Utilizing of Control Chart in the Management of the Measurement Process

[1]D. Jenčuráková, [2]R. Palenčár, [3]M. Kubiš

[1,2,3]Faculty of Mechanical Engineering, Institute of Automation, Measurement and Applied Informatics, Mýtna 36, 812 31 Bratislava 1, Slovak Republic,
Email: dana.jencurakova@stuba.sk

Abstract. *A broad range of methods for measurement control from the simplest comparative methods to the most sophisticated statistical based methods exist. A statistical based approaches play a big role in the measurement quality control. The goal of the statistical measurement control is to increase the probability to detect a measurement error and decrease a false rejections. Moreover, these methods can make an immediate decision whether a requirements on the measurement are fulfilled or not. Control charts of sample average and sample variation range are appropriate. These diagrams are one of the most effective combinations of control means of the measuring process. Using of diagrams the cumulative sums is sometimes more preferred.*

Keywords: Measurement, Measurement process, Control, Control charts

1. Introduction

Requirements on the metrological security of the main activities of organizations are increasing continuously. It is associated with high requirements on quality of services and products. Despite the fact that a large amount of the data comes from measurements, it is common that sufficient effort is not present in metrological security. The system of metrological security is an important part of an overall system of quality control. Hence, the control of measurement with the respect to achieving of the highest possible quality is needed.

2. Subject and Methods

The subject of the research was the process of measurement and its implementation. The current state in the management of measurements was analyzed. In particular, use the methods of statistical process control.

3. Statistical Methods in the Management of Measurement

A few of papers published at home and abroad, are dedicated to the use of statistical methods in the management of measurement. The most of them is devoted to the use of control charts in the management of measurement processes [1], [2], [3].

The present knowledge about control charts can be summarized in nine basic steps which are needed to be implemented regardless of the method of statistical process control [2], [3].

Cumulative sum (CUSUM) control chart is increasingly used in the management of measurement. CUSUM control charts are more sensitive to changes in the process (as opposed to Shewhart charts). These charts are used in the cases when the fast and cheap detection of the relatively short time period acting disturbances must be ensured [2], [3].

Shewhart control charts work with the data obtained from measurements of the gauge. Specific characteristics are calculated for each subgroup of the measured data. The most often these characteristics are sample average and sample variation range. These characteristics are recorded in the control charts [1].

Advantages of CUSUM charts against the traditional Shewhart control charts can be formulated as follows [2]:

- CUSUM charts are more sensitive to small and medium-sized (*0,5σ – 2,0σ*) changes in the process.

  The σ value represents standard deviation which expresses the variability of a measured parameter of a product or service.
- CUSUM charts are more economical for the risk of unnecessary signal $\alpha \leq 0,1$ and the effectiveness is higher as α is going to be smaller.

  The α symbol denotes a risk of false indication of limits violation and represents the probability of an unnecessary seeking of an definable influence based on the information from the control chart that the process is not statistically stable (e. g. a point is out of limits), even if no significant change of the process occurred.
- CUSUM charts indicates mentioned small and medium-sized changes in process 2-4 times faster with the same number of samples *n*.
- CUSUM charts are associated with a lower cost of control (with the smaller number of samples *n*) with the same risk *α*.
- CUSUM charts allows to determine more precisely the instant of change of the distribution of a controlled variable, to estimate the size of this change and the direction of action.

CUSUM control chart can be used in two ways. One of them is to determine the changes in historical values (measurement of planned or unexpected changes). The second way of use is intended to determine the period since the last change occurred [2], [3].

4. A Case Study

The task was using a control chart to manage the measurement process to meet the requirements of the specification. These specifications were based on measurements of the length of the component with a nominal value of 15 mm and the manufacturing tolerance ±60 μm. The measurement method was to measure the length of the component with a micrometer of the range 0 - 25 mm with a permissible error of ±1,0 μm. For monitoring of the measurement process measurements on the gauge block with the nominal size 20 mm and permissible error 0,6 μm under normal workshop conditions were utilized. Overall was chosen $N = 25$ subgroups, each of them with range of five: $m = 5$. The five trained employees conducted measurements five times a day in exactly scheduled time periods. The real situations in the measurement were characterized and the homogeneity of measurement was secured so that variability did not significantly affect the differences between subgroups within measurements.

The basic control chart involves [1], [2]: **Center Line (*CL*)** – represents expected value of the controlled variable, when the process is stable; **Upper Control Limit (*UCL*)** and **Lower Control Limit (*LCL)*** – bounds inherent variability of the process and are computed based on data gained in the time when the process was stable; points of observation, two neighboring points are connected with a line. **The mean value in the subgroup: x_j** and **variance range in the subgroup: R_j** were computed from measured data. Computed sample characteristics were drawn into the appropriate charts. Then **the mean value of the average values of subgroups** were computed: ***CL* for x_j** and **the mean value of the variance ranges of soubgroups: *CL* for R_j** were computed. These values represent **Central Lines** in charts. **Control limits *UCL*** and ***LCL*** were computed based on formulas presented in STN ISO 8258 [1], [2].

For type 1 error *α* = *5 %* Shewhart control charts $\overline{X}$ (Fig. 1) and *R* (Fig. 2) were constructed.

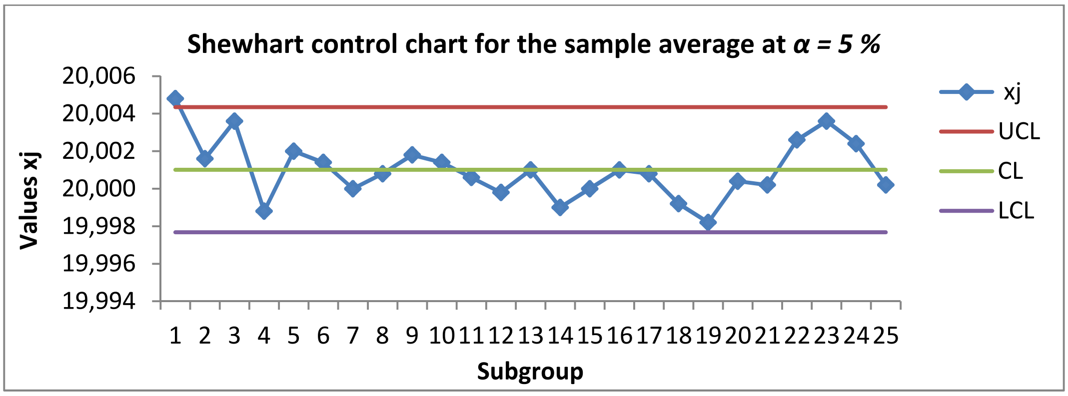

Fig. 1 Shewhart control chart for the sample average at *α* = *5 %* - the 1st analysis

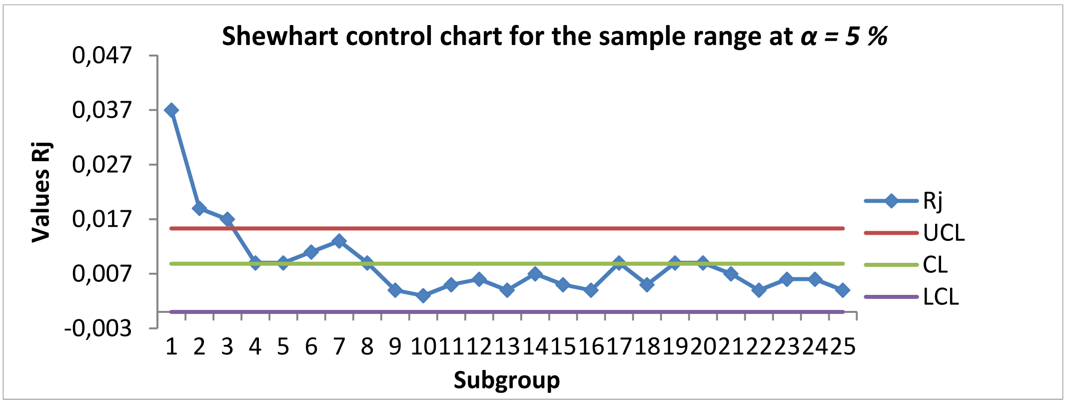

Fig. 2 Shewhart control chart for the sample range at *α* = *5 %* - the 1st analysis

Points of subgroups outside the regulatory boundaries were found. After the sources of errors were found points of subgroups were excluded. Subsequently new boundaries were calculated. Statistically mastered state of the measurement process of the case study was found only after the fourth analysis of Shewhart control charts for the sample average and the sample range.

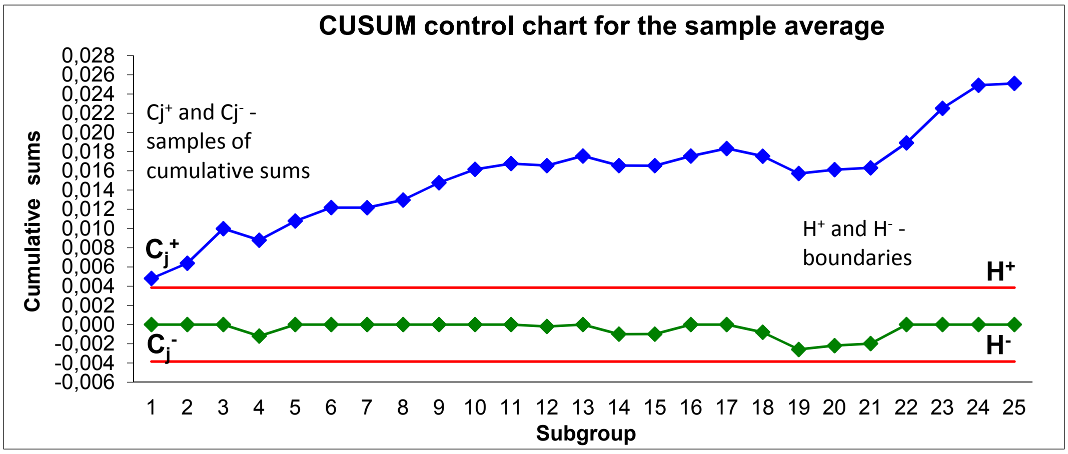

Fig. 3 Cumulative sum control chart for the sample average - the 1st analysis

CUSUM chart after the first utilization showed out that the metering process is not statistically controlled. In the process was a critical shift of the mean value of the measured quantity upward. Fig. 3 it is obvious that in the first subgroup is indicated a statistically uncontrolled state of the measurement process. The recommendation was in the next step to find determining cause, to take corrective action and restart the CUSUM chart from zero. If the setup process will be carried out, it may be useful to estimate the mean of the process caused by sliding.

5. Results

The solution of the case studies showed the ineffectiveness of use Shewhart control charts. Therefore it has acceded to the use of control chart of cumulative sums of sample averages. The following advantages have been confirmed:

- higher efficiency compared with Shewhart diagram,
- easy visual detection of shift of the mean value size,
- simple determination of the place where there was a shift of the mean value,
- suitable for cases where the cost of obtaining experimental data are high,
- efficiency was significant for lower values of α,
- four times faster indication of changes of process was observed by equal number of sample *n,*
- lower cost of process control,
- more precise detection of start of the change in parameters of the distributions of controlled value, direction of influence and its value.

6. Conclusions

The methodology of the utilization control charts introduces the specific rules with individual measurement results, which are outside the specified limits. In terms of the metrological assurance of product quality it is important to follow all measurement processes that are used in the development, manufacture, implementation into the operation and service of products. The aim is to ensure the confidence in the decisions or actions that are based on measured data. Building on the findings from the analysis of the use of statistical methods in the management measurement is suggested to focus on the method of cumulative sums (CUSUM chart). The use of this method in practice management of measurement is so far rare.

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