BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 64 (68), Numărul 4, 2018
Secţia
CONSTRUCŢII DE MAŞINI

IMPLEMENTING THE SIX SIGMA METHOD IN ASSESSING THE PROCESS QUALITY LEVEL

BY

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Received: November 1, 2018
Accepted for publication: December 3, 2018

Abstract. Six Sigma is a management technique that aims to improve processes to create nearly perfect products and services. This method brings together many of the most important management ideas resulting in a flexible system for improving corporate leadership and performance, regardless of the field of activity. The Six Sigma methodology uses a five-step cycle, which represents a development of the plan, do, check, act, known as Deming's wheel. The five stages are: define - define the client and the objective of the project, measure - assess the process to determine the performance and the initial capability, analyze - identify and order the causes that induce the defects in the process, improve - the solutions for the elimination of the defects, control - check the performance of the new process. The Six Sigma methodology can be used together with Lean Manufacturing techniques, resulting in Lean Six Sigma, which combines the elimination of defects with production fluidization methods.

The paper presents a method of assessing the progress made in applying the Six Sigma method by calculating DPMO - defects per million opportunities - and comparing it with known values, in case of relatively long duration processes.

Keywords: Six-Sigma; process; quality; evaluation; organization.

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1. Introduction

In many organizations Six Sigma means a struggle to bring quality near perfection. Six Sigma is a flawless elimination methodology in any process, from manufacturing to sales, from production to service. The Six Sigma goal is to increase profits by eliminating variability, defects and waste that remove customers. Six Sigma is a methodology that provides tools and methods to improve process capability, reduce variability, and enhance quality.

The Six Sigma methodology is based on both a deterministic and a quantitative approach (Pyzdek, 2009). The deterministic side is based on quality assurance and all actions that take place prior to the start of production to implement the Crosby Zero Defect principle. The quantitative side is dedicated to the production phase, using statistical methods and statistical process control techniques.

2. Six Sigma Methodology

The Six Sigma system is a set of techniques and tools designed to improve processes to which it is applied so that the percentage of errors or defects remaining in the implementation of this system is less than 3.4 pieces per 1 million pieces produced.

Made by the electronics industry (Motorola, General Electric, Honeywell) (Pande *et al.*, 2000), the Six Sigma system owes its name to the specialized terminology of the industry's variability of manufacturing process statistics. The capability of a process to produce results in a certain error range from an average is statistically described by six equal ranges which are on both sides of the mean, between the upper and lower boundaries of variability.

This methodology has several advantages, such as: reduction of manufacturing times, cost reduction, loss and pollution reduction, improving the quality of a product.

The Six Sigma methodology uses two methods (Hary *et al.*, 2011): DMAIC - Define, Measure, Analyse, Improve, Control - when pursuing the improvement of an existing process, and DMADV - Define, Measure, Analyse, Design, Verify - when designing a new product, service or process.

In the case of the DMAIC, the following phases and steps will be performed. In phase D-Define - defines the objective of the project, the client and the required documents. The stages are defined: defining the client and its requirements, defining the problem, objectives and benefits, identifying the process owner and the team, defining the resources of the Six Sigma project, evaluating the support from the management, creating the project plan and milestones, process map. The following documents are drafted: project charter, flowchart for studied process, SIPOC (suppliers, inputs, process, outputs, customer) diagrams, analysis of project participants.

In the M-Measure phase, the process is measured to determine the current performance and to quantify the issue that is the subject of the Six Sigma project. The following activities are performed: define defects, opportunities, measurement units and measurement methods, detail the process diagram, make the data collection plan, validate the data collection system, collect the process information, determine the capability of the process and a Six Sigma baseline. The following documents are drafted: data collection plan, measurement system analysis, voice of the customer. The current sigma value for the process is calculated.

In phase A-Analyse - there are identified and investigated the causes of defects in the process. The steps are: defining performance objectives, identifying the stages in the process that yield or not the value of the result, identifying the sources that produce the variation in the process, determining and ordering the causes. The following documents are elaborated: histograms, cause effect diagrams, Pareto charts, systematic questions for identification verification, scattered charts, regression analysis, statistical analysis, data analysis with abnormal distribution.

In phase I-Improve - the process is improved by eliminating defects. The activities are carried out: design of experiments, identification of potential improvement solutions, defining the quality specifications of the new process, evaluation of defects in the proposed new solutions, validation of the improvement solutions and the new process by creating pilot programs, correction and re-evaluation of the proposed solutions. For their realization, brainstorming, error proofing, failure mode and defects analysis are performed. Several simulation software may be used.

In the C-Control phase - evaluate the solution for the improvement and performance of the new process. The following steps are taken: defining and validating the monitoring and control system of the new process, developing internal rules and working procedures, implementing the statistical process control, determining the capability of the new process, developing a plan to transfer the solution to the process owner, and the savings made, the closure of the project and the completion of the documentation. The sigma level for the new process will be calculated.

Lately, a new version of the Six Sigma methodology, Lean Six Sigma (Liker, 2004), has emerged. Lean Six Sigma is a hybrid methodology from the Six Sigma model that dominates the performance and scientific management to reduce defects in finished products and Toyota's Lean Manufacturing whose main objectives are customer orientation and a sleek structure, flexible and quick to reduce execution time.

From the Six Sigma model, which is not a fast-paced model, and the creation of a flawless organization, the Lean type model that does not aim to reduce product defects / process errors is then followed by the Lean Six Sigma model whose priority is management slim, customer-oriented and performanceenhancing in order to reduce defects and errors, increase the speed of response, accurately sizing the workforce and overcoming the limitations of the initial models. Lean Six Sigma is a process-optimizing methodology that considers customer requirements to then identify the most effective way to meet it by reducing variables at each stage of the process, both to produce goods and the supply of services.

Lean Six Sigma, by systematically reducing the process variability, simultaneously ensures the achievement of two apparently opposed strategic objectives of the organization: improving the quality levels of products and services and, at the same time, drastically reducing the costs of production (processes losses). Lean Six Sigma is a rigorous and systematic method based on the use of statistical data and analysis (Hary *et al.*, 2011).

3. Applying the Six Sigma Methodology

The σ designation is based on the average deviations of the sample population s, according to Eq. (1).

$$\sigma^2 = \frac{n}{n-1} s^2 \tag{1}$$

In Eq. (1) n is the number of population samples. The value σ is the magnitude of the variability, provided that the average of the population is approximated by the average of the samples $\bar{x}$.

The quality of the process is given by fitting the value of the quality characteristic pursued between the specified control limits, which may be bilateral (symmetrical or asymmetrical) or unilateral.

The Six Sigma methodology is based on the Gauss normal distribution, comparing the variability of the process with the specified limits.

The capability index of the process *Cp* is determined by the Eq. (2), according to Fig. 1.

$$C_p = \frac{T}{6\sigma} = \frac{USL - LSL}{6\sigma} \tag{2}$$

In the case of asymmetric quality specification limits, the *Cpk* indices are calculated with Eq. (3), as shown in Fig. 2.

$$C_{pk} = max\left\{\frac{USL-\bar{x}}{3\sigma}; \frac{\bar{x}-LSL}{3\sigma}\right\} \tag{3}$$

According to the Six Sigma methodology, the processes, both normal and critical, are classified into three classes according to the capability index value (Pyzdek and Keller, 2009), as is shown in Table 1.

Process variability theory defines short-term variation and long-term variation (Pyzdek and Keller, 2009). In case of short-term variation, it is considered that the process is only under the influence of common causes of variation and the average of the process is fixed. In this case the performance of the process is presented in Table 2.

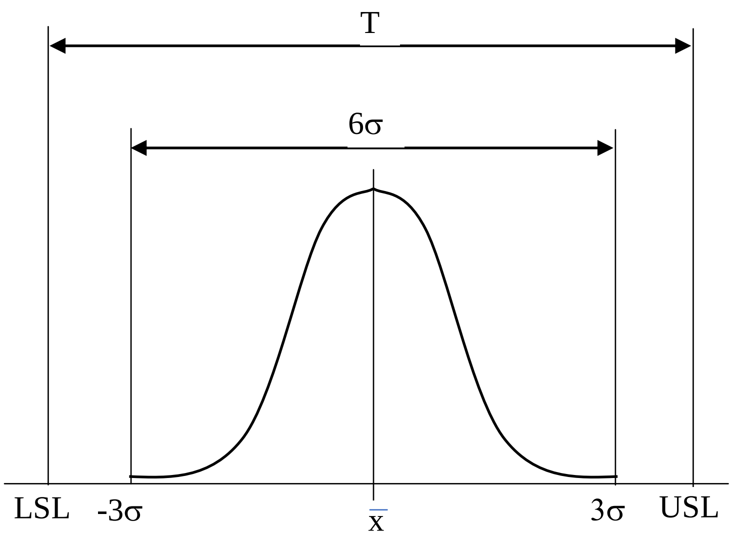

Fig. 1 – Capability index.

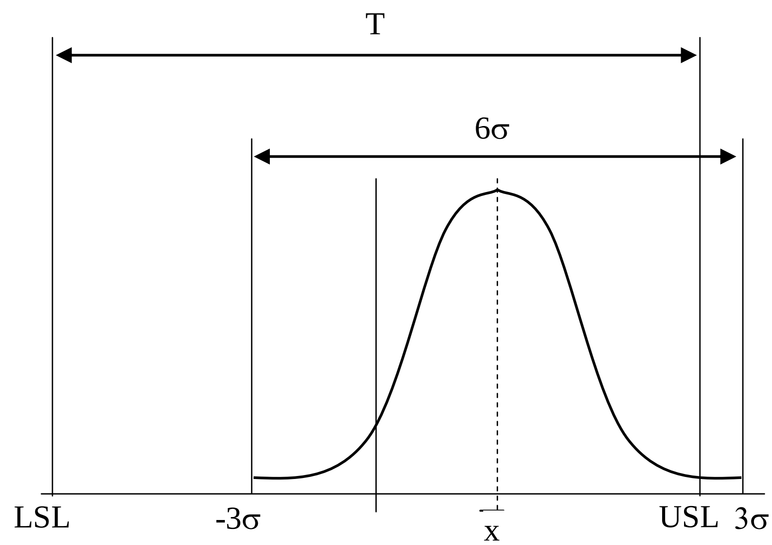

Fig. 2 – Capability index in asymmetrical specifications limit.

Table 1
Capability Index in Process

Process Level	Process			
	Normal		Critical	
	Capability Index			
	C_p	C_{pk}	C_p	C_{pk}
Red	<1	<1	<1.33	<1.33
Yellow	≥1	<1.33	≥1.33	<1.66
Green	>1.33	>1.33	>1.66	>1.66

Table 2
Compliant Production Part in Short Term Variation Process

Control Limit (USL; LSL)	Sigma Level	Compliant Production Part (%)
±1σ	1.0	68.26
±2σ	2.0	95.44
±3σ	3.0	99.73
±4σ	4.0	99.9937
±5σ	5.0	99.999943
±6σ	6.0	99.9999998

Most real processes in industry or business are, however, lengthy processes. In this case it is allowed a slight influence of the special causes of variation that lead to a movement of the average of the process within ± 1.5σ (Dasgupta, 2003). The performance of the process is assessed by the notion of Defects per Million Opportunities (DPMO). Defects per Million Opportunities is not the same as Defects per Million or Defective Pieces per Million. The difference lies in the concept of Opportunity. A production unit can have multiple opportunities to be defective. So, then, DPMO is the actual number of defects observed, extrapolated to each million defect opportunities.

To calculate DPMO the first step is to define the quality criteria or defect opportunities; then a representative sample of units should be taken and measured against the quality criteria. DPMO is calculated with Eq. (4).

$$DPMO = \frac{1000000\,D}{UO} \tag{4}$$

In Eq. (4) D represents the number of defects observed in the sample, U – number of units in the sample (sample size), O – defects opportunities per unit. Depending on the objective level established as a goal by the company, a DPMO is related, for example, in Six Sigma the objective is to achieve that the DPMO is lower than 3.4.

Once the DPMO has been obtained, the performance of the process (Yield) and the Sigma Level of the process can be found, using Eqs. (5) and (6).

$$DPO = \frac{D}{UO} \quad (5)$$

$$Yield = (1 - DPO)100\ \% \quad (6)$$

In Eqs. (5) and (6) DPO represents defects for opportunity, Yield - process performance.

To convert DPMO in process Yield and Sigma Level accomplished by the process Table 3 is used.

Table 3
DPMO, Process Yield and Sigma Level

Sigma level	DPMO	Yield %	Sigma level	DPMO	Yield %
0.00	933 200	6.68000	3.25	40 100	95.99000
0.25	894 400	10.56000	3.50	22 700	97.73000
0.50	841 300	15.87000	3.75	12 200	98.78000
0.75	773 400	22.66000	4.00	6 200	99.38000
1.00	691 500	30.85000	4.25	3 000	99.70000
1.25	598 700	40.13000	4.50	1 300	99.87000
1.50	500 000	50.00000	4.75	600	99.94000
1.75	401 300	59.87000	5.00	230	99.97700
2.00	308 500	69.15000	5.25	130	99.98700
2.25	226 600	77.34000	5.50	30	99.99700
2.50	158 600	84.13000	5.75	17	99.99833
2.75	105 600	89.44000	6.00	3.4	99.99966
3.00	66 800	93.32000			

4. Case Study

To evaluate the performance level achieved by an organization in implementing the Six Sigma methodology, the following steps will be taken: the volume of production is determined over the analyzed time frame (ex. one month), determine the number of failure opportunities for the type of product being analyzed, determine the DPO and Yield for the analyzed process, using Table 3 determines the sigma level achieved by the process, established the steps to be taken to improve the process and achieve the desired level of Six Sigma quality.

In the analyzed case, the production volume is 4000 units. Five defect opportunities were determined for each product and 24 defects in total. Using the Eqs. (4),…,(6) DPMO = 1200 and Yield = 99.88% are determined. From Table 3 the level reached by the process is determined: 4.50-4.75 σ.

To reach the desired Six Sigma level, the following steps will be taken: it will identify the stages in the process that bring yet greater variability, it will identify and hierarchize the causes of the variability, looking for and evaluating potential solutions for improvement, improvement solutions will be implemented in the process and the results will be compared to the goal: reaching the Six Sigma standard, *i.e.* 3.4 DPMO.

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ASUPRA APLICĂRII METODEI SIX SIGMA ÎN EVALUAREA NIVELULUI DE CALITATE AL PROCESELOR

(Rezumat)

Six Sigma este o tehnică de management care are ca obiectiv îmbunătăţirea proceselor pentru a creea produse şi servicii aproape perfecte. Acestă metodă reuneşte multe dintre cele mai importante idei din domeniul managementului rezultând un sistem flexibil pentru îmbunătăţirea conducerii şi performanțelor companiilor, indiferent de domeniul de activitate. Metodologia Six Sigma utilizează un ciclu în cinci etape: define - în care se defineşte clientul şi obiectivul proiectului, measure - măsurarea procesului pentru a determina performanţa şi capabilitatea iniţială, analyse - se identifică şi se ordonează cauzele care produc defecţiuni în proces, improve - se implementează soluţile de eliminare a defectelor, control - se verifică performanţa noului proces. Metodologia Six Sigma se poate utiliza împreună cu tehnicile de Lean Manufacturing, rezultând varianta Lean Six Sigma, care combină eliminarea defectelor cu metodele de fluidizare a producției.

În lucrare se prezintă o metodă de evaluare a progreselor realizate în aplicarea metodei Six Sigma prin calcularea numărului DPMO - defecte la un million de oportunităţi - și compararea sa cu valori cunoscute, în condiţiile în care procesul are o durată relativ mare.