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Some Possibilities of Using Statistical Methods While Solving Poor Quality Production

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Abstract

This paper presents an overview of a research on six practical cases that were solved in a precise casting company where parts are cast by the mean of the low-wax casting method (investment casting) in order to decrease poor quality production. The steel cast parts production technology by the lost-wax method requires the detailed work procedures observation. On the base of statistical processing data of given types of casting products, it was possible to assess the significance of each particular checking events by using the statistical hypothesis testing. The attention was focused on wax and ceramic departments. The data in technological flow were compared before and after the implementation of the change and statistical confirmative influences were assessed.
The target consisted in setting such control manners in order to get the right conditions for decreasing poor quality parts. It was evidenced that the cast part defect cause correct identification and interpretation is important.

Keywords: Poor quality, Statistical hypothesis, Production process, Investment casting, Wax pattern

1. Introduction

Within the frame of quality production system, there is effectuated the cast parts poor quality evaluation and their solving as it belongs to the scope of employment of all of the company´s employees, who can exert any influence on this domain.

The poor quality production evaluation and solving current principle in the CIREX company begins by accounting the occurrence of the individual cast parts at interoperational production phases as for example the wax models production, the ceramic treatment department and it finishes by the evaluation of the cast parts quality in the field of identification and summarization of the cast parts defects in a given production batch. The main task consists in examining the causes of concrete defects occurrence and it is followed by the presentation of the defects from the point of view of the number of cast parts as well as the evaluation of expenses loss.

On the base of poor quality production statistical evaluation, precisely defined products sorts are proposed in order to improve the cast parts quality. Consequently, technological changes are realized on concrete production operations. These groups of products are subject to exceptional analyses and consequently we decide to implement the recommended technological changes for production tests. After a new evaluation, these final recommendations are implemented into batch production [1].

2. Current Situation and Poor Quality Production Evaluation

Quality ensuring and improving is not a technical problem only but it is also an economical matter. The ISO quality management system conception deals with the economic aspects in a very little extent and this kind of thoughts are only present in the ČSN EN ISO 9004 norm, issued in the year 2001. That is why quality management should be an integral and a key element of every management. If companies deal with economical quality, the most often, they just account losses from different products and claims. This approach is insufficient [2, 3].

An integral part of the production quality management consists in the continuous daily checking of the material whole production flow and it belongs to the scope of employment of all of the company´s employees who can exert any influence on this domain. Information concerning the reached poor quality production are important and not for the producer only, but they are also especially significant information for the customer.

Theoretical possibilities how to evaluate production poor quality are based on selecting a sort of product and a concrete defect, analysis of the possible causes of the defect occurrence, data collection, data analysis, looking for the basic causes of the product defect occurrence, creating a model for defect prediction [4, 5, 6, 7, 8].

3. Analysis of Practical Examples of Poor Quality Production Occurrence

We did the analysis of several examples of poor quality of production occurrence and we consequently realized the proposed solution. The general view of the results for each individual example from 1 to 6 is illustrated in the Table 1. The report describes in details the example No. 3 with all of its inputs and outputs.

3.1. Example No. 1 resolving

On the base of the Pareto chart, a concrete cast part with a concrete defect was chosen.

It concerned unburnt wax defect where the poor quality production value exceeded EUR 6 000. Furthermore, we used the Ishikawa diagram to find out the possible potential causes in order to reduce the production poor quality occurrence. Among the high amount of scrap possible causes, we chose the following ones – wax quality, insufficiently molten wax in the boilerclave, short period of trees annealing before casting, the trees bad structure and the too low casting temperature. By the mean of the statistical methods, we could find out the basic statistical data concerning the production poor quality. We found out the differences from the minimal loss of 4 pieces up to high loss of 322 pieces of cast parts. In the greatest extent, it consisted in defects on wax models which had already been caught on the injection press and on final cast parts in the course of the production phase itself.

As first, we focused our attention on checking the correct working of the injection press. The effectuated analysis of the injection press correct working could prove nonstandard operational parameters. On the base of the results has been decided to effectuate its total reparation.

To determine the correctness, efficiency and effectiveness of the implemented measure during the wax department operation, we used a t-test and determined the significance of the difference between two selection averages.

The t-test result plainly proved that repairing the injection functioning of the injection press had a statistically significant influence on the product scrap

Table 1.
General view of the resolved examples

		Example No. 1	Example No. 2	Example No. 3	Example No. 4	Example No. 5, 6	
Problem		Wax defect – jump poor quality	Ceramic defect – jump poor quality	Wax defect – constructive failure	Broken and trees run-out	Broken off ceramic shells	
Determination		Bad injection machine	Bad fastness of connections while bonding the wax tree	Ceramic adhesions between the individual structure stages	The poorly dried-up area around the central stake	Impossibility of production the shape of casting by the lost-wax method	
Poor quality [pcs]	$X_{max.}$	322	391	1 693	2 759	2 995	5 070
	$X_{min.}$	4	41	6	48	661	196
Box plot		Outlier volume	Without outlier volumes	Without outlier volumes	Outlier volume	Without outlier volumes	
Solving		Total reparation of injection machine	New production tool for model assembling	Degreasing the number of stages on the structure, consequently increasing the annealing period	The design extension ⇒ degreased the pieces on the tree number by 10%	Change management	
Statistical signi-ficance BEFORE and AFTER		**yes**	**yes**	**no**	**yes**	**yes**	

3.2. Example No. 2 resolving

While we had a high increasing of poor quality production, we effectuated a checking analysis of the technological process on a given cast part with a focus on wax defects as well as on ceramic defect. The continuously repeating bad fastness of connections while bonding the wax tree was determined to be a possible cause of high scrap. While bonding the whole structure, there was an insufficient access to all of the connections to provide quality fastening of all of the connections [9]. However, there occurred shrinkage and the connection opened while cooling down. In the case of insufficient fastness or repeatedly consequent verifications and eventual reparations, there occurred spaces between the connected parts into which slip-slop could get while packing and this way, it created a wall in the shell cavity and this wall was broken off and leaked into the cast parts while casting.

The production technology conditions analysis reached results proved the necessity to do changes in the form of implementing a new production tool at the wax department.

Consequently, to this, we effectuated a checking test concerning statistical significance of the difference between two selection averages and it proved the statistical significance of the implemented changes.

3.3. Example No. 3 resolving

The problem detailed analysis within the frame of the quality resolving team revealed an incorrectly solved branch and this, at the construction phase already. The Fig. 1 illustrates an example of construction defect on a wax tree.

Fig.1. Structural defects on the wax tree

On Fig. 2, there are designated the defects that were found on a part of the cast part. They appeared under the level of leaking wax within the course of smelting. When there is a bad burning of wax in the course of annealing, lack of oxygen while burning or gas overpressure in the form, then there came to the creation of wax unburnable parts and its consequent gasification within the course of casting.

Fig. 2. Defect on the cast part

The tree cast part showed ceramic adhesions between the individual structure stages which limited sufficient oxygen access and then, the shell surface was insufficient during annealing. It was proposed to decrease the number of stages on the structure by 16 % of pieces on one single tree. The shell showed better properties during drying-out, wax-lost smelting and casting after the above mentioned step. The next step consisted in increasing the annealing period prolongation for a better combustion of the wax.

The basic statistical analysis was performed before and after these measurements' implementation.

The basic statistical analysis values deviations were not considerable.

The statistical evaluation of the results achieved from the example No. 3, significance are presented in the Table 2.

Table 2.
Statistical evaluations of the achieved results significance from the Example No. 3

Signature: xxxxxx	Before reparation	After reparation	Date: dd.mm.yyyy **WM XXXX**	
Average	5,70	5,14		
Standard deviation	2,10	2,23	**Result: NON STATISTICALLY SIGNIFICANT EFECT**	
F-test	$T = \frac{S_1^2}{S_1^2}$		**t-test**	$T = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{(n_1-1)S_1^2 + (n_2-1)S_2^2}} \cdot \sqrt{\frac{n_1 . n_2 (n_1 + n_2 - 2)}{n_1 + n_2}}$
F-test	$T > F_{(n_1-1, n_2-1)}(p)$		**t-test**	$\lvert T \rvert > t_{n_{1+}n_2-2}(p)$
F-test	$P - Value > 0{,}05$		**t-test**	$P - Value > 0{,}05$
F-test	Accepted H0; $\sigma_1^2 = \sigma_1^2$		**t-test**	Accepted H0; $\mu_1 = \mu_1$

Using the Ishikawa diagram on the Fig. 3, the cast parts defects occurrence was analysed in detail. The influence on all of the statistically significant defects was also shown logically and expertly by using the brainstorming method. The feeding is influenced by the tree design. The tree run-out is avoided in the case of correct feeding.

Temperature concentration has a suitable location in the case of an optimal design and drying-up also gets easier in this case. The whole design firmer shell is guaranteed by a lower water content and a lower dilation stress.

The course of the test selected on the base of the non-quality production results was specific in the point that it proved the financial saving on non-quality production but the statistical significance on the selected non-grooved and wax rat tails defects was not evidenced. Therefore, the other non-quality production defects were treated by the mean of Ishikawa diagram and the brainstorming method in order to understand the defect rising and its influence on the tree designed change. It was determined that the shrinkage, cracked shell, ceramics and bubbles defects have had a statistically significant impact effect on the change made.

It was proved by this example how important the defect formation identification and interpretation are.

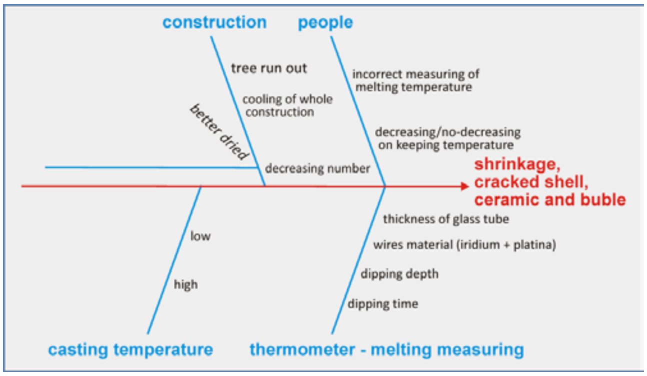

Fig. 3. The cast parts defects demonstration by the means of the Ishikawa diagram

3.4. Example No. 4 resolving

Casted central inlets showed cracklings with apparent grooves on the edges and the trees run-out possibility in a large extent. Based on the brainstorming method, the poorly dried-up area around the central stake where the crudest ceramic layer is located was determined as the probable cause. The poorly dried-up ceramic layers contained water residues capable to create vapor during further operations with high temperature and thus to create local cracklings. A higher casting temperature that gets even into the smallest cracklings impaired the tree entirety.

As a result, the design extension was performed and thus, decreased the pieces on the tree number by 10 %. The results prior and after the tree designed change were statistically evaluated with a positive result. Only the decreasing by 1,45 % on the trees run-out was achieved. The total defectiveness was lowered by 3,55 % and the ceramic defects caused by lower number of cracklings in the shell and by the ceramics released from the steel casting parts cracklings were also decreased by 0,87 %.

The example solution demonstrates the necessity of the technologic prescription observation during the tree structure assembly.

3.5. Example No. 5 & 6 resolving

Within the serial process, it was hard to create a stable, equally thick and firm ceramic layer for the sharp edge. Several different tests with a different ceramic cover density were performed together with special manipulation in the ceramic slurry and with variants of drying up period between the individual ceramic layers spreading on the tree. Change management was chosen with the customer regarding the cast part edge radius increasing. A subsequent parameter change was applied to the batch production. The achieved values were subjected to significance statistical analysis with a positive result.

4. Conclusion

The steel cast parts production technology by the lost-wax method requires the detailed work procedures observation. The presented non-quality production solution examples proved the state-of-the-art statistical methods significance for determination the cause of the steel cast parts foundry defects. We could verify the influence of other possibilities how to complete the human factor while solving poor quality production by the mean of solving each individual example of significance tests between two variances, tests presuming the basic set medium value, tests about the significance of the difference between two selected averages and also by using data analyses graphic methods by the mean of box plot, by illustrating the individual values or by the mean of using Ishikawa diagram.

It was evidenced that the cast part defect cause correct identification and interpretation is important. Another significant thing was also the recognition that in the non-quality extreme specific solution states, it is economically favourable to choose the change management with the customer method with the subsequent test, which confirmed the statistically significant influence for the cast part quality improvement in the given examples.

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