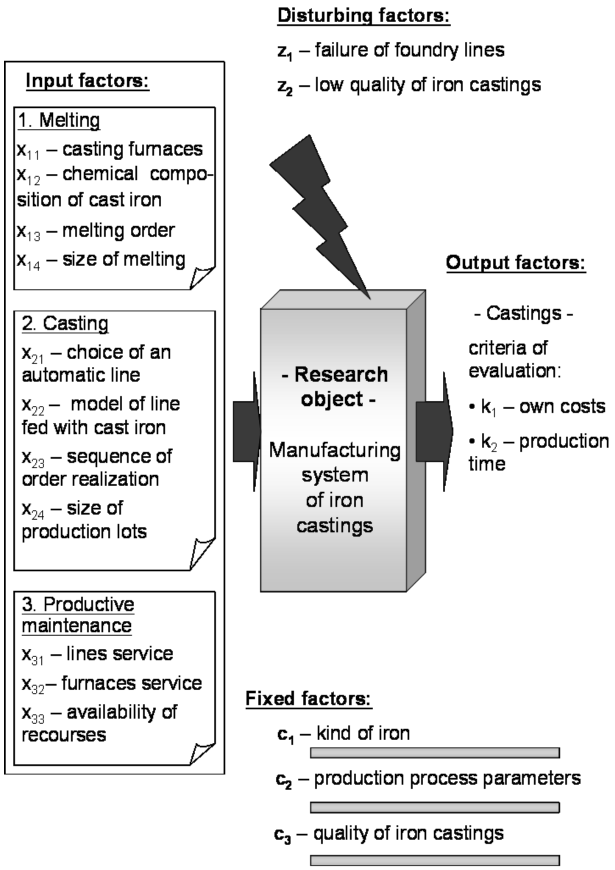

Fig. 1. Factor analysis of research object

Cost of direct materials was analysed on the basis of batch optimisation spreadsheet. The sequence of making casts depended on chemical composition of grey cast iron as well as spheroidal graphite iron (Fig. 2). Such activity facilitates modification of cast iron composition by increasing the content of a chosen element and allows for a change of assortment in case of disturbances in the process. This will make it possible to realise orders in smaller production lots and will contribute to diminishing redundant reserves [13].

Casting furnaces are characterized by different melting loss quantities and thermal capacity which influences electric energy consumption in particular stages of batch melting and its subsequent storage. An advantage of arch furnaces is their higher thermal capacity on the stage of melting (in comparison to induction furnaces), ease of starting and stopping in case of downtime, possibility of melting polluted scrap metal and pieces of batch with different size. Disadvantages include burning out of expensive electrodes and the need of removing gases formed by this process, load work and local overheating of liquid metal. Induction furnaces are quiet, have high efficiency (particularly on the storing stage) and offer possibility of getting accurate composition of liquid metal before final correction with additives.) It is, however, quite troublesome to start them, as usually liquid metal is poured into a furnace in the beginning, and for its downtime (eg. days off work) a pillow of liquid metal is left in the furnace, which influences the cost for electric energy. In practice, induction furnaces are also more often damaged than the arch ones [14].

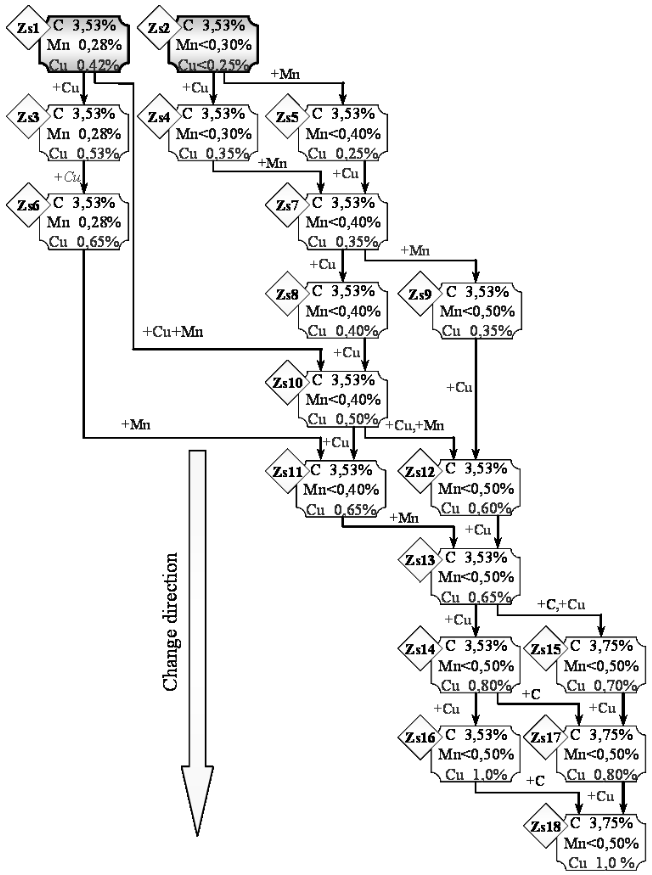

Fig. 2. Planning of pouring order depending on spheroidal graphite iron composition

Choice of the furnace is also connected with choosing the preferred variant of casting lines feeding with liquid cast iron presented in Figure 3. The lines may be fed interchangeably with batteries of arch furnaces, where metal is melted in a furnace of high efficiency and poured into induction furnaces, in which it is stored or the lines may be fed with metal melted and stored in induction furnaces.

The next input factor is the choice of casting line, in which a given order part will be realised. Castings may be made interchangeably on many lines, and time of realizing a given operation on an alternative line may differ. A line with a vertical form division is characterized by higher efficiency (measured by the number of poured forms per hour), but one form may take fewer models than in a traditional form on a horizontal line. What is more, lines with vertical form division demand service activities more often.

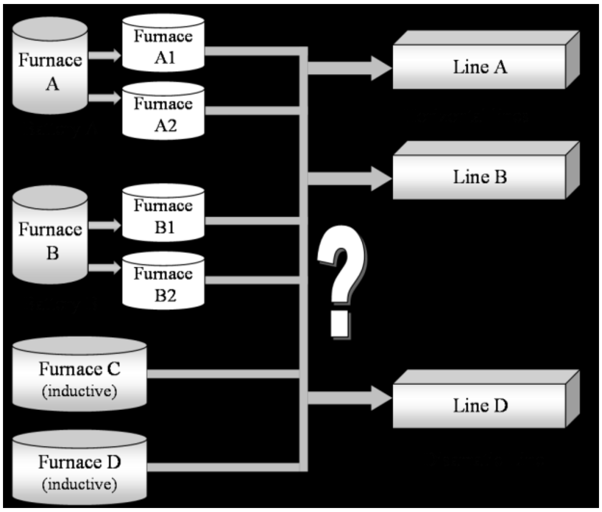

Fig. 3. Collection of possible solutions of applying variants of lines feeding with liquid iron

The next input factor analysed by this work is order division into production parts of different size, which influence, above all, the size of resources in progress, total set-up time and rational use of production resources. It is assumed that maximal size of a lot is equal to the order size in the analysed period with a reserve taking into account a possibility of shortages. Minimal quantity of a production lot depends on furnace capacity storing cast iron in arch furnace battery. An exception here may be orders realised one after the other from the same type of cast iron or orders realised with the use of iron of similar composition according to the direction of changes presented in Figure 2. In this case, minimal lot size is assumed to be the size related to capacity of foundry tub or furnace storing on the line.

The last group of analysed factors relates to maintenance of casting lines and furnaces and to setting theoretical and practical work flexibility of these devices.

The following formula determining minimal own costs of manufacture on the basis of factory spreadsheet constitutes a purpose function in the presented project (ESC).

$$f(K_{mb}, K_{st}^{st}, K_{st}^{z}) \rightarrow \tag{1}$$

In order to determine own costs of casting production in an organizational company structure, cost positions were specified, on which particular costs are settled directly or indirectly according to additional calculation.

In additional calculation according to cost centres a factory spreadsheet is used, in which indirect prime costs are settled onto cost positions which are organizational cells of an enterprise. These costs mat be settled directly on the basis of consumption or indirectly with use of division keys. Next, all-factory costs and costs of auxiliary production positions are settled on main production positions according to the quantity of rendered services. Factory spreadsheet is in a form of a table, where cost kinds are specified and cost positions are placed in columns (Fig. 4).

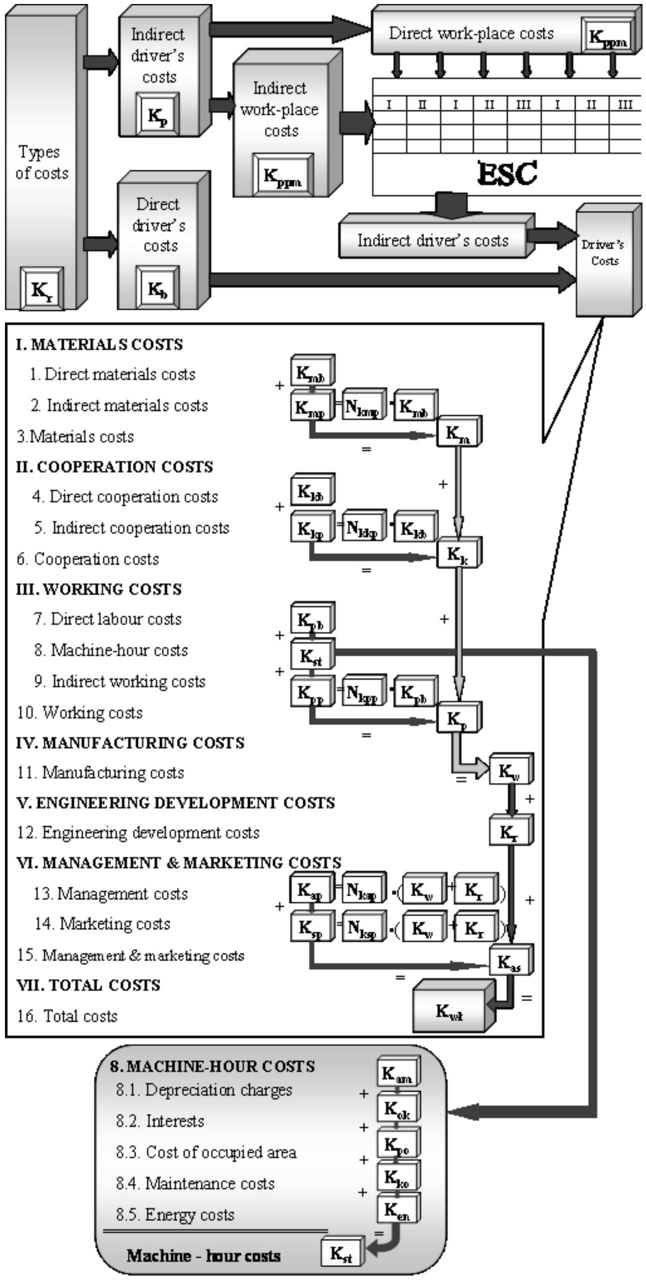

Fig. 4. Own cost estimation with the method of additional calculation according to cost centres

As a result of calculation which was carried out, we obtain own costs expressed in PLN per item or per tone of products, which are a sum of manufacturing costs and costs of administration and sale.

3. Description of the results

Within cost optimization of direct material a spreadsheet was prepared in Excel, which, thanks to using the „solver" module, determines the share of particular raw materials in the batch with consideration of melting loss and minimizes direct material costs.

As a result of simulation research and cost estimation basing on factory spreadsheet, variants of cast manufacture schedules were compared in order to choose a rational solution and apply it in production practice (Fig. 5 and 6).

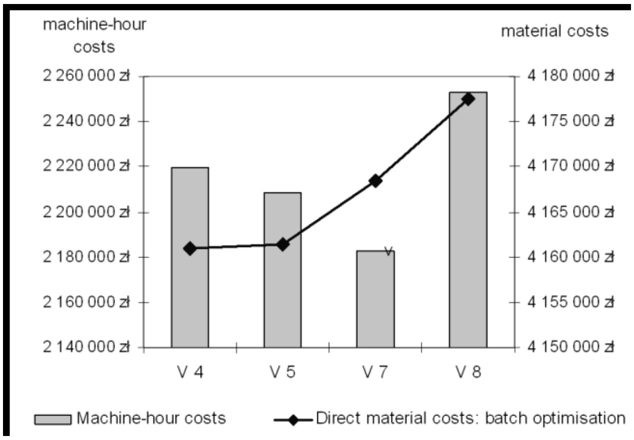

Fig. 5. Machine-hour costs and direct material costs

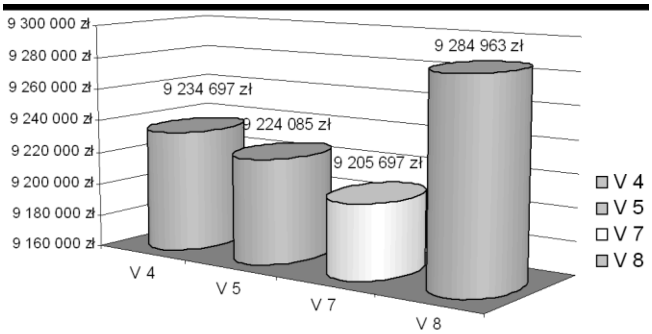

Fig. 6. Self cost on the basis calculation sheet

4. Conclusions

By observing enterprises dealing with casting manufacture we can notice that in the sphere of construction and technology, cost cutting possibilities are more and more limited. More faults which influence the formation of manufacture own costs should be looked for in the domain of production organization, planning and production tasks management.

The planned sequence of batch preparation and pouring forms with liquid iron is not indifferent. Thanks to simulation experiments it will be possible to determine the order and size of production lots from the point of view of assumed and forecast order portfolio, which can have a significant influence on own cost formation in manufacturing iron castings.

In order to reduce costs, it is advisable to use resources rationally and aim at maintaining production reserves on minimal permissible level.

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