

Investigation of Stability of Fabrication System of Casting Parts

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Abstract

The article presents the results of stability analysis of castings manufacturing system. For the analysis, the Six Sigma DMAIC (Define-Measure-Analyse-Improve-Control) methodology has been applied. The studies demonstrated the ability to reduce the variance of the process, and therefore the quantity of defects.

Keywords: System, Process, Process stability, SIX Sigma methodology

1. Introduction

The term Six Sigma was created by Motorola and NC in the 80's of XX century and above all its essence was based on the assumption that if the process will be conducted according to a Gaussian distribution (mean value and standard deviation are known), we can conclude that nearly 100 % of all possible results of the process will be in the interval $x \pm 3s$. In practice it means that no more than 3-4 incompatibility occurs among the million results of the implemented process [1, 2]. The main task of Six Sigma method is based on data and facts long-term strategy for reducing variation and waste eliminating in all processes in company. A critical approach to quality from the customer perspective we define a situation where the Six Sigma method is used as an approach to improve all critical processes in the company to meet customer requirements. It requires identification and systematization of both production or service potentials, or current analysis of financial results in order to improve and control of processes.

Critical approach in management represents all the parameters of the product or service that are expected by the customer, e.g. tolerance range, surface roughness, corrosion resistance. It should be remembered that customers do not judge us on the basis of average values because they are aware of the changes that take place in any delivered product. Reductions of these changes to a

minimum provide a Six Sigma method. The aim of this method is to maintain repeatability. The hallmark of the methods of Six Sigma is a methodology of Define - Measure - Analyse - Improve - Control (DMAIC) and infrastructure. According to experts on the subject [3-11] the negligence in the construction of Six Sigma is the main reason of irregularities in the implementation of the Six Sigma project. People who are responsible for implementation and continuation of the project must first of all look at the whole enterprise. So, Practitioners have the skills and the information necessary to assess the degree of implementation of the tasks and the analysis of the results, they also have undergone the appropriate training and they are able to use the statistical tools for meeting the needs of the enterprise. The ability to catch the process absorbing too much time, material resources, and personnel is a key feature while using the Six Sigma methodology.

2. DMAIC methodology

Two basic methods to make implementation of projects easier in accordance with the Six Sigma guidelines have been developed. The first of these is generally known [12, 13], and is mainly used in the case where we do not know the effective solution for the existing product, process or service. This method is called DMAIC. The other one is relatively recent developed and is

called as Design for Six Sigma (DFSS) method. The objective of DFSS is to create a new process product or service that is devoid of defects in the eyes of the customer. It should be remembered that DMAIC is only the stage between the planning and the actual action. Furthermore, it is a process for Six Sigma projects but not a way of designing. DMAIC methodology diagram is shown in Figure 1.

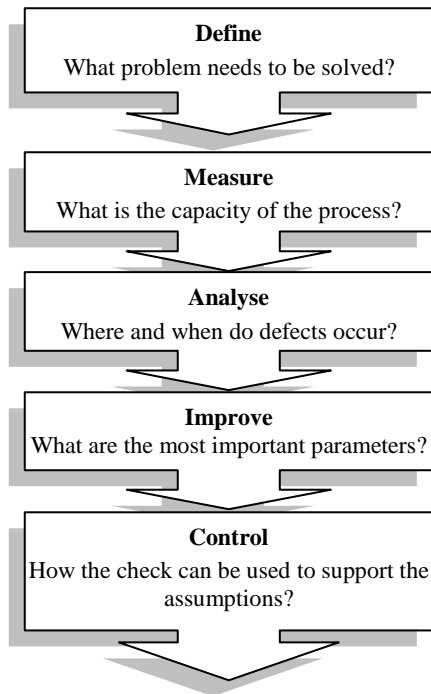


Fig. 1. Schematic DMAIC methodology

- D – defining the objectives to be achieved (development of detailed map of the process, the generation and selection of variables, developing a plan for data collection, assessment and verification of the measurement system, the development of a statistical picture of the process),
- M – the measurement of the current state (development of a detailed process map, the generation and selection of variables, development of a plan for data collection, assessment and verification of the measurement system, the development of a statistical picture),
- A – analysis of the current state carried out in order to suggest a way to eliminate the defects identified in the process (initial analysis of the data, verification of hypotheses, building a statistical model of the process),
- I – the use of the proposed solution to eliminate defects (generating solutions, evaluation and selection of solutions, risk assessment, a pilot project, the choice of solution),
- C – evaluation of performed changes (evaluation of the obtained results, the amendment, the establishment of new standards, evaluation of business results, conclusion of the project).

Six Sigma is undoubtedly a diversified but well-considered industry strategy for the enterprise. It is the strategy for continuous and consistent process improvement. Tools offered by Sigma Six are not closely assigned to any of the stages, what provides

operational flexibility and ensures the improvement of any process and product.

STAGE I – DEFINE

On the department of mechanical treatment there are more than 25% of the parts that do not meet quality requirements. These defects are revealed during mechanical working. The aim of the project is to improve the production process of the cast part by analyzing all stages of the process and reducing the number of parts that do not meet the requirements to the level of 6σ . The project includes two departments: department of foundry engineering - internal supplier and department of mechanical working. A preliminary cost analysis is presented in Table 1.

Table 1.
Preliminary analysis of the costs

Estimation of costs	
The cost of the casting	40 zł
The cost of the finished part	120zł
Estimated average share of pieces that do not meet the requirements	25%
Approximate cost of the part does not meet the requirements in batch of size $n = 1000$ pcs	17760zł
Savings on the one batch after changes	17 000 zł

STAGE 2 - MEASURE

The production system is called stable when there are not special reasons for variation - it is a system where the results of the operation are within the limits of its natural dispersion. Natural causes (accidental) are an integral part of the process. They consist of many partial causes (individual), but each of them results in a minimum number of variations. But acting together they may result in overall large wastes. Special causes (systematic errors) need to interrupt the process and explain the reason. They consist of one or only a few individual causes and each of them can cause a high variation value.

Figure 2 shows a control graph of the amount of wasters in 19 production batches of cast bracket lot size of each 1,150 pcs. In the case of system stability all results values should be between the upper (UCL) and lower control limit (LCL). The process is especially influenced by the causes of the variation that lead to shift in the mean value of the process and increase the variance of the process (Figure 2). In the stable system these errors must be identified and eliminated.

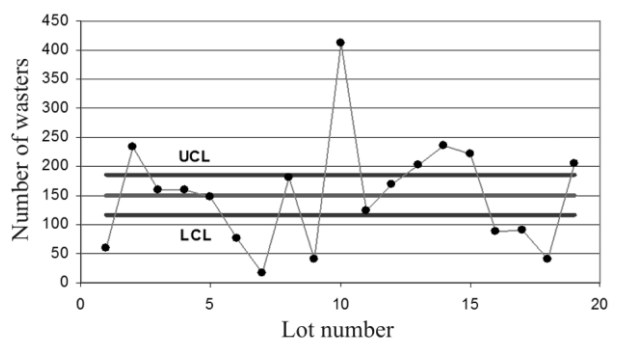


Fig. 2. Inspection diagram of the number of wasters

STAGE 3 – ANALYSE

To identify special causes of defects appearance the 10th and 17th batches of the cast brackets are analyzed. In Table 2 and 3 the details of the type and quantity of their occurrence are shown.

Table 2.

Identification of defects for 10th batch

No.	Defect name	Amount of faulty pieces	Percentage, %
1	Material discontinuities (oxides, porosity)	576	50.1
2	Surface check	207	18
3	Near-surface material loss	174	15.1
4	Dimensional errors	148	12.9
5	Internal misrun castings	45	3.9

Table 3.

Identification of defects for 17th batch

No.	Defect name	Amount of faulty pieces	Percentage, %
1	Material discontinuities (oxides, porosity)	435	37.8
2	Near-surface material loss	294	25.6
3	Dimensional errors	230	20
4	Internal misrun castings	102	8.9
5	Surface check	89	7.7

In order to determine the main causes of disturbance of the process for both inspection lots, it is developed Pareto - Lorentz charts presented in Figures 3 and 4.

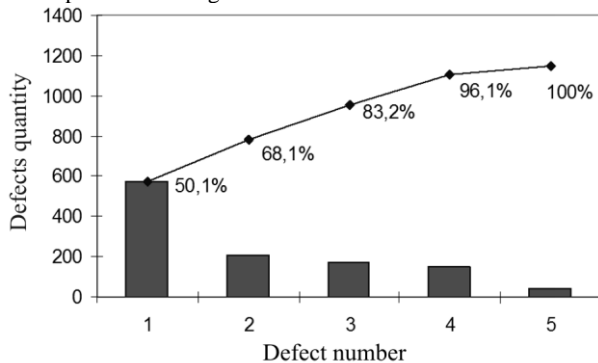


Fig. 3. Pareto - Lorentz chart for 10th inspection lot

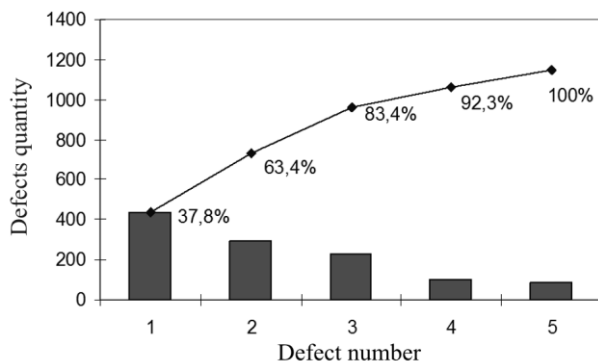


Fig. 4. Pareto - Lorentz chart for 17th inspection lot

As can be seen from the Figures 4 and 5 the main defects are:

1. Material discontinuities - average of 44.5%,
2. Near-surface material loss - average of 20.3%,
3. Dimensional errors - average of 16.4%.

These defects account for nearly 80% (79.8%) of all the defects in the test product.

A detailed analysis of the process showed that the most important causes of defects include:

1. Employee:
 - to cast unskilled people transferred from another departments are recruited,
 - workers remove the cast from the permanent mould too quickly that causes cracks in the outer surface of the casting (provided by technology permanent mould hold time is 2.5 min),
 - workers can perform the activities which are not in conformity with the technology (installation of filter mesh and the speed of pouring of permanent mould).
2. Material:
 - currently supplied material has worse pour properties and it is more contaminated comparing to the material obtained from the previous supplier,
 - gases during solidification can cause air bubbles and contribute to the formation of internal defects and near-surface material defects.
3. Cast core:
 - incorrect core dimensions directly affect the dimensions of the casting,
 - not dried core after painting in the casting process causes the release of steam and consequently the formation of air bubbles,
 - escaping gases can cause internal defects in the form of local material discontinuities and they also can cause subsurface defects.
4. Gating system:
 - incorrect construction of gating system, supply ducts and riser head.

STAGE 4 – IMPROVE

As the result of the conducted analysis the following operations are undertaken:

- staff has been trained in order to carry out their activities in accordance with the technology, particularly in the treatment of permanent mould before re-pouring, speed of permanent mould pouring, the length of time of holding the cast in permanent mould and the proper placement of the core,
- to reduce the effect of air bubbles it is necessary to reduce the amount of emitted gases. To achieve this better material for the core was used and the structure of the riser head was changed.
- to eliminate the dimensional errors the new permanent moulds were fabricated and the employee was instructed to pay attention to the surface of the cast during cut of the gating system.

STAGE 5 – CONTROL

To determine the effectiveness of the actions the test batch of castings of size 1376 pieces was fabricated and it was analyzed for the presence of defects. Table 4 shows the details of the type and quantity of their occurrence.

Table 4.

Identification of defects

No.	Defect name	Amount of faulty pieces	Percentage, %
1	Near-surface material loss	32	53
2	Dimensional errors	26	43
3	The removal of excessive amounts of material at cleaning	1	2
4	Internal misrun castings	1	2

As seen from the data presented in Table 4 the taken into consideration changes was allowed to eliminate the surface layer cracks and limit the total amount of wasters to 4.36%.

3. Conclusions

After making changes the casting process proceeded correctly and the number of defective parts did not exceed 5%. This means that the technology of casting is correct and the formation of defective parts was primarily caused by a lack of qualified staff and inappropriate materials. In order to determine the stability of the system more batches of products should be checked to determine if the number of defective parts will stabilize at a level of 5%. If yes, a more effective way to control materials and qualifications of employees should be developed, what should result in the decrease in the variance of the process. Otherwise the changes in casting technology should be done.

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