POSSIBILITIES FOR QUALITY CONTROL OF CASTING PRODUCTS

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Abstract

This report presents some possibilities to reduce production scrap during steel casting production by the mean of the smelting mould method. Most of the time, standard ways of casting products finishing are the only possibility for the product to reach the required quality. By the mean of an advanced solution and from the quality control point of view, there appears the making up of a prediction concerning the occurrence of casting failures within the course of the material processing flow. On the base of statistical data determination methods for specially selected casting products types, it will be possible to consider the significance of each single nodal checking point. Thanks to the subsequent estimation and eventually to the refinishing of the checking methods, all of the conditions for a further reduction of undesirable scrap will be created and this, already within the course of the processing flow. This way, it will be possible to achieve a significant reduction of factory costs.

Key words: steel casting production, required quality, quality control

INTRODUCTION

The CIREX Company is a modern foundry plant producing steel casts. These are cast by the mean of the low-wax casting method. It produces high quality components for the automotive, technological and machinery industries. One of the most important domains of the company’s development consists in the production quality control which has been going through a continuous phase of permanent improving since its subsidiary company was founded in the Czech Republic in the year 1993.

1. CURRENT STATE OF POOR QUALITY PRODUCTION CONTROL IN THE CIREX, s.r.o. STEEL CAST FOUNDRY PLANT

The poor quality production control, whose integral part is the daily continuous checking of the entire production flow, is all of the company’s employees ‘scope of employment who can have some influence in this domain within a different extent. Information details concerning the poor quality production are not important for the manufacturer only but they are also sensitive pieces of information and this, for the customer above all.

The poor quality production control current principle in the CIREX company begins by the occurrence recording of each individual cast at inter-operational production phases just as the wax patterns production, the ceramic treatment department for instance, and it finishes by the evaluation of the casts quality in the domain of identification and summarization of the casts defects within the frame of a given production lot. During the consequent and regular poor quality production results analysis, the working team’s task especially consists in examining the causes of the concrete defects origination. The presentation of the defects is a matter of fact and this, not only from the number of casts pieces point of view, but it serves also as an evaluation from the economical point of view. An illustration by the mean of the Pareto chart method for example does not have to be directly proportional to the number of casts from the poor quality production. To improve the steel casts quality, some technical changes are proposed and consequently realized in the production at concrete production operations and this, for each precisely determined sorts of products. These products groups are subject to exceptional analysis and consequently to that, it is eventually decided
2. THEORETICAL POSSIBILITIES FOR POOR QUALITY PRODUCTION CONTROL
To evaluate poor quality production, it is recommended to proceed according to the below mentioned steps:

A. Selecting the cast sort and the concrete defect.
B. Analysis of the possible causes of the defect origination.
C. Data collecting.
D. Data analysis.
E. Looking for the elementary causes of the cast defect origination.
F. Creating a pattern for the defects prediction.

2.1 Selecting the cast sort and the concrete defect
The Pareto chart [1] is the most suitable method to determine priorities while solving a problem. By its application, there can be determined that only one group of factors – the significant minority – takes a share in the occurring poor quality production within a decisive extent. The resting part is called the effective majority.

Method principles:
- Defining the analysis points – selecting the process, the activity where it is necessary to increase the profit or effectiveness. It can concern for example complaints, incompliance in production, in administration, the products fruitfulness, etc.
- Data collecting – for the analysis, it is necessary to obtain the suitable data concerning functioning and their values are recorded into a chart.
- Data sorting – the obtained data are sorted according to the greatest occurrence, frequency, the greatest weight or according to any other criteria. However, they are always sorted from the greatest selected value to the smallest one.
- Creating the Lorenz cumulative curve – this curve occurs by the cumulative summation of the values and their plotting into a graph.
- Stating determination criteria – Pareto rule 80/20 or our own selected rule.
- Identifying the main causes – plotting the line (80%) on the Lorenz cumulative curve. Then, a vertical line is executed from it, and it separates the cases and causes which are necessary to be dealt with. Those which have the greatest influence on the results.
- Stating corrective measures to remove or to develop the causes which create the most losses or at the contrary those which lead to an increasing of profit [1].

2.2 Analysis of the possible causes of the defect origination
The causes and consequences chart is a possible graphical tool to be utilized for the analysis of the possible causes of a concrete defect origination – Ishikawa chart (fig. 1). Team work is an essential condition to build up this chart, at best in the form of brainstorming [1].

Method principles:
- Defining the problem – noticed on the right side of the surface and drawing the main horizontal line.
- Determining the categories of the problem possible causes – material, installation, methods, people, environment, and management – main branch towards the horizontal line.
- Analysis of all the possible causes in each individual category + eventual decomposition of the causes cause.
- Evaluating the most important causes – Pareto analysis by the mean of point evaluation [1].
2.3 Data collecting

Data should be collected from the process currently in progress within such a time period so that all of the possible sources of variability could come into effect. That also means within the course of the ordinary operating personnel changes, of the production installations adjusting, during the regular maintenance operations and so on. [1].

The analyzed data suitable for the analysis can be those which are standardly recorded but there can also be collected new data, which are not led in general. They can result from a discussion within the frame of Ishikawa chart.

2.4 Data analysis

There are different methods how to analyze the needed data. While having a data statistical treatment, it is suitable to have a combination of numerical and graphical methods because the disadvantages of one of the methods can be compensated by the second one [1]. It is important to keep in mind all what the analysis should provide. At the beginning, it is necessary to determine if the data are going to be analyzed individually, the way they were recorded or if they are going to be configured, for example, according to the production batch. Under our conditions, the methods of Histogram, Box-Plot, the Ishikawa chart as well as the correlational analysis were utilized.

- **Histogram chart**
  Histogram enables to evaluate the data normality (symmetry), the distant values identification:
  - finding $x_{\text{max}}$ and $x_{\text{min}}$;
  - calculating the variation interval $V = x_{\text{max}} - x_{\text{min}}$;
  - determining the number of categories towards:
    a) $n > 100$ 
       \[ k = \lceil 10 \log (n) \rceil \]
    b) $40 > n \leq 100$ 
       \[ k = \lceil 2 \sqrt{n} \rceil \]
    c) $n \leq 40$ 
       \[ k = \lceil 1 + 1.4426 \ln (n) \rceil \]
  - calculating the categories width $h = V/k$;
  - selecting the lower limit $x_0$ of the first category and dividing the files into categories;
  - determining the categories frequency
  - Creating and analyzing the chart [2].

- **Box-Plot Chart**
  The Box-Plot Chart evaluates the symmetry at the end of dividing, identification of the distant values with another point of view in contrary to the chart:
  - Calculation of quantiles $X_{25}, X_{50}, X_{75}$;
- Calculation of the rectangle length \( R = x_{75} - x_{25} \) (quantiles range);
- Determining the edges of the horizontal beams \( A = x_{25} - 1.5R \)
  \( B = x_{75} + 1.5R \);
- Chart building illustrating the median;
- Chart analysis [3].

2.5 Looking for the elementary causes of the cast defect origination

On the base of the numerical and graphical analysis results and at the points where some deflections compared to the process have been detected, it is necessary to find and remove the problem elementary cause. In the best case, it is possible to avoid the repetition of the detected cause in the production process and this, even in the future.

2.6 Creating a pattern for the defects prediction

In the case that a relation between the monitored values and deflection in the process has been found out during analyses, then there is a real possibility to create a chart which could be really able to predict its future development.

3. METHOD HOW TO SOLVE AND SET-UP THE PREDICTION OF STEEL CASTS DEFECTS OCCURENCE WITHIN THE COURSE OF THE MATERIAL PRODUCTION FLOW

For the purpose of our solution and by the mean of Pareto analysis we selected a cast where the scrap proceeded steeply and where the financial loss was also high. One kind of defect distinctly appeared on the selected cast: un-burnt wax.

The working team built up an Ishikawa chart by the mean of brainstorming and this chart helped to look for the potential causes of the defect origination. Among the most important causes of un-burnt wax, we recorded:
- Wax quality;
- Insufficiently smelt wax in the boilerclave;
- Short time period of tree annealing before casting;
- Tree incorrect structure;
- Low casting temperature.

Furthermore, a production detailed checking was proposed and this, at all of the individual production phases.

We effectuated a basic analysis of the produced pieces as well as the poor quality produced pieces due to un-burnt wax as it is illustrated in the tab. 1. The values mentioned in this table confirmed the step displacement of the poor quality production. Within the frame of a single production batch, it is possible to produce four pieces of poor quality casts and within the frame of another one, it can amount up to 322 pieces. This only defect represented a financial loss exceeding EUR 6 000.

**Tab. 1** Statistic analysis basic values

<table>
<thead>
<tr>
<th>Total amount</th>
<th>103 368 pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor quality production – un-burnt wax</td>
<td>4 469 pieces</td>
</tr>
<tr>
<td>Mean value</td>
<td>93.10</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>72.55</td>
</tr>
<tr>
<td>( x_{max} )</td>
<td>322 pieces</td>
</tr>
<tr>
<td>( x_{min} )</td>
<td>4 pieces</td>
</tr>
</tbody>
</table>

Other analyses were effectuated:
- By the mean of the chart, the poor quality casts number greatest frequency within an extent of 37-94 pieces of casts was demonstrated (fig. 2) and this, within the frame of 18 production batches (from a total amount of 48 production batches and within an extent up to 37 pieces within the frame of 12 batches.
Poor quality casts number frequency within each individual production batch

By the mean of the Box-Plot method (fig. 3), we can discern one distant value. The increased quantity of produced scrap was most probably caused by a greater production batch. On the base of available pieces of information concerning this production batch, no greater deviation has been detected.

The relation between the number of produced pieces and the number of poor quality produced casts is illustrated by the fig. 4. The correlation coefficient between these two values is of 0.8 (tab. 2). It consists in a strong linear relation. One can say that the greatest production batch is produced, the greatest the number of scrap there is. Generally taken, the number of poor quality pieces should decrease as the production batch increases. That is the reason why it will be necessary to deal with this relation in the future.

**Tab. 2 Correlations**

<table>
<thead>
<tr>
<th></th>
<th>Col 3</th>
<th>Col 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col 3</td>
<td>0.8061</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>(48)</td>
<td>(48)</td>
</tr>
<tr>
<td>Col 4</td>
<td>0.8061</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

**Fig. 2** Poor quality casts number frequency within each individual production batch

**Fig. 3** Box-Plot

**Fig. 4** Correlations chart
- By the mean of the Ishikawa chart illustration, the possible cause of the casts poor quality production emerged: wax quality. That is the reason why data coming from the wax department (fig. 5) were analyzed. It consists in the following data: nozzle temperature (Col_12), left plate temperature (Col_13), right plate temperature (Col_14), filling pressure (Col_15), amount of scrap in the wax department (Col_16) and produced pieces (Col_17).

![Fig. 5 Correlations chart](image)

Thanks to the correlation index calculation values (tab. 3), there could be confirmed that there is a relation between the cooling plates as it was logically expected and there also appeared to be an evident relation between the number of produced pieces and the number of poor quality produced pieces manufactured during the wax department operation.

**Tab. 3 Data correlation – wax department operation**

<table>
<thead>
<tr>
<th></th>
<th>Col_12</th>
<th>Col_13</th>
<th>Col_14</th>
<th>Col_15</th>
<th>Col_16</th>
<th>Col_17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col_12</td>
<td>-0,0389</td>
<td>-0,0035</td>
<td>0,2553</td>
<td>-0,5872</td>
<td>-0,5121</td>
<td></td>
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<td></td>
<td>(22)</td>
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<tr>
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<tr>
<td>Col_14</td>
<td></td>
<td>0,9775</td>
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4. **CONCLUSION**

On the base of Pareto analysis, a concrete cast with a concrete defect was selected among the products final scrap and among each individual type. It consisted in un-burnt wax defect whereas the poor quality...
production value exceeded EUR 6 000. Furthermore, we utilized Ishikawa chart in order to find the possible causes to decrease poor quality production occurrence and to propose analyzing data in each individual production phases. Among the high scrap possible causes, we selected: wax quality, wax insufficient smelting in the boilecave, short time period of tree annealing before casting, tree incorrect structure and low casting temperature. By utilizing statistical methods, basic statistic data concerning poor quality production could be found out. We found out some differences from minimal loss amounting to 4 pieces up to high loss amounting to 322 pieces of casts. By the mean of the Histogram, we detected the greatest frequency of poor quality production occurrence within batches in an extent of 37 – 94 pieces. The Box-Plot chart gave information concerning the distant value which was analyzed with such a result that it was the greatest production batch. The following correlation analysis revealed that an increasing number of produced pieces within a batch means an increasing number of produced scrap pieces too. It is also for this reason that it was decided to focus on the production from its first phase: in the wax department. In this case too, we found out that the greatest amount of poor quality wax patterns was produced while having greater production batches. That is the reason why we will consequently focus our attention on precisely defined poor quality wax patterns.

The correlation analysis was evaluated as the most useful as it enabled to calculate the relation between the inserted data within the frame of the production process and consequently, it offered the possibility to work with those data. Thanks to this method, the relation between data was revealed on the base of which a prediction chart with tolerance limits could be built up in the future and this should inform about eventual poor quality production. The advantage is that this method can be applied for a single selected defect or on a group of defects, where we are able to determine the same basic and elementary causes of poor quality production origination.

If the process is stable and if suitable and sure data are available, we can utilize statistical analyses in the production process to look for the causes of the defects origination.

REFERENCES CITED AND OTHER USED LITTERATURE

