Abstract

Within the survey focused on perceptions and use of controlling in Czech industrial companies, it was found that the most commonly used form of controlling is the cost controlling. Currently all enterprises are trying to be cost-effective. For a number of foundries it is the question of keeping production and preserving the effectiveness of the company. It follows management efforts to reduce costs. In this case, it is necessary to focus on separate manufacturing or working task (production stage). For this recognition and control of costs appear to be most appropriate to use the Cost model. Detailed recognition and cost allocation using the Cost model gives enterprises the opportunity to model possible situations and their impact on the production phase. This article presents initial work on the development of a complex cost model of cast production. It represents the different stages of cast production and costs that arise during this process. These facts are confronted with the obtained data on the current fleet of electric arc furnaces. EAF is actually one of the key means to produce liquid metal. Monitoring and evaluation of the costs is therefore almost necessary.

Keywords

Controlling, cost model, casting, electric arc furnace

1. INTRODUCTION

The survey focused on perceptions and use of controlling in Czech industrial companies, which took place mainly during the 40th meeting of the economic expert committee of the Czech foundry society [1] found that the most established form of controlling is the cost controlling. Cost controlling is also considered as the most important kind of controlling.

The general objective of cost controlling is to monitor the costs, analyze the effectiveness of their use, and eliminate bottlenecks. Bottleneck is called areas where there is inefficient consumption of costs. Currently, all businesses are trying to be cost effective. It follows the effort of controlled reduction of costs. In this case, it is necessary to focus on separate manufacturing or task (production stage). You need to focus on a production stage, where the restrictive intervention will not cause negative impacts. Otherwise, it may ultimately lead to such negative impacts that exceed the original planned positive contribution.

For this recognition and control of the costs seems to be most appropriate to use the cost model. The cost model is used to measure and control of costs. The goal is at least a prevention of their uncontrolled growth, at best, finding areas where it may be reduce. This is achieved mainly by clarifying the costs of the production stage. Detailed knowledge of costs and their correct assignment allows the measurement and control. Certainly applies here well-known axiom that what businesses do not measure, it also does not control.
In the above survey, [1] it was also found that the least introduced species of controlling is the risk controlling. The importance of risk controlling is among interviewed managers perceived and the most of them said that it plans to implement. Risk controlling is the modelling of the potential impacts of decisions or the impact of external influences on the functioning of the company.

Detailed recognition and allocation of costs with the help of cost model gives the opportunity to model possible situations and their impact on the production stage. Ultimately, it is possible to model the effect on the entire company. Therefore, a properly defined cost model is very important for controlling risks.

Metal production is an important initial step in the value added chain of many industries producing practically any type of goods. The global financial and economic crisis that began in 2008 as the first hit producers, processors and ultimately steel users. Compounded by the pressure to reduce costs in production. For a number of foundries it is a question of keeping production and preserving the effectiveness of the company. Often we have seen unsystematic efforts to "investigation" without a comprehensive assessment of the costs and benefits of possible solutions. It is necessary for efforts to reduce the costs based on their in-depth knowledge and analysis of the specific conditions of the production. The production flow analysis is the need to use appropriate methods for monitoring their own operating costs.

Phase of the cast production

1. Production of liquid metal
2. Preparation of sand mixtures
3. Production of molds
4. Casting into the mold
5. Finishing

2. COST OF THE ENTERPRISE [2,3]

The costs, as it is commonly known, are monetised practical and purposeful handling of money and labour during the economic activities of the company. It is a consumption materialized and human labour for the production and implementation of production expressed by money. Costs are economic indicators of production units. They reflect the production, supply, sales activities of the enterprise and its technical, economic and organizational level.

For direct monitoring and subsequent management cost consumption was gradually introduced calculation of incomplete own cost (NVN). This is the kind of calculation that takes into account only the costs directly related to the production phase. This means that only considers those costs that may economic centres (work crew) directly affected by its activities. So simply, i.e. direct materials, direct labor and other direct costs. Calculation of NVN from classical type costing model based on ÚVN is differ mainly because it does not include overheads items (production, sales or administrative overhead). Excludes eg lighting of the hall, depreciation, etc.

Then focus on each stage of production and casting their assessed costs.
3. PRODUCTION OF LIQUID METAL[3]

Creation of costing model for liquid metal

NVN costing model of liquid metal usually has the following form:

a) material costs:
- Cost per batch;
- Cost of the metal additives
- Cost of non-metallic additives;

b) processing costs:
- Cost of energy used for melting (electricity, natural gas, oxygen, argon, etc.);
- Cost of proportional to the melting time (personal costs, masonry of furnace, pans, etc.);
- other processing costs (analysis of metal, slag, temperature metal, etc.).

The sum of both items we receive incomplete own costs.
Calculation unit is usually a ton of liquid metal. Or, if a so-called metal-to-trough. The above outlined a costing formula result in the following equation (1) to calculate the NVN.

Calculation NVN: NVN = MN + ZN  [CZK / t]  (1)

where:

NVN … incomplete own expense … [CZK / t]
MN ..... material costs [CZK / t]
ZN ….. processing costs … [CZK / t]

Calculation of material costs

Material costs, which include cost per batch, metallic and non-metallic additives make up about 60-70% of the NVN of liquid metal.

Determination of material costs is performed by equation (2):

\[ MN = NC_{vs/t} + NC_{kp/t} + NC_{nkp/t} \]  [CZK / t]  (2)

where:

MN .... material costs [CZK / t]
NC_{vs/t} ... overall cost of the charge in the furnace [CZK / t]
NC_{kp/t} ... overall cost of metallic additives embedded in a furnace and the pan [CZK / t]
NC_{nkp/t} ... total cost of non-metallic additives embedded in a furnace and the pan [CZK/t]

First there are calculated cost of smelting [CZK / tav], followed by conversion to the fixed cost unit - a ton of liquid metal [CZK / t].
**Batch** includes all metallic and nonmetallic component inserted into the furnace prior to the actual switching (scrap return material, various kinds of metal and non-metal waste, pig iron, etc.). In calculating the costs of the batch start from batch quantity of the component embedded in a furnace, and its price. Batch participates in largest share on the material costs.

**Metallic additives** are a group of ingredients that are in the furnace and then added to the pan during the melting process. To determine the cost of metallic additives is necessary to know the price of metal components and weight. Metallic additives are the second largest item of material costs.

**Non-metallic additives** represent a group fluxes. These are mainly coke, fluorspar, lime and other fluxes. The cost evaluation of non-metallic additives is similar to the other components of the material costs and expected knowledge of prices and quantities consumed non-metallic additives. Non-metallic additives occupy the smallest share of material costs of production of liquid metal.

**Calculation of processing costs**

The second group are the processing costs. Those involved in the production of liquid metal by 30-40% from NVN. Processing costs are assessed the cost of melting energy (eg electricity) cost related to the duration of melting (personal costs, and lining furnaces etc.) and other processing costs (metal temperature measurement, cost analysis and other metal) by equation (3). A special case is at EAF cost of graphite electrodes, the amount of which is modelled according to the time of melting and electricity consumption.

**Determination of processing costs:**

\[
ZN = N_{ee/t} + N_{ge/t} + N_{os/t} + N_{vv/t} + N_{vp/t} + N_{ak/t} + N_{mt/t} \quad [\text{CZK} / \text{t}] 
\]  

where:
- \( ZN \) ... processing costs [CZK / t]
- \( N_{ee/t} \) ... the cost of electricity consumption [CZK / t]
- \( N_{ge/t} \) ... the cost of consumption of graphite electrodes [CZK / t]
- \( N_{os/t} \) ... personal costs [CZK / t]
- \( N_{vv/t} \) ... the costs of masonry of the furnace lid [CZK / t] - for electric arc furnaces
- \( N_{vp/t} \) ... the costs of masonry walls of furnace [CZK / t]
- \( N_{ak/t} \) ... the costs of analysis of metal and slag [CZK / t]
- \( N_{mt/t} \) ... the costs of temperature measurement of metal [CZK / t]

Similarly to the material costs are first determined the cost of smelting [CZK / tav], which are subsequently converted to the chosen calculation unit, which is a ton of liquid metal [CZK / t].

**Electricity** is consumed in electric furnaces during melting batch and additives. In determining the cost of electricity is expected understanding of the amount of electricity consumed and its price. Electricity is the largest cost item group processing costs.

**Graphite** electrodes constitute a major part involved in the economics of operation in liquid metal production. The cost of consumption of graphite electrodes in the calculation formula of liquid metal include only heats held in EAF.

**Personnel costs**, labour costs, which the crew of the furnace directly involved in the production of liquid metal. Calculation of personnel costs based on the knowledge of the furnace crew members, their gross salary, current rates of social and health insurance, the employer and the cast time.

**Walling of the lid** and furnaces represent another of the items that cost model includes production of liquid metal. Their incorporation into costing formula is trying to express the cost of wear. It is based primarily on the knowledge of the time of the cast that when determining the cost of masonry plays an important role.
Furthermore, knowledge of the total cost of masonry for the year and the sum of all time heats per year or if the so-called gross operating time. The cost of the masonry cover assesses the cost model especially in the case of melting in the EAF.

**Analysis of the liquid metal** is another item which cost model within the processing costs assessed. Through these analyses, it is determined by the chemical composition of the liquid phase, depending on the quality produced twice or more for melting. For heats held in the EAF is usually a chemical analysis performed after melting, oxidation, and prior to tapping (final analysis). In the case of EIIP chemical composition analysis are less frequent (about twice per heat). When calculating the cost of liquid metal analysis method based on knowledge of the exact number of analyses per heat and the price of a single analysis.

**Measurement of the temperature of the liquid metal** is the last of the items described generally considered cost model. The temperature of the liquid metal in electric furnaces are measured using removable probes to measure the temperature. The cost of measuring the temperature of steel or cast iron thus based on the number of probes consumed and their prices.

Through cost model is for example possible to determine how much the IWC of concrete quality metal, what proportion of these costs form the batch, additives, electricity, graphite electrodes, etc. Based on this information we obtain a detailed overview of the cost effectiveness of each melt.

The cost of electricity is one of the key components of the cost, it should be given attention. During the investigation which compares parameters of electric arc furnaces in the Czech and Slovak Republic with respect to the melting unit with a nominal charge weights 5 tons in last 45 years was found to significant decline energy consumption. This is probably due to the use of new technologies, involving secondary metallurgy process of melting and modernization melting furnaces.

**4. COMPARISON OF THE PARAMETER TOTAL ELECTRICITY CONSUMPTION**

In the following chapters is paid attention to the statistical assessment of the monitored parameter. In this assessment, first test the statistical files to the existence of outliers. Subsequently, we will focus attention on assessing whether the sample has a normal distribution. We continue enumeration statistics. Graphic evaluation assessed values is the last point survey.

**4.1 Testing the outliers**

The first step in assessing the statistical analysis parameter testing outliers (OH). With this method we are looking for OH, ie atypical values relative to the rest of the file. Graph showing the necessary information is called Boxplot and is shown in picture 1a and picture 1b.
As you can see the picture 1a, with consumption of electrical energy we record the occurrence of OH in both groups. These values have been removed and a picture 1b shows Boxplot removed without OH. Next, we proceed for testing of normality.

4.2 Testing of the normality

Testing of normality, as its name suggests, is used to determine whether the observed statistical ensemble has a normal distribution (according to the Gaussian curve). For this testing was used "Probability Plot" (probability plots) of Minitab. These diagrams are seeing in the picture 2a and picture 2b. If the p-value greater than 0.05, it can be stated that the file has a normal distribution. If this value is less than 0.05, has a normal distribution.

P-Value in both cases is higher than 0.05 (for a set of 1968 is equal to 0.797 and in 2013 is equal to 0.055). It can be said that both files have the normal distribution. For further assessment will be working with the arithmetic average.
4.3 Basic statistical indicators

For statistical assessment identified the following indicators: minimum and maximum value, arithmetic mean, mode, median, variation range, variance, standard deviation and coefficient of variation. These values have been arranged into the tab. 1. This reflects their values for samples 1968 and 2013 and differences between these values.

Tab. 1: Basic statistical indicators

<table>
<thead>
<tr>
<th>ř./sl.</th>
<th>Indicators</th>
<th>Units</th>
<th>Sample 1968</th>
<th>Sample 2013</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minimum</td>
<td>kWh/t</td>
<td>611</td>
<td>579</td>
<td>-32</td>
</tr>
<tr>
<td>2</td>
<td>Maximum</td>
<td>kWh/t</td>
<td>886</td>
<td>764</td>
<td>-122</td>
</tr>
<tr>
<td>3</td>
<td>Mean</td>
<td>kWh/t</td>
<td>754</td>
<td>652</td>
<td>-102</td>
</tr>
<tr>
<td>4</td>
<td>Mode</td>
<td>kWh/t</td>
<td>722</td>
<td>615</td>
<td>-107</td>
</tr>
<tr>
<td>5</td>
<td>Median</td>
<td>kWh/t</td>
<td>769</td>
<td>630</td>
<td>-139</td>
</tr>
<tr>
<td>6</td>
<td>Variation range</td>
<td>kWh/t</td>
<td>275</td>
<td>185</td>
<td>-90</td>
</tr>
<tr>
<td>7</td>
<td>Variance</td>
<td>kWh/t</td>
<td>4140,9</td>
<td>3395,3</td>
<td>-745,6</td>
</tr>
<tr>
<td>8</td>
<td>Standard deviation</td>
<td></td>
<td>64,4</td>
<td>58,3</td>
<td>-6,1</td>
</tr>
<tr>
<td>9</td>
<td>Coefficient of variation</td>
<td>%</td>
<td>8,5</td>
<td>8,9</td>
<td>0,4</td>
</tr>
</tbody>
</table>

For current fleet of EAF observed to decrease energy consumption. The minimum value is decreased by 32 kWh / t, the maximum value decreased by 122 kWh / t. The average value in 1968 was 754 kWh / t in 2013 is 652 kWh / t. The most commonly represented values show a decrease (from 722 kWh / t in original file to 615 kWh / t in the current file).

This should be regarded as indicative only and default, as in the assessment was not taken into account the different technological processes apart 45 years. This issue is currently engaged and will be the subject of further investigation.

4.4 Graphic representation

On the pic. 3a and 3b can be seen in the layout of data within the frequency histograms.

Pic. 3a: Frequency histograms (1968)  
Pic. 3b: Frequency histograms (2013)
On the pic. 3a and pic. 3b we can observe a noticeable narrowing of the range of file 2013. They also drop most values below 660 kWh / t

**Preparation of molding mixtures**

Incomplete own costs are again defined as costs which include the main direct costs of production process of preparing molding materials, which are directly or determinable and crew management of the center can directly affect their spending. These include the direct costs of inputs such as grog, connective system, additives, all costs of energy, transportation, wages, etc. In addition, the cost of secondary raw materials - thus regenerate and return mixture, etc. Return the mixture was valued only the cost of handling and editing reversible mixture.

Determination of NVN main production phase of preparation molding mixtures based on its division into the production phase.

**Acquisition, handling and preparation of new grog**

The output of the production phase is costs of acquisition, handling and preparation of new grog - a grog transported to the mixer.

**Regeneration**

Calculation unit is 1 tonne regenerate usable to the production of relevant new molding mixture. The output of production stage is cost of producing regenerate.

**Handling of return mixture**

The output are the costs of transport and "adjust" returnable mixture (calculation unit is 1 t return of the mixture) and its transport into the mixer.

**Connective system**

The output of this phase are the costs to purchase and transport of binder (calculation unit is 1 t binder) and its transportation to the mixer.

**Handling of carbonaceous additives.**

Calculation unit is 1 tonne of carbon additives. The output of the production phase, the cost of purchase and manipulation of carbonaceous additives (including their transport into the mixer).

**Preparatory work - premix**

Calculation unit is 1 tonne of produced premix. The output of stage of production the cost of premix composition.
Mixing of the components in a mixer
Calculation unit of the production phase is 1 tonne of produced molding mixture. The output of stage of is production cost of mixing the components in a mixer.

Technological properties of produced molding mixture
Calculation unit is 1 ton of produced molding mixture. The output of the production phase is the cost of testing the technological properties of manufactured molding mixture.

Deponie
Calculation unit is 1 tonne of waste generated during the manufacture of molding mixture. The output of stage of production is the cost of 1 ton of waste.

Mold Making [7-8]
Determination of the cost of production format is based on, as well as in the previously solved the main production phases of casting (liquid metal production, preparation of molding sand), a detailed description of all operations.

The operation phase of production forms that include both manual and mechanical production method forms:
A. Preparation of the model for formation
B. Production of the lower half-mold
C. Production of the upper half-mold
D. Composition of Forms
E. Move mold to casting field
F. Production of cores
G. Production of auxiliary parts

Casting into the mold - this production phase hasn´t been investigated yet

Finishing [9-11]
The final main phase of production of the casting is finishing or cleaning the casting. First, it was necessary to the breakdown of on production phase.

Production phase of finishing of castings:
A. Transport and removal of molding mixtures
B. Mechanical cleaning (blasting)
C. Heat treatment (TZ)
D. Removing risers and gating (cutting, burning, insulting, etc.)
E. area adjustment after removal of risers and gating system, rough grinding
G. Preserve defects
H. Fine grinding
I. Ironing of weld defects
J. grinding welds

NVN groups are made up of the sum of the cost items, and the cost of material and processing.

Calculation formula NVN finish castings have the following form:

**Material costs:** water, abrasives, sand, electrodes, grinding wheels, etc.

**Processing costs:** energy, labour costs, etc.

5. **THE CONCLUSION**

Cost effectiveness of casting production is an important factor in the evaluation of casting production. However, it is also useful to know their other demands. In particular, the intensity of the material, energy and time.

It should be added that a comprehensive and very complicated finishing cost item is as elaborated in detail as the above-described main production phase of metal production, preparation molding mixtures, etc.

**LITERATURE**


