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STATISTICAL PROCESS CONTROL BY THE PRECONTROL AND DIGITAL MEASURING MEANS WITH DATA OUTPUT

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Abstract. *Possibilities for realizing the statistical control of technological processes using the Precontrol technique and measuring means with digital data output have been presented. The realization of Precontrol is a further stage in the statistical control development, at which it is necessary to have high requirements as regards the process capability to be preliminarily ensured.*

Key Words: *Measurement, Measuring Means, Statistical Process Control*

1. INTRODUCTION

The application of the Precontrol technique is an up-to-date form for statistical control of technological processes, which can be successfully used in series and mass production and in the normal distribution of measurement results for its having a high level regarding the process capability (it is recommended that the Precontrol application implies an index of the process capability of $c_p>1.67$). Determination of the process capability potential is carried out according to the well-known way from the practice:

$$c_p = \frac{T}{6\sigma} \tag{1}$$

where: T is tolerance of controlled quantitative parameter;
σ is a standard deviation.

$$T = UTL - LTL \tag{2}$$

where: UTL and LTL are upper and lower tolerance limit correspondingly.

The probabilities for a parameter's appearance within the framework of tolerance at normal law of distribution have been presented in Fig. 1, where mean value $\overline{x}$ coincides with the target value and the corresponding values of standard deviation σ.

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At ±3σ the probability for receiving non-conformable products is 0.27% or 2700 ppm, which conforms to the process capability c_p=1. In practice, this is a base for applying the control chart according to quantitative character (Shewhart's control chart) about statistical process control.

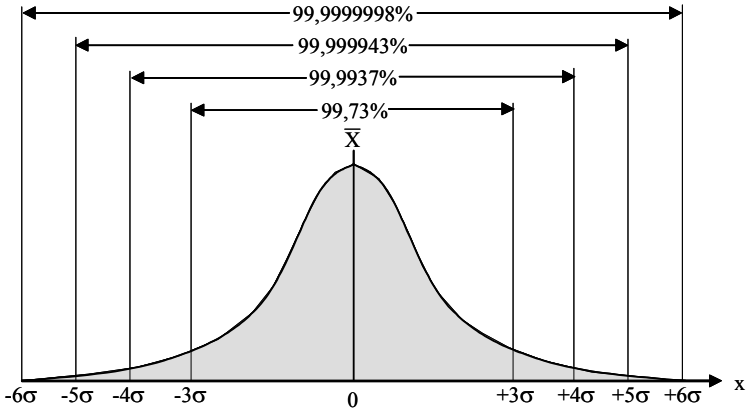


Fig. 1. Probabilities for meeting the requirements at normal law

At ±4σ the probability for receiving non-conformable products decreases to 63 ppm during c_p=1.33. Towards the moment these are some of the most frequently met index values, which are minimum required, about process capability (required by the standard concerning the automobile industry as ISO/TS 16949:2002, etc.).

At ±5σ the probability for receiving non-conformable products is 0.57 ppm during the index value about process capability c_p=1.67. These are also the conditions at which an effective application of the Precontrol technique is guaranteed.

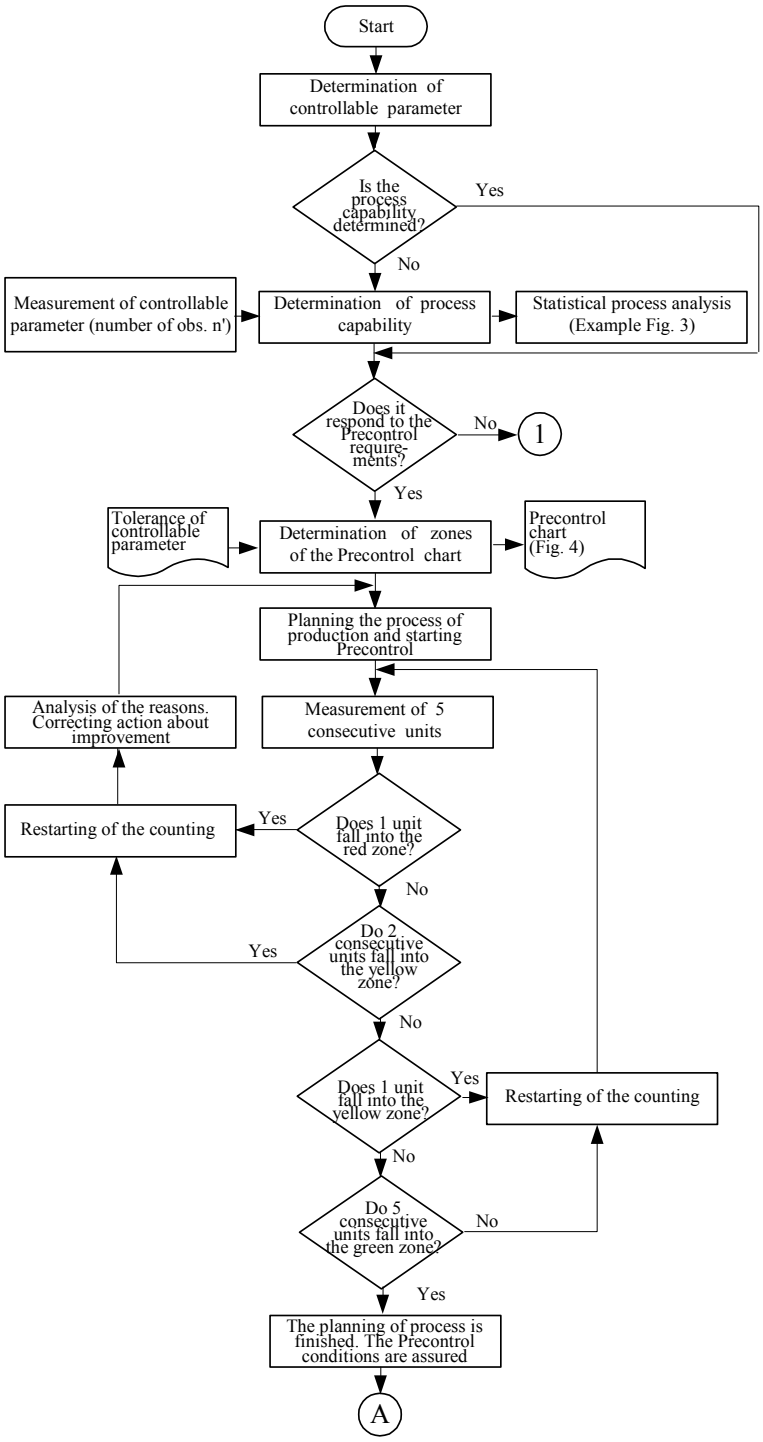
At the achievement of the process capability c_p=2.00 the probability for receiving non-conformable products is 0.002 ppm, which conforms to "Six sigma" program about quality (developed and implemented in the Motorola for the first time).

Digital measuring means used for realizing the Precontrol technique have to assure a value of discrete lower than the half of standard deviation of the controllable parameter. They provide a possibility for the process to be controlled in real time using the specialized software products. The leading manufacturers of digital measuring instruments and systems suggest software about registration, processing and analysis of data including the statistical process control with control chart and Precontrol.

2. STATISTICAL PROCESS CONTROL WITH PRECONTROL CHART

The algorithm for realizing the statistical control of technological processes with the Precontrol chart is presented in Fig. 2.

The controllable process parameter can be the most important functional dimension, the parameter with the strongest technical requirements or the largest share of arising non-conformities, etc. For an efficient usage of the Precontrol chart, the necessary condition which has to be met is the serial-ness of production, normal law of distribution concerning measurement results and the proven process capability of c_p>1.67.


Start
Determination of controllable parameter
Is the process capability determined?
Yes
No
Measurement of controllable parameter (number of obs. n')
Determination of process capability
Statistical process analysis (Example Fig. 3)
Does it respond to the Precontrol require-ments?
No
1
Yes
Tolerance of controllable parameter
Determination of zones of the Precontrol chart
Precontrol chart (Fig. 4)
Planning the process of production and starting Precontrol
Analysis of the reasons. Correcting action about improvement
Measurement of 5 consecutive units
Restarting of the counting
Yes
Does 1 unit fall into the red zone?
No
Yes
Do 2 consecutive units fall into the yellow zone?
No
Does 1 unit fall into the yellow zone?
Yes
Restarting of the counting
No
Do 5 consecutive units fall into the green zone?
No
Yes
The planning of process is finished. The Precontrol conditions are assured
A

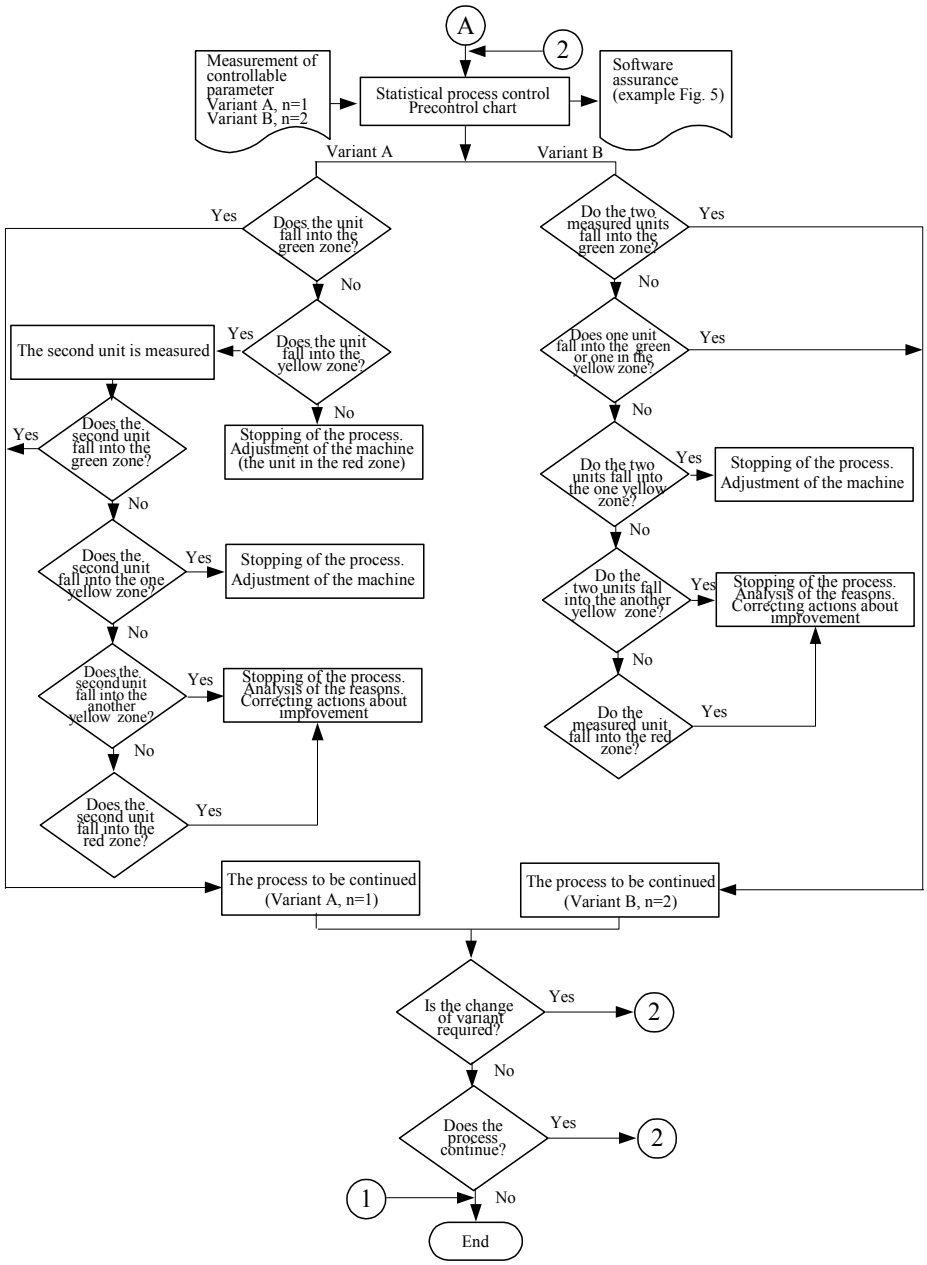


Fig. 2. Algorithm for the Statistical Process Control with Precontrol

For determining c_p at measurement of the controllable parameter by means of the measuring means with digital data output, the applied software products can be used (in

Fig.3 an example about statistical analysis of the measurement results is presented using the Measurlink about the Mitutoyo instruments and systems).

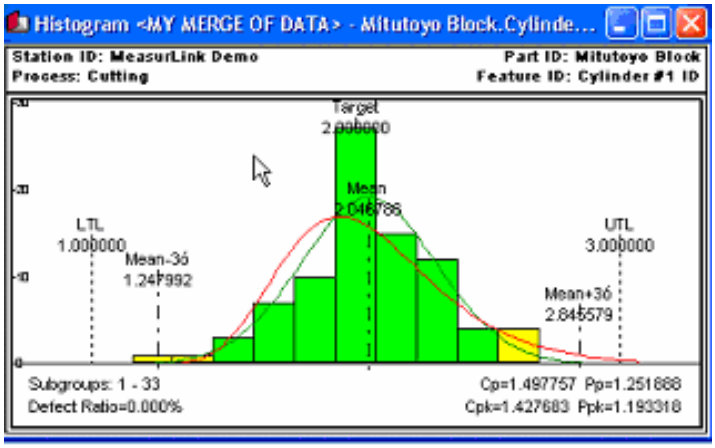


Fig. 3. Statistical analysis of the results

The zones and lines of the Precontrol chart are presented in Fig. 4 including the density of distribution of the random quantity as the controllable parameter of the process. The tolerance zone of the controllable parameter is divided into four equal intervals. The two intervals, which are found in the middle (symmetrically situated towards the middle of tolerance where the target value emerges), form the "green" zone 1 (the target range) of the Precontrol chart bounded by the lower and upper Precontrol lines. The "yellow" zone 2 is determined by the Precontrol lines and tolerance limits. The "red" zone is found outside the tolerance limits.

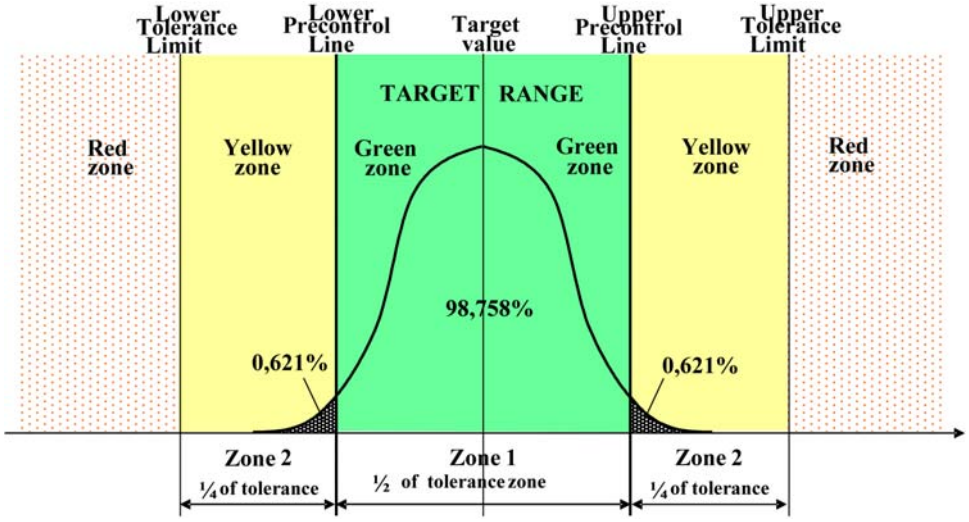


Fig. 4. Zones and lines of the precontrol chart

In the Precontrol chart the density of random quantity x at normal law of distribution and statistical probability for receiving the results in green and yellow zone at c_p=1.67 have been shown. The probability for leaving the value from measurement outside the Precontrol lines is 1.242% implying the coincidence of the mathematical expectation of distribution with the target value. In this instance, α-risk (the risk for obtaining the signal about process regulation when such one is not required) is up to 2% in the worst case. The risk about production of non-conformable units of products without receiving the signal about regulation (β-risk) is from 1 to 1.5%. The α and β-risk are calculated with the assumption about normal distribution of qualitative characteristics, mathematical expectation μ coinciding with the target value and ±3σ coincidence with the upper and lower Precontrol lines.

After achieving the needed capability, it is necessary to control the process adjustment with the Precontrol chart and to reach the critical process capability c_{pk}>1.67, respectively. The determination of critical values of the process capability is accomplished according to (3), i.e.:

$$c_{p_K} - \min\left\{c_{p_U} = \frac{T_U - \overline{x}}{3\sigma} \text{ or } c_{p_L} = \frac{\overline{x} - T_L}{3\sigma}\right\} \tag{3}$$

where: c_{p_K} is a critical value of the process capability;

c_{p_U} is a value of the index of process capability at Tu (upper tolerance limit);

c_{p_L} is a value of the index of process capability at T_L (lower tolerance limit);

$\overline{x}$ is a mean value of the controllable parameter about the process;

σ is a standard deviation.

At starting the process, which is controlled by the Precontrol chart, five consecutive units of products have been measured. This is imposed in order to prevent any reception of non-conformable products because of variations in the production process during its start. After ensuring the conditions necessary for the use of the Precontrol technique, the statistical process control with the Precontrol chart starts. The results obtained from the measurements done with the digital measuring means are processed with specialized software (in Fig.5 an example concerning the Precontrol chart is presented).

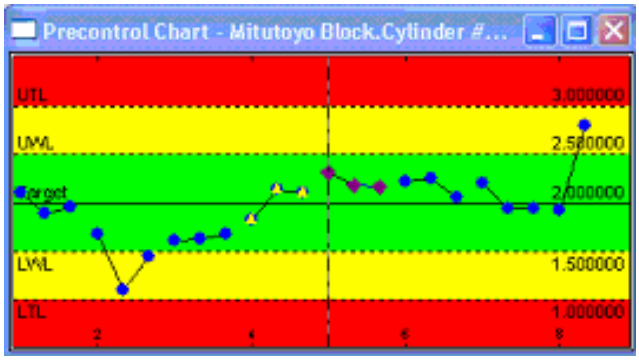


Fig. 5. Precontrol Chart for Statistical Process Control

Practically, two variants are possible for carrying out the Precontrol technique, i.e.:

- Variant A – initially one measurement is performed and depending on the result obtained the process either continues or stops or the second value is measured (as is shown in Fig. 2 – variant A) for the final decision-making;
- Variant B – initially two measurements are performed and depending on the result obtained the process continues or stops (as is shown in Fig.2 – variant B).

The measurements of units of products are performed by the measuring means with digital data output as is presented in Photo 1.

Photo 1. Digital measuring system

The frequency for sampling from units of products is concretized after using the Precontrol technique in one or two weeks depending on the speed and serial-ness of production. It is adopted that the frequency of samples to be normalized in the period between two regulations of the process. Practically, the following values of samples are established and recommended: from 10 to 15 samples between two regulations of the process but for a higher degree of security the number can be increased up to 25 samples.

3. CONCLUSIONS

The application of the Precontrol technique using the measuring means with digital data output provides a possibility for performing an efficient control of the technological processes. The basic advantages are connected with the minimum sample size (the

number of observations is n=1 or n=2 depending on the selected variant about the Precontrol) of the controllable details, the process control in real time with digital measuring means and applied computer software; data bases of minimal size where the history of measurements, the quality of product and the capability of process have been recorded. The Precontrol is one of the methods for performing the processes according to the principle "Zero defect" and the precondition for introducing the program about the quality control "Six sigma".

REFERENCES

1. Fasser, Y. and D. Brettner, *Process improvement in the electronics industry*. Wiley&Sons inc., New York. 1992.
2. Ivanov, I. N. and I. Zhelezarov. *Quality Management – Part II*. Publishing house Technical Univercity. Gabrovo, 1999.
3. Juran, J. M and A. B. Godfrey. *Juran's Quality Handbook* (Fifth Edition). McGraw-Hill, New York. 1998.
4. Montgomery, D. C. *Introduction to Statistical Quality Control*. Wiley&Sons inc., New York. 1990.
5. MiCAT. Measurlink 6.0.38 - Demoversion. Mitutoyo Corporation. 2005.
6. Stefanov, N., H. Radev, I. Burov, V. Stancheva, R. Vodenicharov. *Quality Management. Work and low*, Sofia. 2004.
7. Zhelezarov, I. "The measurement of the processes and products as factor for improvement of Quality Management Systems," Machinebuilding and Electrical Engineering, b. 1. Sofia, 2006, pp. 22-25.

STATISTIČKA KONTROLA PROCESA SREDSTVIMA PREKONTROLE I DIGITALNA MERNA SREDSTVA SA IZLAZNIM PODACIMA

Iliya Zhelezarov

Prikazane su mogućnosti za realizaciju statističke kontrole tehnoloških procesa koristeći tehniku Prekontrole i merna sredstva sa digitalnim izlaznim podacima. Realizacija Prekontrole je dalji stepen u razvoju statističke kontrole, kod koje su potrebni visoki zahtevi u pogledu sposobnosti procesa du bude prethodno osiguran.

Ključne reči: *merenje, merna sredstva, statistička kontrola procesa.*