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THE CONCEPTION OF ADVANCED STATISTICAL CONTROL SYSTEM OF PRODUCTION STABILITY

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ABSTRACT
The authors of a paper developed a procedure which allows for an on-line calculation and monitoring the measurement system characteristics which determine this system usability for a manufacturing process control. The authors intention is to integrate that procedure with the manufacturing statistical processes control as an advanced statistical control system of production stability and to minimize (eliminate) a human share in making decision about the stability of the manufacturing or the measuring process. To obtain this, they consider and propose to use a patterns recognizing method – the paper presents conception of this idea.
Keywords: patterns recognizing method, statistical process control, measurement system analysis

1. INTRODUCTION
In making decisions about manufacturing process it is important to be sure that process is under statistical control, that it is stable in statistical way. To obtain this, the decisions made by production processes managers must be based on a reliable data. They should be gained in properly performed measurements with the use of adequate measurement systems (MS). Therefore, the measurement system is one of the most important component of production system. It should be stable, predictable, capable and lean. MS, if it is not good enough, may have a significant influence on quality of the decisions made about the production process.

2. THE STATISTICAL CONTROL SYSTEM OF PRODUCTION STABILITY
2.1. SPC and MSA
Using standard statistical process control (SPC) tools is not enough to learn about process variation – a distribution of process characteristics observed on a control charts is masked by the variation of the measurement system. That variation has an influence on taken decisions about the production process. Thus, talking about the statistical control system of the stability, the authors think both about using SPC tools for the manufacturing process control and about using MSA procedures for the statistical control of the measurement system. Data taken from manufacturing process are a reliable source of information about that production only if SPC is integrated with MSA. Using these tools, it is possible to make decisions about the process stability by operators even without their mathematical background.

The most popular tool of SPC are control charts. They are used to monitor the manufacturing process. The idea of the charts is to assess the stability of manufacturing process – stable process is the process, which monitored statistics are kept within the control limits. The charts show how the statistics changes over the time. They (and other SPC tools) are described in details in [1].
The measurement system is a set of procedures, equipment for measuring, software and staff which are necessary for determining numerical values of the characteristics which are to be measured in the process, and also an object on which the measurements are performed is a part of it [2]. To assess quality of the measurement system there are few procedures, which are called MSA (Measurement Systems Analysis). They are generally based on the analysis of variance. In practice, the MSA procedures are performed off-line (beyond the production) [2], in accordance with a schedule prescribed for their implementation. The best known examples come from an automotive industry and are described in details in [3]. In [2] there is presented an innovative procedure of MSA (this procedure was also mentioned during TMT 2009 and TMT 2010).

2.2. The on-line conception of MSA

On-line procedure allows for the on-line calculation, that is during the manufacturing process (Fig. 1), and to monitor the measurement system (MS) characteristics which determine the MS usability for the manufacturing process control. This procedure is combined with the standard procedure of statistical process control with the use of the process control charts. The procedure is based on two control charts. The first one is called AD-chart (Average Difference chart) and it allows to estimate the variability between the MS operators. In other words, it monitors the stability of the measurement system. The second control chart of the on-line procedure reflects the *%R&R* index (*R&R* means repeatability and reproducibility and it is a measure of quality level and capability of MS) and it allows to monitor the capability of MS.

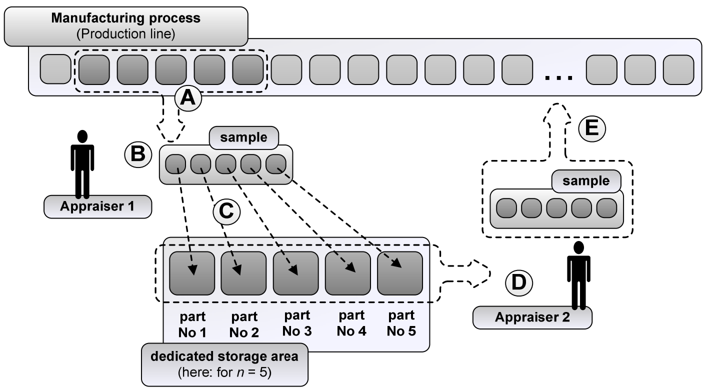

Figure 1. Illustration of the on-line procedure for two appraisers, which starts by taking a sample from the production line by the first process operator (Appraiser 1) (A). He measures the defined characteristic and after performing the prescribed set of measurements on the controlled sample (B), puts it aside in an assigned place (C). After a certain time predetermined in the procedure, another Appraiser (App. 2) repeats on the shifted sample the prescribed measurements (D). Next, he returns the parts into the production line (E). Source: own study based on [2]

2.3. The advanced statistical control system of production stability – conception

The authors conception assume that the manufacturing process control charts (such as a average chart and range chart) are carried out simultaneously with the measurement system charts (AD-chart and *%R&R* index chart). This combination is main element of stability control system. All of these charts should be supported by using dedicated software to analyze appearing draws/graphs, especially to identify the patterns.

There are many patterns which appears on the chart and which are indicate process instability. The most popular (and frequently encountered in practice) are: a point outside the control limits (Fig. 2. a.), trend built from few points (b), run (c) and shifts (d).

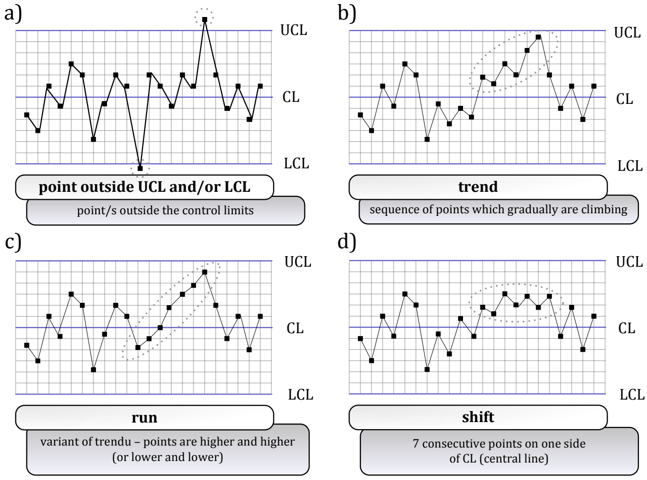

Figure 2. Typical symptoms on the control chart which indicates about the possible deregulation of the process. Source: [2]

Other patterns are often not easy to identify ad-hoc and it shouldn`t be expected that operator will be able to make the right decision. Decisions of the operator are results of his experience and sometimes they are intuitive. There is a disadvantage of such a solution. It consists in the necessity of constant observation of the pattern on the control charts by the worker, whose attention should be focused mainly on the machine and the manufacturing process. Another weakness of such solution is that operator knowledge of the sources of the special-cause variation and correcting actions is insufficient. Moreover, there is always a risk that an experienced worker will resign from his post. Thus, the company loses his knowledge, know-how.
However, it is possible to support (or even to replace) the decision making process by designing and programming method of chart patterns classification.

2.4. The pattern recognition method

The authors developed a novel method which allows to recognize the patterns on the SPC control charts [4]. It is called Matrix Weights method (MW). Presently they are conducting a research which result will be the method for pattern recognizing dedicated to charts for on-line MSA.
MW method is called "smart" because it is based on simple observation and does not need to use sophisticated mathematical tools. The main idea of MW method is to find on the chart the patterns which are called the trends (Fig. 3). Denoting by x_i subsequent values of a variable X, a rising trend occurs if the following condition is met: $x_1<x_2$ and $x_2<x_3$, and … and $x_{n-1}<x_n$.
Unfortunately, trends structure /shape in practice trends complicated by variety sequences, for instance, the second sequence in Figure 3 can be defined by the relations: $x_1<x_2$ and $x_2>x_3$, and $x_3<x_4$, and $x_4>x_5$, and, …, and $x_{n-1}<x_n$. In fact, there are many various of such trends combinations. One observation is a starting point to develop the method described below – no matter how the points are situated towards each other, they are located in a specific strip on the control chart.

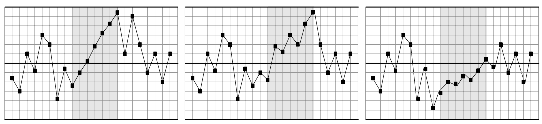

Figure 3. Examples of the trends on the control chart. Source: [4]

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The developed method is based on the division of the chart into the matrix of [k x n] size (k-columns, n-lines), and each of them is assigned the weight $w_i \in <0, 1>$. The idea of the method is described in stages. There are two stages of the method – preparation (steps 1st and 2nd) and recognition stage (steps 3rd and 4th):

Step 1. Dividing the process control chart (PCC) field into matrixes of [kxn] dimensions.

Step 2. Attributing weights to the matrix fields. Distribution of the weights is correlated with a specific symptoms of process instability. Defining the patterns data base.

Step 3. For a given sequence of points on PCC sheet a value is calculated. The S measures is a sum of weights w_i attributed to the points from the sequence.

Step 4. Comparison of S with the threshold value S_{th} which is fixed by an expert. If S has a greater value or equals to the limit value then there is a signal produced indicating the appearance of the pattern.

An example of rising and falling trends matrix shows Figure 4. The method limitation is the necessity of matrix creation for each class of patterns as well as choosing the limit value S_{th} that determines the picture's recognition as a symptom.

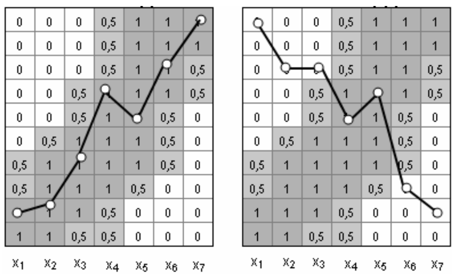

Figure 4. MW method – examples of rising and falling trends matrix. Source: [4]

3. CONCLUSION

The authors presented the conception of an advanced statistical control system of production stability. Their intention was to integrate the on-line procedure of MSA with SPC tools, and to minimize (eliminate) a human share in process of making decisions about the stability of the manufacturing or the measuring processes. They described a piece of their research in this area.

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