Improving the Production Efficiency by Using the InfinityQS - a Real-time SPC Software

Miljana Milić, Zoran Milić, and Alex Crittenden

***Abstract*—Statistical process control (SPC) is a method of production process quality control which employs statistical calculations to monitor the manufacturing process, and keep it under control. InfinityQS is a software solution which enables implementation of a real-time SPC. The idea is to collect a real-time data from sensors and statistically process it in order to obtain a real-time image of the process stability and quality. This software is specialized in this field allowing for and easy data connectivity, and a real-time reporting/charting. Among numerous features, the most useful are basic SPC control charts. Control limits, specification limits, target values, mean values, and process capability indicators are measured/calculated and displayed on the control chart. This allows for a very effective visual recognition of situations where process is out of control, and immediate detection and action can be initiated to maintain the quality and minimize the scrap. The software also facilitates other actions which will eliminate special i.e. systematic causes of variations in parameters of the process, and make it stable and predictive, i.e. under control.**

***Index Terms*—Statistical process control; reliability; sensor networks; production lines.**

I. Introduction

Improving the quality of a product is the deciding aspect of any production or service, and it leads to enhancement, growth, and success in business and consequently better competitiveness [1]. The quality of a product is one of the most important factors that a consumer (regardless of whether it is an individua, an industry or etc.) takes into consideration when choosing among many competing products and services. The return on investment is more certain when high quality of the product is considered as the targeting production parameter in any planning of business [1].

To quantify the amount of quality of a certain product, one has to answer the following questions, and determine the level of corresponding issues:

- Will the product perform specific functions and how well it performs them? - Product performance,
- How often does the product fail when operating under a stated operating condition? – Product reliability,
- How long is the service life of the product? – Product durability,
- How difficult and financially affordable are maintenance and repair procedures for the product? – Product serviceability,
- How attractive is the visual appeal of the product? Product aesthetics,
- What are the features added to the basic performance of the product? – Product added features,
- What is the past reputation of the company concerning quality of their products? – Perceived quality of the product
- How exactly does the manufactured product parts meet the customer's/designer's requirements? – Product's conformance to Standards [2].

In order to fulfil the quality standards of the product or a production [2], [3] and achieve high reputation among customers, it is highly recomended to implement a specific control over the production process on the plant floor. Statistical process control (SPC) is defined as a group of software tools that use statistical measures to maintain the stability of the product manufacturing process, improve its capabilities, and minimize process variabilities [4].

The implementation of the SPC is highly corelated and dependent on the parameters of the manufacturing process, obtained i.e. measured from sensor networks. Sensors for this purpose represent sensing and measuring devices which can communicate through the network and whose activities can be controlled, since these nodes may have limited capacities [5]. Process measurements are obtained in real-time during manufacturing. If the right kinds of data are being collected from the right points of the production lines, it is easier to determine the cause of quality issues [6]. Sensing devices should be positioned in a way to enable maximal information extraction from the field. Collected data are later analysed and often support decision-making at the higher-level of management [5].

This paper describes some basic features and benefits of a particular SPC environment implementation. The InfinityQS represents a leading SPC solutions applied by a number of leading corporations. Some basic definitions and equations from the theory of the SPC will be given next. Then, some possibilities and features of the InfinityQS will be listed. A practical case study implementation of the InfinityQS for the particular production line will be shown at the end, as well as some concluding remarks.

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II. About Statistical Process Control

There is a very limited amount of variations in the process that mass-production can tolerate. When variations do not exceed certain limits, it is sad that the manufacturing process is under control in each of its phases. In general, there are five groups of causes of unwanted variations that can be identified in the process. They are: raw materials, equipment, human actions, environment conditions, and methodology [7]. Variations are categorized in two groups:

- usual – tolerable variations, which are normal in the mass-production and have random nature, but are predictable, and
- specific – unwanted variation, whose causes are beyond the usual random changes of the process parameters, and cannot be predicted.

The key task of the SPC is to determine the cause of the specific process variations, by monitoring all relevant process parameters in time. Statistically predictable and tolerable variation do not require any actions, but for processes with some specific causes of variations, some actions need to be conducted to diminish them and they should be defined with a production Control plan [8].

With a SPC, process measurements' data obtained during manufacturing is then plotted in real-time on a graph referred to as a Control chart. Each process as well as the chart has two types of pre-defined limits: control limits are determined by the capability of the process (Voice of a process – VOP), and specification limits that are defined by the client (Voice of a customer – VOC). The parameter distribution as well as the corresponding limits are shown in Fig. 1. It should be emphasized that the VOC and the VOP are independent.

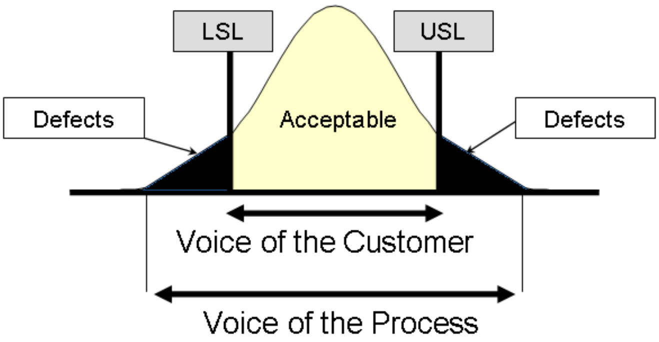

Fig. 1. Types of process limits.

When a process forms a stable distribution over time it is said to be under control. These distributions express the VOP. Process capability on the other hand expresses the goodness of a process, and is strongly related to customer specifications. These specification ranges i.e. the tolerances express the VOC here. This is illustrated in Fig. 2 [9].

Besides the usual statistical measures of the statistical process, such as the mean μ of the parameter and its standard deviation σ, some additional indicators need to be defined in order to implement SPC. They are: Cp - Process Capability, Cpk - Process Capability Index, Pp - Process Performance, and Ppk - Process Performance Index. Each of them will be defined and briefly explained next.

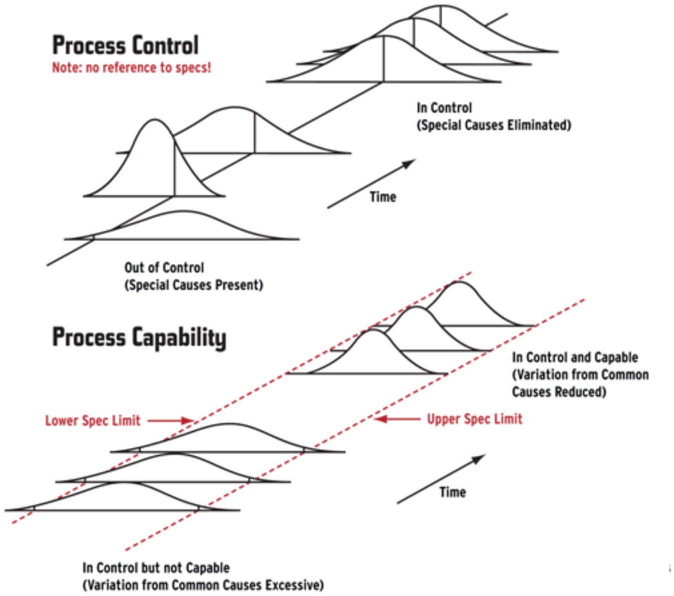

Fig. 2. Process control versus process capability.

Process capability can be calculated using as in (1):

$$\text{Cp} = \frac{\text{USL-LSL}}{6\sigma} \tag{1}$$

where USL and LSL represent upper and lower specification limits, respectively [1], while σ stands for the standard deviation of observed process parameter. It is the measure of how well the process meets customer specifications. At the other hand Process capability index Cpk, takes into consideration process centring and is calculated using (2):

$$\text{Cpk} = \min\,(\text{Cpu, Cpl}) = \min\left(\frac{\text{USL-}\mu}{3\sigma}, \frac{\mu\text{-LSL}}{3\sigma}\right). \tag{2}$$

In the simplified explanation, Cpk represents the one-sided Cp for the specification limit nearest to the process average μ [1]. Process Performance Pp, and Process Performance Index Ppk, can be calculated using the same equations (1), and (2), respectively. Differences between these two groups of measures are as follows. Process Capability indices Cp, and Cpk are calculated on samples; they are short term indices, and describe how well the process will perform in the future. At the other hand, Process performance indices Pp, and Ppk are calculated on the population; they are long term indices, and define how well the process has performed in the past. If the process is in statistical control, Cpk and Ppk are essentially the same [10].

Control charts are the basic graphical representation of the process quality that enable displaying and predicting of the process performances. By using them one can simply identify the existence of special causes of variations. With an SPC, control charts are used to provide information about weather a process is in statistical control or out of it, which is determined by the nature of the process variations, as stated earlier in the text. One example of a control chart is shown in Fig. 3 [11]. The x axis represents the time, while the y axis represents the observed parameter values. Components of the control chart are the following lines: USL and LSL, target value of the parameter, average value, upper (+3σ) and lower (-3σ) control limits. Some areas of the control chart are also important to monitor. They are: a region of the expected variations - placed between upper and lower control limits, and a region of the unwanted variations – placed out of the control limits. Usually, the statistical control limits are set to +/- 3σ. In such cases, 99.73% of the charted variable fall within those limits. When a point appears outside of the control limits of the control chart, this should be alarmed, and an operator should perform actions defined by the Control plan or the plan of the reactions.

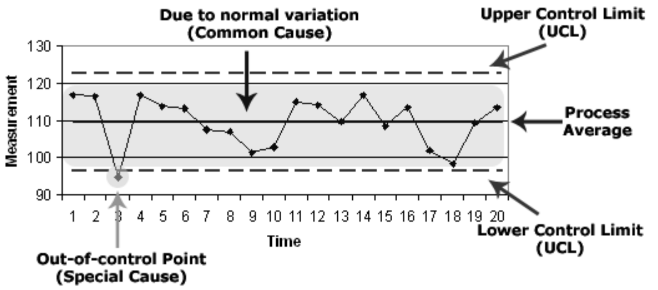

Fig. 3. The control chart.

In order to keep the process under control it is necessary to fulfil the following: the mean of the observed parameter should be as close as possible to the target value, and the Ppk should be greater than 1.3.

One implementation of a SPC using the InfinityQS solution for a simple example of the manufacturing process will be given next.

III. Implementing the InfinityQS on a Simple Production Process

ProFicient is the most important application of the InfinityQS solution that provides a customizable data-collection interface that supports multiple types of data input, manual and automatic [12]. Different charts are available for detailed insight into both real-time data, and historical trends of the process: control charts, pareto charts, Cpk reports, box & whisker plots, capability analysis, scatter plots, trend charts, SPC monitor, etc. It enables detection of the cause codes, and corrective action codes, to quickly identify and prioritize the potential issues. There are also some very useful traceability features, such as log genealogy, descriptors and serial numbers.

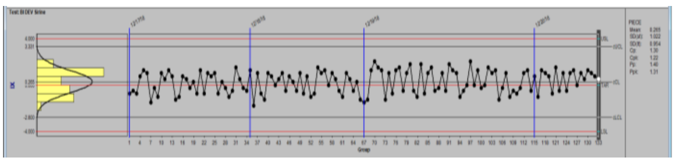
Fig. 4. The InfinityQS Xbar and Range control chart.

A case study of the simplified example of a part of the manufacturing process will be given next. The studied production system part is an extrusion line. The extrusion is often part of the mass-production process. The plastic material is melted with the application of heat and extruded through die into a desired shape. A cylindrical rotating screw is placed inside the barrel which forces out molten plastic material through a die. The extruded material takes shape according to the cross-section of die. There are five important process parameters to be monitored during the extrusion process using a network of sensors: melting temperature, speed of the screw, the extrusion pressure, shape of the material that exits the die, and the cooling mechanism.

The Xbar and range control charts for the width of the extruded material is shown in Fig. 4. The Xbar gives the real-time histogram of the material width variations, while the Range control chart displays width variation trend with the respect to USL and LSL, and a target value.

If the process exceeds some of the limits, the chart alarms it with the change of the color, and turns red. This is shown in Fig. 5.

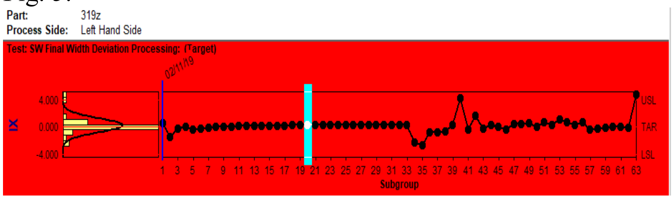

Fig. 5. Alarming an issue with the InfinityQS – process is out of control.

IV. Conclusion

In this paper, one highly reputable, commercial SPC solution have been presented. It is greatly recemented in the mass-production for implementing the production quality standards on the plant floor. The most important benefits of the ProFicient as the most important application of the InfinityQS SPC solutions are: significant reduction of the process variability and scrap, significant reduction of the production expenditures, scientific improvement of the process productivity, instant alarming and reactions to unwanted process variations, enabling the corresponding real-time decisions at the plant floor. The software also enables improved data collection from the network sensors, their analysis, processing, reports, storage, in order to compare qualities across multiple products, production lines and production sites. The complex analysis of data can be performed in real-time or using historical data within one chart or report.

Acknowledgment

This research is partially funded by The Ministry of Education and Science of Republic of Serbia under a contract no. TR32004.

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