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IMPROVING QUALITY MOULDING LINE THROUGH SIX SIGMA

BY

ALEXANDRA GEORGIANA DZETZIT*

"Gheorghe Asachi" Technical University of Iaşi, Romania,
Department of Machine Manufacturing Technology

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Abstract. Quality it is one of the most targeted objectives of the nowadays products and processes. For developing and helping to find the best results, analyze and understanding the usage of the tool Six Sigma will be elaborated during the research. The methodology used is based on the Six Sigma concepts (DMAIC) and most of the calculation it is based on formulas and charts already launched. The statistical data of the process can determine if all the requirements are fulfilled if the product and process's values are in tolerance. By using this kind of charts, it is removing the probability causing the defects and reduces variation into the objective or even exceeding it. The results will show an improvement for delamination on a casted housing used for the assembly of a brake system using the concepts of Six Sigma.

Keywords: Six Sigma; DMAIC; product and process improvement; quality.

1. Introduction

Into the latest automatic and manual line, it can be recorded relevant data that can be used for improving the quality of the work, of the products and the output of the line. This can be done through statistical analysis, production

*Corresponding author; *e-mail*: dzetzit.alexandra@yahoo.com

data from the machines, process appointing. In the end in the manufacturing production lines was successfully introduced the process of Six Sigma. Of course, the successful it is not guaranteed due to incomplete data or misaligned of the Six Sigma methodology.

Six Sigma is a method and a selection of proper tools with the specific goal of developing a process regarding a deviation of results and rates of failures. In the beginning, this method was developed in 1986 by Bill Smith at Motorola (Gitlow and Levine, 2005). The Six Sigma is aligned from the process variation's standard deviation. A usual process is normally distributed in a bell-shaped curve, The Gaussian error distribution curve (Ben Ruben *et al.*, 2018).

2. Six Sigma Roadmap

Usually one of the steps used for the optimization of the Six Sigma it is the circle DMAIC. This division of the process is made into 5 steps: Define, Measure, Analyse, Improve and Control.

This step can be figured out in Fig. 1 with additional remarks that can be used for identifying the relevant steps.

Fig. 1 – Six Sigma Roadmap DMAIC.

2.1. Define Phase

One of the first steps into the description of the DMAIC tool it is the define phase. Here can be find different concepts like:

– timeframe usually the quality improvement program is lasting 1 year long;
– milestones that needs to be achieved during the project;
– budget based on quantities and deliveries;
– Project Charter: sponsors, stakeholders;
– SIPOC Diagram;
– Voice of the Customer. Since into the project is not necessarily directly involvement it should be discussed also with him.
– CTQ. After we found out the needs of the customer, the CTQ in general founds out the critical specification of the process and sets the target to that. Usually Critical to Quality can be replaced by CTX, where X it is cost or CTS, where S satisfaction. That applies to the project and the needs.
– Introduction to Data

Defining the description of the problem it can be said that it would be presented a program for improving the delamination on a plastic housing used for the assembly of a brake system. Usually these kinds of projects are running for improving the 3 top-down projects: quality, cost and delivery for the upper housing from supplier XXX.

The product it is housing and the main function it is the central locking of the product, assurance of tightness to high impacts and fits into car for maintaining the exact communication with the body controller unit.

Problem statement and baseline period: December 2017 – February 2018. The purpose of starting the program was to reduce the flatness of the product and to bring it in the specification. The flatness fluctuates between the 2 cavities of the tool. The distribution of the flatness values it is increased. The scrap rate of the assembly line in the power pack it is 30%.

The mission statement it is to bring flatness for upper housing tolerance until the production it is increasing and the scrap rate to be reduced under <2%.

The expected result for the expected savings (COPQ- Cost of Poor Quality) should be 35000 euro (Fig. 2).

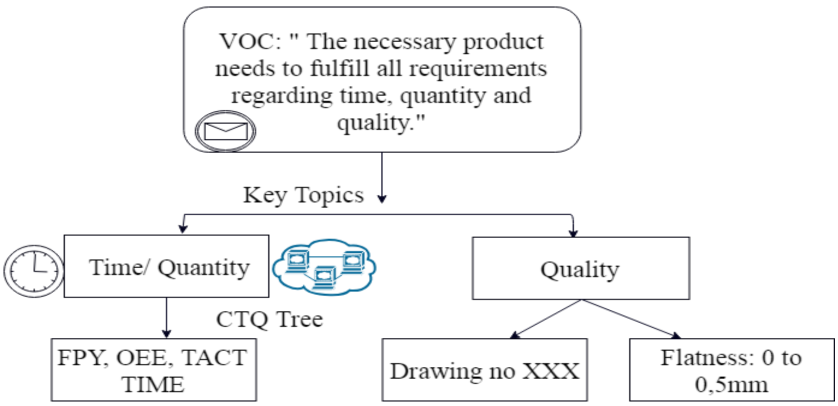

Fig. 2 – Key points for the result.

2.2. Measurement Phase – What we Have Now and which Base?

The actual status of the process can be evaluated from measurement point of view. Performing some of the necessary measurements, from capability index you can see where the problems are in the current process lies.

Another goal is to select the input and output variables, to have it correctly and to follow it until the final results. A data acquisition strategy is elaborated, when the measurement equipment was proven to be suitable using Gage R&R.

The term of SIPOC is using for analyzing all the process, from raw material, incoming inspection until the final customer that makes the assembly (Fig. 3). On the left part of the diagram are required the input parameters and their suppliers required that are written on the next columns, the middle ones are containing an overview over the process steps and on the right side the output and related customers.

For our process description and our problem solving, the following Fig. 3 is describing some of the topics.

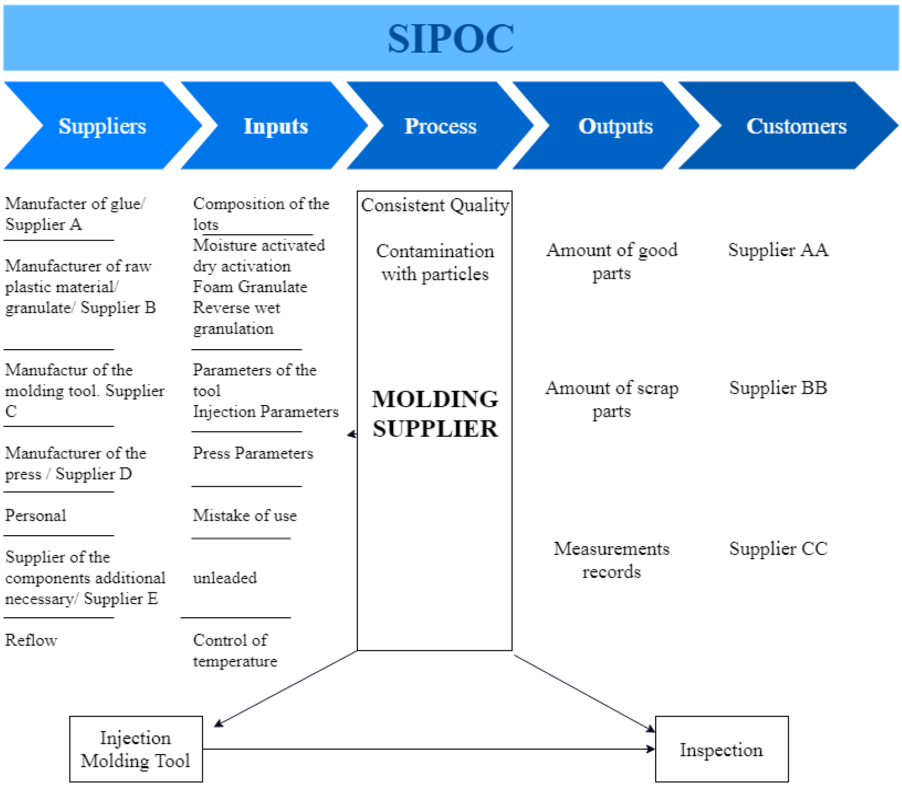

Fig. 3 – SIPOC analyze for our investigation.

The measured data, like it is presented below, can be used for determining the process capability.

In the below chart, the value of the flatness calculated with the next formulas can be seen that is fluctuating consistently.

Rbar standard deviation estimate of σ:

$$R_i = x_{i,max} - x_{i,min} \tag{1}$$

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_m}{m} \tag{2}$$

$$\hat{\sigma}_{\bar{R}} = \frac{\bar{R}}{d_{2,n}} \tag{3}$$

S charts are preferred when the subgroup sizes are large (n>8) because the range based approximated of standard deviation that becomes increasingly less efficient than the simple standard deviation form (Eqs. (4) and (5))

General Form:

$$UCL = d_{2,n}\hat{\sigma} + 3d_{3,n}\hat{\sigma} \tag{4}$$

$$CL = \bar{R} \tag{5}$$

$$LCL = d_{2,n}\hat{\sigma} - 3d_{3,n}\hat{\sigma} \tag{6}$$

If using the pooled standard deviation estimate $\hat{\sigma}_{u,p}$:

$$UCL = d_{2,n}\hat{\sigma} + 3d_{3,n}\hat{\sigma} = d_{2,n}s_{u,p} + 3d_{3,n}s_{u,p} \tag{7}$$

$$CL = d_{2,n}\hat{\sigma} \tag{8}$$

$$LCL = d_{2,n}\hat{\sigma} - 3d_{3,n}\hat{\sigma} = d_{2,n}s_{u,p} - 3d_{3,n}s_{u,p} \tag{9}$$

So using data from the machines and the formulas upper, next chart that can show the values out of specifications were created (Fig. 4).

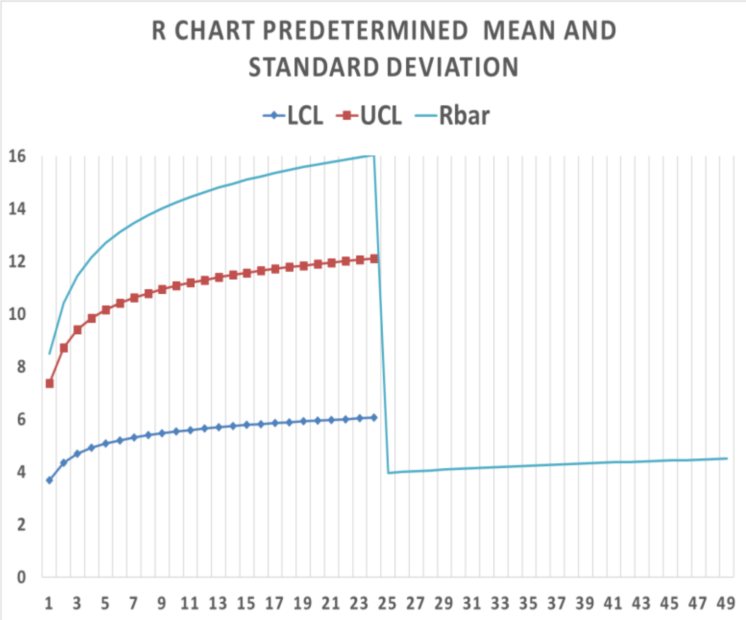

Fig. 4 – Experimental results with formulas for flatness.

The values are put of specification and after some improvements on the line have even gone on the lower limit or even down (Figs. 5 and 6). For the values with lower values was used an application for interpretation of data, Minitab that can shows us the evaluation of the values and process capability (Chee Kai, 2017).

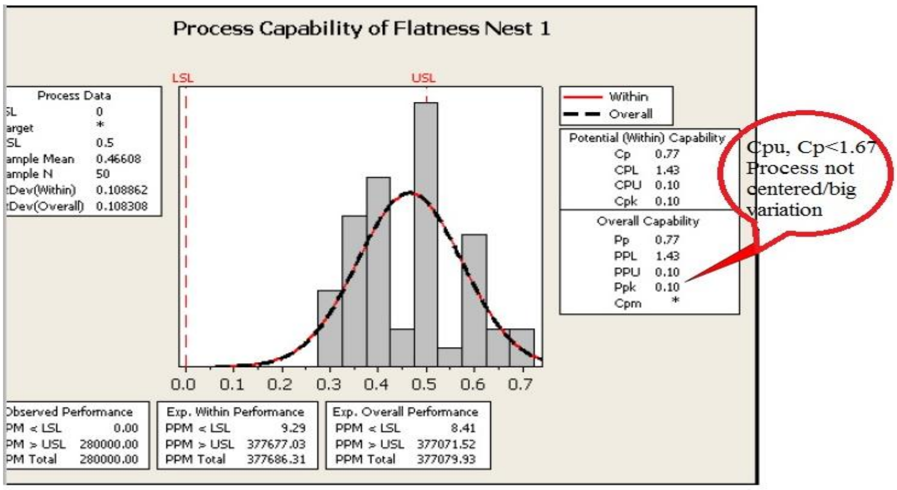

Fig. 5 – Process capability of flatness for nest 1.

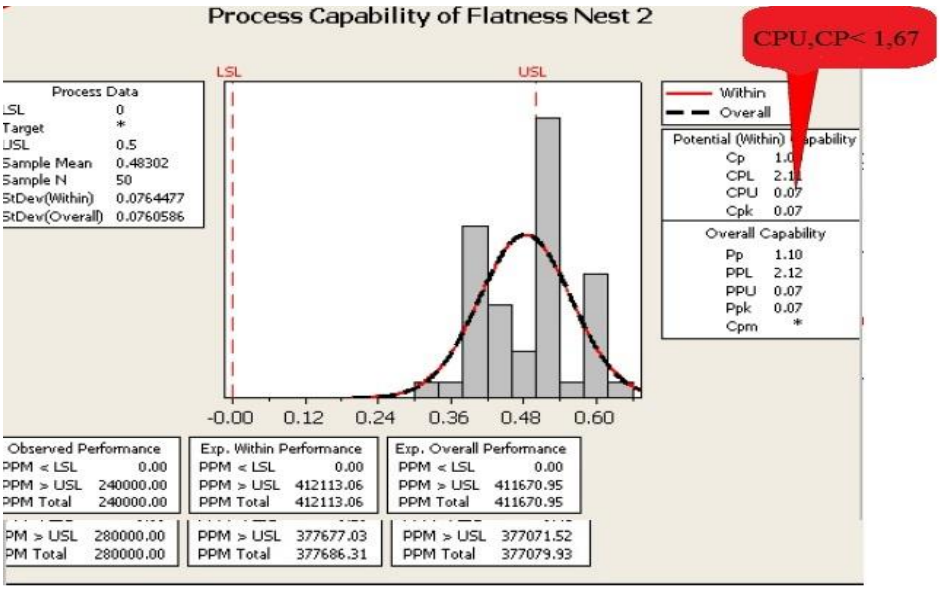

Fig. 6 – Process capability of nest 2.

The performance of the process it is determined by the values of the process capability. In the diagram interpretation, they are multiple capabilities indices which can vary differently from each another:

Cp that shows on shortened period the process, disregarding the centering; Cpk that shows process capability, regarding centering; Pp long standing capability, regardless of centering; Ppk long standing capability, taking centering in account.

These values are precisely connected to the sigma level. A good performance of a process should have at least a Ppk of 1.33 and a Cpk of 1.67.

How it can be say that the cp and ppk are a measurement tool to indicate how stable it is the process and within the specific limits, it can be possible to improve the process capability both by improving the process and the controlling limits.

It can be seen in the Figs. 5 and 6 that the process it is not yet capable, and it can improve (Indrawati and Ridwansyah, 2015). It can be seen, from the experimental data that the short-term capability is mainly affected by variance of the process results caused by tolerances, while the other one on a bigger period includes effects like changing temperature and wear of tools over longer time frames.

2.3. Analyze Phase

After the values had been established, during the analyze phase the goal it is to filter the Xi constrained for the observed deviation of the results Yi from the possible influences Xi.

Seen the values below it can be visible that the variations are coming from the process of casting so in order to analyze the process outputs a cause and effect matrix it is necessary to be established.

From the Fig. below, it can be seen some of the important X's:

X1 – Casting tool Temperature (°C)

X2 – Pressure holding (bars)

X3 – Hot runner temperature (°C)

X4 – Cooling system acting in time (s)

X5 – Injection speed and filing time (mm/s)

Introducing this values into an equation we can determine Y(flatness) = f (Casting parameters).

In this phase can be used a lot of methods for find the right approach. This can be: the hypothesis testing, t-Test, f-Test, test of correlation of two variables, analyses of variance (ANOVA), design of experiment.

Usually this is done after it had been examined for relevance to the problem the determined influencing inputs have to be verified to see if the inputs are impacting or not (Lópeza *et al*., 2016). During this experiment, the size of the new sample is determined which should be big enough to verify the assumptions without doubt, but no bigger than necessary (Gitlow and Levine, 2005).

5 Factors / 2 levels /1 center points/ 1block

1. Tool temp.	70	80	92	
2. Holding pressure	500	600	700	bars
3. Hot runner temp.	255	260	270	
4. Cooling time	11	16	21	s
5. Injection speed	15	20	30	mm/s

Output(Y) = Flatness<0.5mm

2.4. Improvement Phase

In this phase are used tools aiding inspiration and creativity like Six thinking Hats, Poka Yoke or solutions that are implemented on the process to really improve the output. For this, many researchers have been applying DOE (Design of Experiments) methods for the injection process that could make a difference on complex or simpler geometries (Lópeza *et al*., 2016; Gitlow and Levine, 2005) (Fig. 7).

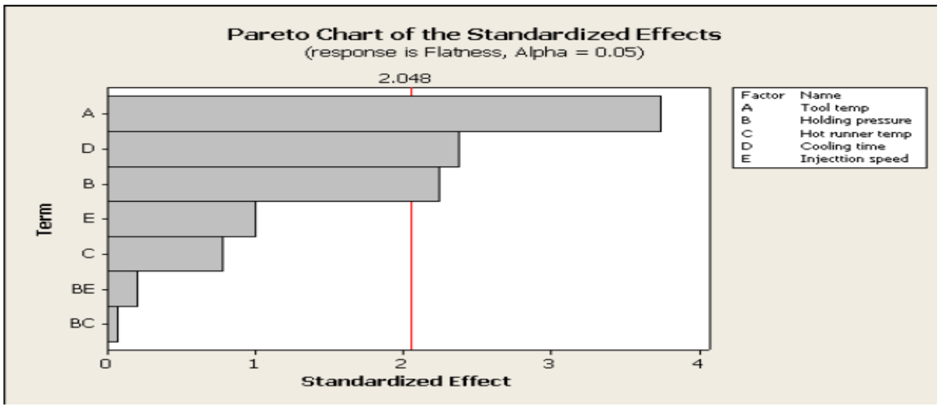

Fig. 7 − Important factors into DOE process analyze.

2.5. Control-Phase

After all the improvements are introduced it is very important to document it and to store the data inside the databases and distribute internally.

The achievement of the project is evaluated and the complementation of the project is completed. In the graph below it can be seen the improvement that were done on the final phase of the project (Fig. 8).

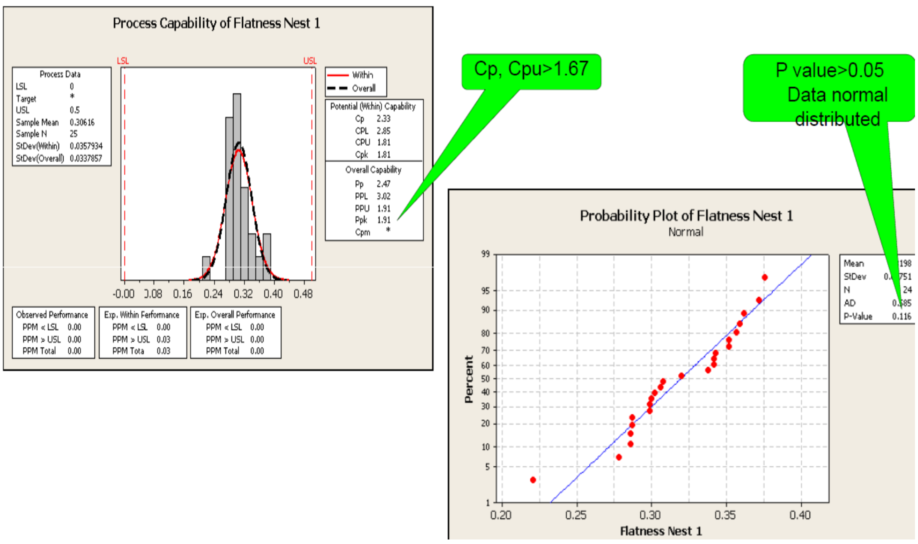

Fig. 8 − Values positive for cpk and ppk for flatness.

The introduced corrected measures are incorporated into standards documents, specific documents and work instructions. But even the best solution is useless if they are not control by trained and responsible people.

In the final result can be shown that the team documented the final results at project close out:

- Static flow defect rate was decreased from 31.5% to 1.9%
- This exceeded the goal of 1%.
- Savings was $37K.

That is why it is very important to monitor the process and to correct the problem even from the initial phase.

3. Conclusions

Multiple methods have been proposed to face with the manufacturing problems. An efficient assessment methodology is essential for the desired model. This paper put away by describing the fundamentals of six-sigma methodology (Wang *et al.*, 2014). Statistical process control can be used to every phase of manufacturing and business unit. This project can be more investigated and to be prolonged to a variety of risk for sustainable environment.

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ÎMBUNĂTĂŢIREA CALITĂŢII UNEI LINII DE INJECTARE PRIN SIX SIGMA

(Rezumat)

Calitatea este unul dintre cele mai dorite obiective ale producţiei şi ale produselor din ziua de astăzi. Pentru dezvoltarea şi găsirea celor mai bune rezultate, pentru analiza specifică a acestui caz s-a utilizat unealta Six Sigma în elaborarea acestei lucrări. Metodologia folosită este bazată pe conceptele (DMAIC) şi majoritatea calculelor sunt bazate pe formule şi grafice deja lansate în alte lucrări. Datele statistice ale procesului, pot determina stabilitatea procesului, dacă toate cerințele sunt îndeplinite şi dacă valorile produsului şi ale procesului sunt în parametri. Prin utilizarea acestor tipuri de grafice şi acestui tip de evaluare şi îmbunătățire a procesului, este eliminată probabilitatea producerii de defecte şi reducerea variaţiei, îndeplinind astfel obiectivul final. Rezultatele vor putea îmbunătăţi astfel procesul delaminării unei carcase injectată pentru asamblarea unui sistem de frâne folosind conceptul Six Sigma.