Application of Production Management Methods for Improving Manufacturing Processes

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Abstract
The paper presents several stages developed in order to improve the production quality of an impeller by using Six-Sigma-DMAIC methodology. The paper highlights the importance of implementing, in the area of production, of management activities seen from Lean Six-Sigma point of view, as instruments for activities improvement. It involves a number of techniques, which lead, in case of correct implementation, to stable processes based on eliminating defects and reducing variation. Combining Lean instruments with the ones for reducing variations (Six Sigma) determines, in the end, not only elimination of errors but also preventions further of errors. In the case analysed, the large number of scraps is leading to delays in product delivery to customers. As documented not only process identification but also practical changes in manufacturing process is the key to delays and scraps reducing.

Keywords
DMAIC, impeller, balancing, scraps, delays

1. Introduction

Process, subject to the analysis in this article, is the one of balancing an impeller. This process is important, of course from vibration point of view, and must respect tight client requirements. Unlike other rotating parts, is not simple to calculate how much weight to remove and exactly where to remove it. At this balancing process are involved two equipment, namely the one that read the imbalance and the one that correct the imbalance. The scope of the first process is to sort the parts by level of vibrations. If the part is under specifications this ones must be balanced. Balancing the impeller is made by material removal, from specific areas, through milling. As documented below, the production process is impaired by numerous factors and decision was taken to improve by using Lean Six Sigma [1] methods.

In accordance with the certification requirements, DMAIC actions (Define, Measure, Analyse, Improve and Control) involves the following steps [2]:

1. Define - in this phase, activities are oriented to define the problem, improvement, or finding opportunities for improvement and custom requirements.
2. Measure - at this level are measured the process performances.
3. Analyse - this stage implies the identification of causes of process variation that conduct to poor performances.
4. Improve - knowing the causes, in this stage are applied several measures to correct them, therefore to eliminate defects.
5. Control - this last phase is the key to maintain the desired quality because control activities address the future process performance.

Each presented phases are accompanied by corresponding deliverables. This stages will be applied to the process described in chapter two in order reduce the instability.

What makes this method for improvement very attractive is the fact that makes possible to translate qualitative factors in a numeric format. In this way, it is possible to apply statistical methods for exact identification of problems respectively for the adequacy of the remedies. Combining Lean instruments with the ones for reducing variations (Six Sigma) determines, in the end, not only elimination of errors but also preventions of errors. It is recommended to start the process improvement with a FMEA (Failure Mode and Effects Analysis) analysis. FMEA is a systematic approach for identifying all possible failures in a design, a manufacturing or assembly process [3]. The use of "Sigma" methodology, as a benchmark of process capability, is now becoming a common thing in industry. This measure of sigma is referring to the distance to target or to the center of process. One of the challenges for the production process refers to obtaining of precise estimations of capability by using data collected for shorts periods and that is at least one reason why Six-Sigma [4] is increasingly in usage.

2. Process Description

The process under evaluation in this article is the one applied to balancing an impeller (Fig. 1). According to standard ISO 1925/2001 [5], unbalance is "that condition which exists in a rotor when vibratory force or motion is imparted to its bearings as a result of centrifugal forces". In the first instance, the impeller is mounted for three seconds magnetisation cycle. This stage is very important for further development of balancing process. After this, the impeller is mounted in the balancing machine (Fig. 2). Initially, the process of balancing is done by eliminating material, though milling in one plane, from the surface of the nut.

Fig. 1. Impeller mounted for magnetisation

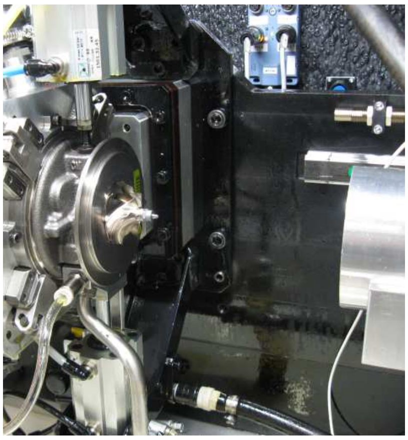


Fig. 2. Impeller mounted in the balancing machine

For the impeller balancing process, according to the first stage of DMAIC activities, the following were resulted:

- In analysed period, 88% of impeller batches (balanced on balancing machine) were delayed.

- The overall time was greater than the one agreed with the client, in other words, the production time it is greater than the planned one.

In particular, the exact causes and number of losses are presented in Table 1.

Table 1. Initial process assessment

Reasons for delay	Annual losses - pcs.	Recovery possibilities
Scrap	8.000	-
Incorrect positioning	1.200	Nut change
		Rotor change
Wrong cuts	6.000	Nut change
		Rotor change
Magnetization	500	Nut change
Part contamination	500	Nut change

The first analysis conducted was the one centred to production time, based on following:

- 180.000 part/year; 1.500 parts/month; batches of 215 parts planned for 7 days / month
- measurements of ten pieces per batch
- cycle time for a normal process: 90±5 sec/ part
- 1 cycle = imbalance read + 1st mill
- different operators

The measured values for cycle time were 105, 130, 150, 99, 110, 97, 105, 99, 110, and 130. As evident, none of these values is closer to normal work cycle.

Evaluation of data collected from balancing process can be analysed using various technics, histogram being the chosen method of representation. Numerical analysis and graphical representation was done by using Minitab software [6] from the PRO-DD-Research and Development Institute of

Transilvania University of Brasov. The overview of initial situation is presented in Figure 3. As visible from histogram, from measured values, and Cpk value, the process cannot fit to into normal cycle.

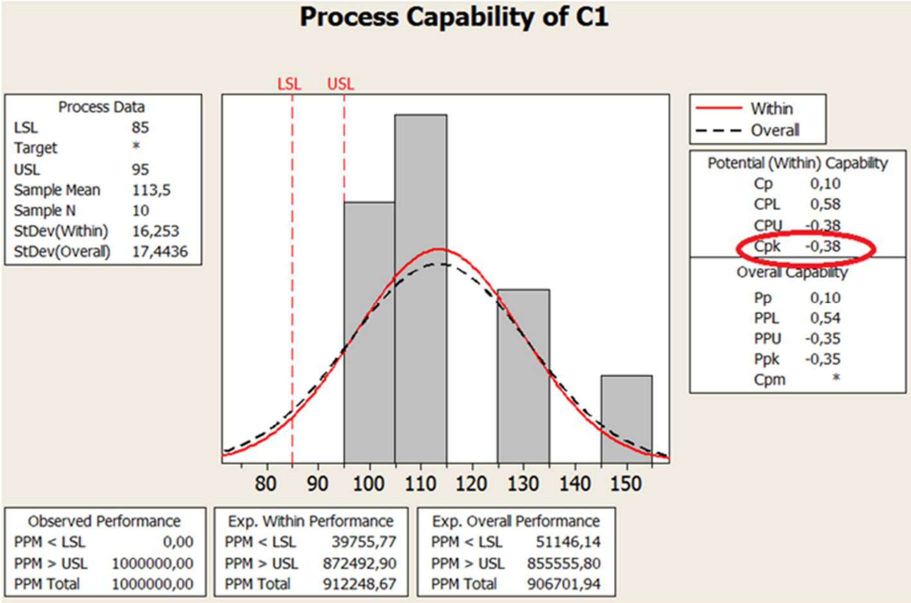
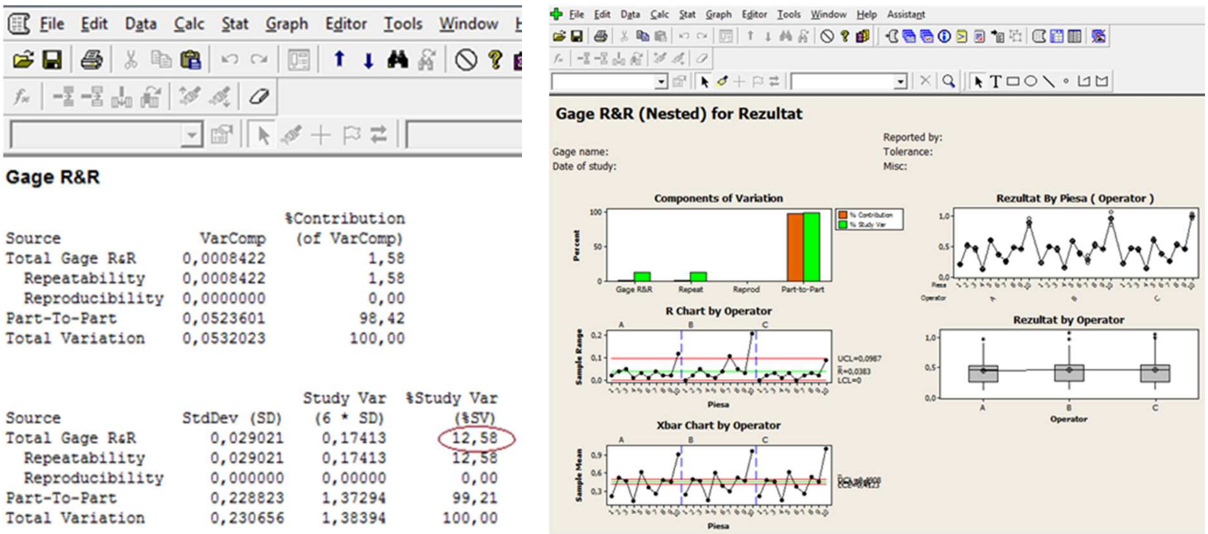


Fig. 3. Initial assessment of process capability

A related analysis was conducted to identify whether the scrap problem and delays are generated by operators or by measuring methods and devices. These measurements were performed to establish the process repeatability and reproducibility. In order to asses these, Minitab's Gage R&R analysis [7] was used. Gage R&R study helps investigate the following:

- whether measurement system variability is small compared with the process variability.
- how much variability in the measurement system is caused by differences between operators.
- whether measurement system is capable of discriminating between different parts.

The Gage R&R initial results are presented in Figure 4. A process is conform is the value for "Total Gage R&R" is below the level of 10%. In the initial evaluation, the calculated value is 12.58.



Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0,0008422	1,58
Repeatability	0,0008422	1,58
Reproducibility	0,0000000	0,00
Part-To-Part	0,0523601	98,42
Total Variation	0,0532023	100,00

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)
Total Gage R&R	0,029021	0,17413	12,58
Repeatability	0,029021	0,17413	12,58
Reproducibility	0,000000	0,00000	0,00
Part-To-Part	0,228823	1,37294	99,21
Total Variation	0,230656	1,38394	100,00

Fig. 4. Initial Gage R&R analysis

3. Corrective Actions and Evaluation

At the production level, there are many losses. These values can be evaluated only from client point of view. Taking in consideration those presented, it is decided, in the first instance, to accurate identification of the specific phases in relation to balancing process, the graphical form being presented in Figure 5.

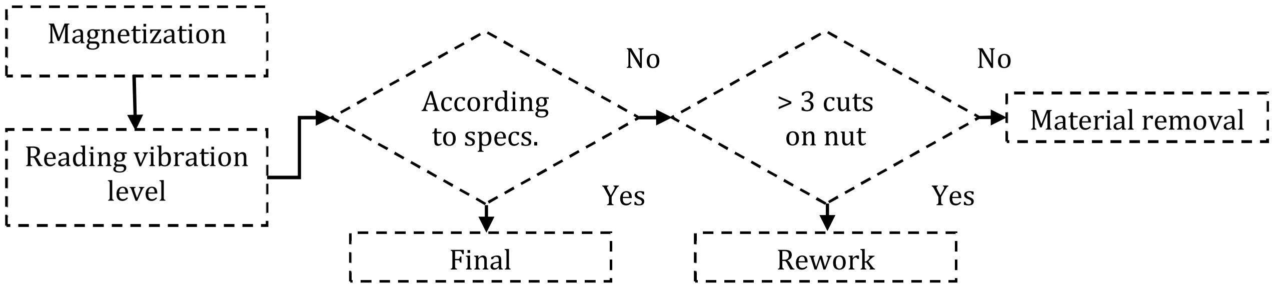


Fig. 5. Process mapping

Because of large numbers of nonconforming products, the first practical action was the one to balance the impeller using two-plane method, as presented in Figure 6, milling both nut and impeller. Two-plane balancing is a procedure by which the mass distribution of a rigid rotor is resolved into two planes and adjustments made by removing mass (in this case) in those planes in order to reduce the primary and secondary force couple caused by the initial unbalance.

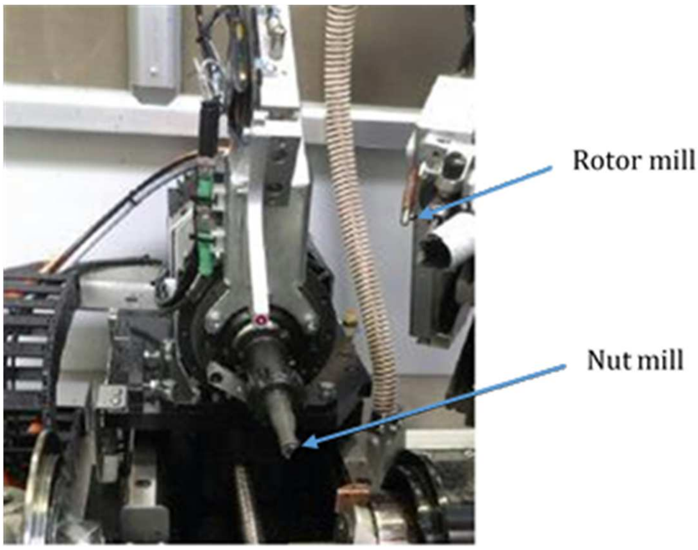


Fig. 6 Two-plane balancing

Because many non-compliant products result from incorrect positioning, the second implemented action it was to equip the working stations with supplementary checking and control systems. The new systems are used in combination with sensors and limit switches. In this way, devices are acting as a switch, which will start or stop a certain operation. In particular, for balancing process were implemented the following:

- Lateral sensors - they prevent process evolution in the moment when an obstacle or the operator interferes with the process. These two sensors are mounted on lateral sides of the milling machine. Sensors purpose is to protect the operator, to support the efficient running of the process, and to prevent unauthorised interventions. When a balancing process is interrupted, the machine must be stopped and current part must enter into rework area.
- Video camera - via related software/monitor is used to inspect the rotor dimensions and to help the operator to reference the impeller.
- Grippers with sensors - in order to maintain the rotor in a steady condition, and to facilitate an easy and correct mounting position, a set of grippers were developed specifically for this impeller (Fig. 7).

In the end, a new set of documents were elaborated in order to document the improved process.

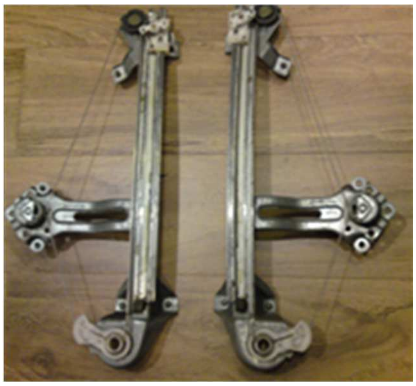


Fig. 7. Grippers with sensors

After all modifications presented, a new set of measurements were conducted in the same conditions as the first one. From capability point of view, the results are presented in Figure 8. The process is now centred and present a Cpk equal to 0.5.

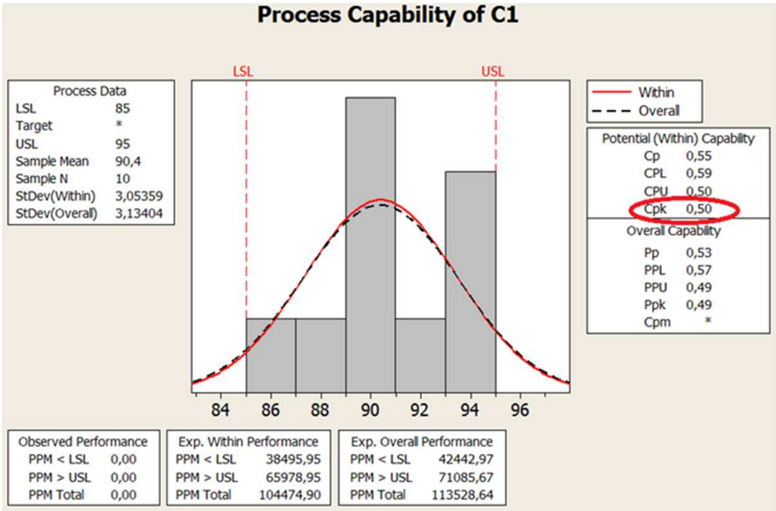


Fig. 8. Process capability after improvements

The results for Gage R&R analysis after improvement is presented in Figure 9, and the value for Total Gage R&R is now down to 7.22%.

4. Conclusions

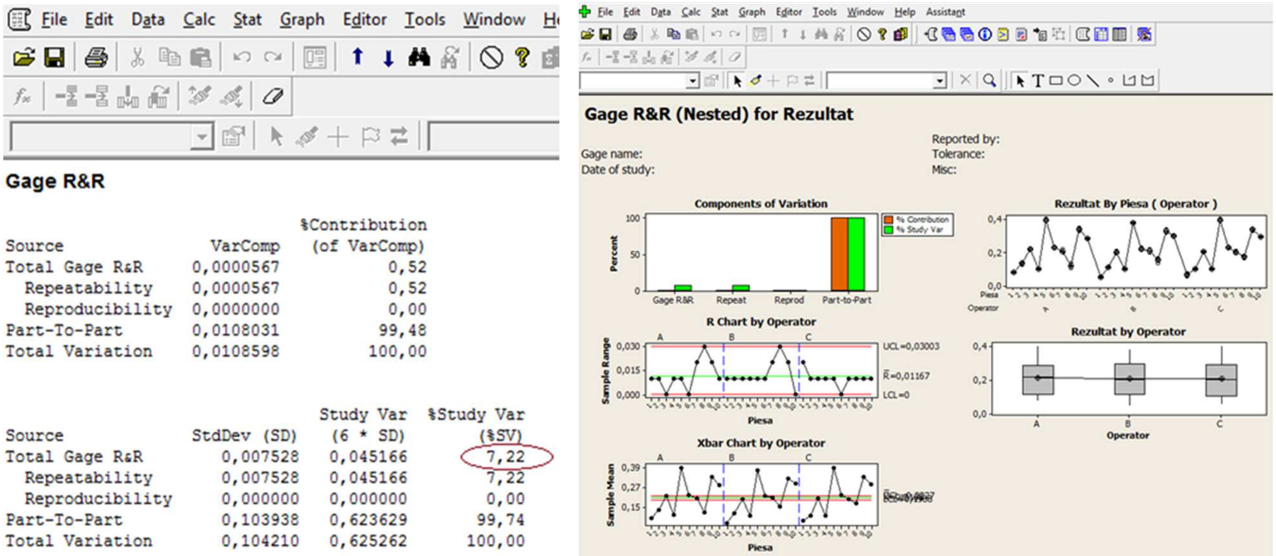
In this paper are presented some production management technics in order to precise identification of activities that are not adding value to the process, which determined the subsequent steps:

- Establish process phases and detecting problems leading to delays,
- FMEA analysis based on identified problems,
- Preparing the improvements implementation plan,
- Implementing of corrective actions,
- Results analysis before and after implementation of process improvements.

To identify process capability and stability before and after modifications, the following phases were covered:

- determining sample from which data will be collected,
- realisation of graphic representation of data before and after changes to better analysis
- identification of Cpk and Total Gage R&R values, before and after improvements, was done using Minitab software.

In the end, the process of impeller balancing could be characterised as a Six-Sigma process and the delays and scraps were reduced.



Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0,0000567	0,52
Repeatability	0,0000567	0,52
Reproducibility	0,0000000	0,00
Part-To-Part	0,0108031	99,48
Total Variation	0,0108598	100,00

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)
Total Gage R&R	0,007528	0,045166	7,22
Repeatability	0,007528	0,045166	7,22
Reproducibility	0,000000	0,000000	0,00
Part-To-Part	0,103938	0,623629	99,74
Total Variation	0,104210	0,625262	100,00

Fig. 9. Gage R&R analysis after improvements

The results from loses point of view are presented in Figure 10.

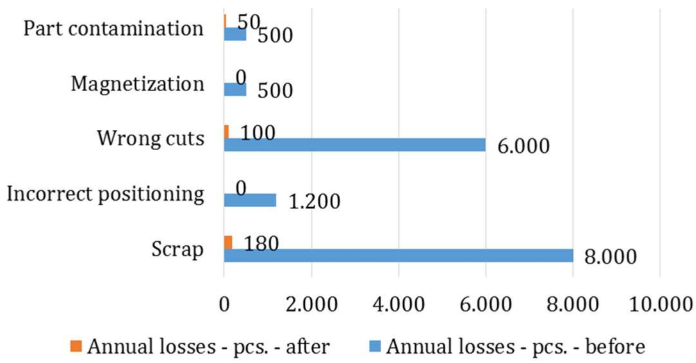


Fig. 10. Process evaluation after improvements

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