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MEASUREMENT SYSTEM ANALYSIS AIDED BY NEW CONTROL CHARTS

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ABSTRACT
Measurement process must be regularly monitored and evaluated to make accurate decisions about manufacturing process condition or products quality. It is able by statistical methods and tools usage. A paper is a discussion about necessity for measurement systems analysis (MSA) during manufacturing process. There has drawn up a new attitude to MSA which can be characterized by taking the measurements directly from the work position and during the production process. There is also an intention to subject the research results to the readers consideration. Changes proposing by authors will help in eliminating a part of the observed changeability characteristic for the analysis in its so far type, which is laden with the impact of changing environmental conditions during the assessment. What is also significant, that way of data collection limits number of repeats - values of first set measurements are from these taken for statistical process control (usage existing data). They propose two new charts for current control - Average Difference chart (AD-chart) and %R&R index chart (%R&R-chart). It is important to lead them concurrently (simultaneously) to make correct decisions about measurement system quality condition.
Keywords: measurement system analysis (MSA), statistical process control, control chart, precision

1. INTRODUCTION
To be sure that the benefit derived from using measurement data is great enough to warrant the cost of obtaining it, attention needs to be focused on the quality of the data [4]. Historical leaders in the quality evaluation said that if you cannot measure something you cannot manage it. In recent years measurement data is used more often and in more ways than ever before and that statement is particularly truthful nowadays. An analytical study is one that increases knowledge about causes that affect production processes. The credibility of measurement data is essential for taking right decisions about a production process (a good or bad product, a stable or requiring regulation process) – hence, production processes should be monitored in the way which makes us certain that collected data is reliable. It means that not only manufacturing process but also measurement methods should be validated and regularly monitored. It is able by statistical methods and tools usage.

2. CURRENT IDEA FOR MEASUREMENT SYSTEM ANALYSIS
Statistical process control (SPC) is an analysis of the manufacturing process carried out in the real time with usage of analytical and visual statistical tools [1]. Information in the process control is collected straightforward from a particular workplace in the course of the process. The idea of SPC provides for linkage between a production process and its statistical analysis in the form of feedback. The information from the coupling allow the preventive and not corrective impact on the process. But using standard SPC tools is not enough to learn about a process variation – the distribution of process characteristics observed on control charts is masked by the variation of a measurement system, which

has an influence on taken decisions about a production process. Because of that, there is a need for regularly measurement system analysis (MSA).

The measurement system is a set of procedures, tasks, assumptions tools (measurement equipment) software and staff which is necessary for determining numerical values for the characteristics which are to be measured [2,3,4]. The purpose of the assessment of MSA is to obtain information about the extent and types of measurement variation caused by the measurement system [5]. To evaluate the measurement system some concerns must be fulfilled. Firstly, it must demonstrate adequate sensitivity. Secondly, it must be stable and finally – the statistical properties must be consistent with range and adequate for the purpose of measurement [4]. Motor industry enterprises assess their measurement systems obligatorily – world motor corporations strictly require that MSA is applied by cars and parts producers [6,7].

In the business course-book of automotive industry [4], which is an additional document referring to QS-9000 standard [6], there are different procedures of measurement system analysis depending on properties characterizing a given process. There are many methods and procedures designed for measurement system analysis, for instance: simple "range method", the most frequent and most willingly used "average-range method" (ARM) or complicated "ANOVA". All of them are based on analysis of variance and all of them seem to have offline nature as well – they cannot be implemented in manufacturing process that the data could be gathered directly from the work position and during the running production process. None of them allow to current monitor precision, that is both repeatability (variability of measurements obtained by one person while measuring the same item repeatedly) and reproducibility (variability of a measurement system caused by differences in operator's behavior) of measurement system.

Authors of this paper carried out a research in order to establish if measurement system could be examined, analyzed and evaluated during manufacturing. This idea is called "running MSA". In the "running MSA" first worker, being at the same time operator of the measurement equipment, carry out the in sequence measurements of a given feature immediately on their workplaces in the course of daily work (like it is done for SPC control charts), for instance at the end of his shift, and lay the parts aside in assign place. Next one, for example during second shift, repeats a measurements on the same parts and put them back into the manufacturing process. That change will help in eliminating a part of the observed changeability characteristic for the analysis in its so far type, which is laden with the impact of changing environmental conditions during the assessment. What is also significant, that way of data collection limits number of repeats – values of first set measurements are from these taken for SPC (usage existing data).

3. CHARTS FOR MEASUREMENT SYSTEM PRECISION AND ABILITY CONTROL

Authors of this paper noticed that there is a possibility to current monitor the measurement system ability and usefulness by means of control charts. Control charts are an effective tool for process monitoring and evaluation in reference to stability and maintaining accepted quality level. Thus authors proposed two new charts for current control – Average Difference chart (AD-chart) and %*R&R* index chart (%*R&R*-chart). It is important to lead them concurrently (simultaneously) to may make correct decisions about measurement system quality condition and acceptance it.

In AD-chart the random variable has a symmetrical distribution with expectation value equal zero. That is a $R_{diff\overline{Ap1,2}}$ – difference between averages from taken from measurement process sample and measured by two appraisers, as in (1):

$$R_{diff\overline{Ap1,2}} = \overline{x_{Ap1}} - \overline{x_{Ap2}}, \quad (1)$$

where: $\overline{x_{Ap1}}$ is operators (Ap_1 – appraiser 1) average from measurements taken from the sample collected from the manufacturing process during the first shift and $\overline{x_{Ap2}}$ is operators (Ap_2 – appraiser

2) average from second measurements on the same sample (measurements taken from parts asides in assign place) during the second shift.
In a stability production conditions and with acceptable measurement system, values of random variable should be broken down randomly on both sides on central line on the chart (Fig. 1).

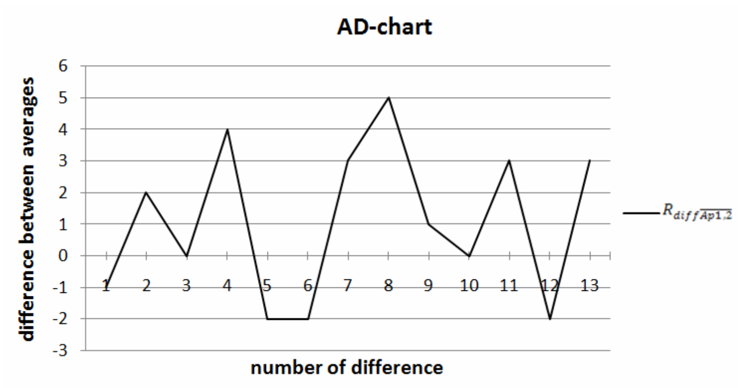

Figure 1. AD-chart for measurement system current precision evaluation.
Source: own study.

The difference $R_{diff\overline{Ap1,2}}$ will includes total changeability result simultaneously from equipment impact and operators impacts (there is lack of ability to separate repeatability and reproducibility for the sake of through lack of measurement repeats by the same appraisers).
The most important advantages of the AD control chart are:
– opportunity to monitor measurement system precision,
– the number of indispensable to carry on the chart is half lesser than for standard average-range chart in ARM method (first set of values are taken from SPC measurements),
– there is no need to mark samples and parts,
– it is easy to notice the differences between operators measuring method,
– it is able to be carry on the work-station without aborting the running manufacturing process.

The yardstick of the measurement system acceptance state is %*R&R* index which symbol integrate three components: repeatability (first *R*), reproducibility (second *R*) and process changeability (% – it symbolize reference to total process variation in percentage). Evaluation criteria (characteristic for the automotive process) are as follows:
– %*R&R* below 10% – measurement system is acceptable;
– %*R&R* from 10% to 30% – measurement can be conditionally accepted, is marginal;
– %*R&R* above 30% – measurement system is not acceptable, requires correction (measurement system must be improved or replaced) [4].

To control at the same time also ability of measurement system, there is a need to carry on the %*R&R*-chart. The random variable on %*R&R*-chart is %*R&R* index estimated according to analysis of variance principles on the ground earlier calculated differences from averages. Because %*R&R* index can be estimated in research make of at least 10 parts (10 parts, 2 or 3 appraisers and 2 or 3 trials [4]), first assessment is available after collected ten number of difference (after ten points on AD-chart). This chart has a constant control limits – 0, 10 and 30% lines (Fig. 2). They aid current ability evaluation.

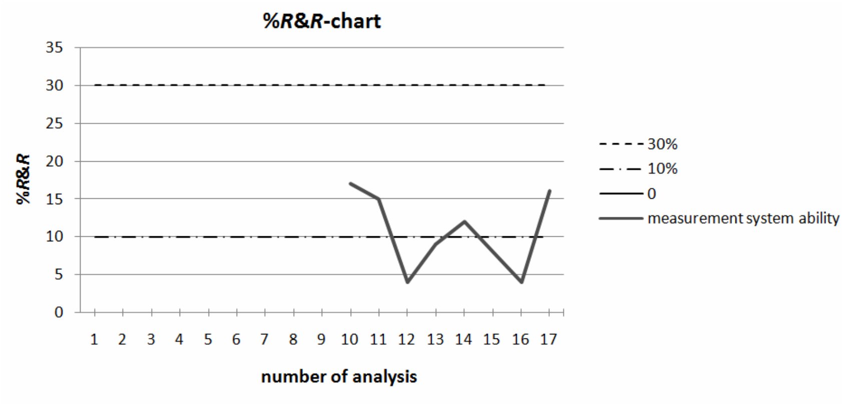

Figure 2. %R&R-chart for measurement system current ability evaluation.
Source: own study.

4. CONCLUSION

The aim of this paper and authors taken research were to prepare and present a new method that could identify changeability of measurement system and could evaluate it as an aid before full MSA procedure according to recommended practices for simple measurement systems [4]. The idea of current measurement system analysis use statistical, analytical and graphical tools. Procedure of the examination and evaluation of the running measurement system is using already existing data (measurements taken from statistical process control) and it is able to be carried out during the realization of manufacturing process.

Presently, to confirm theoretical researches, there is going on a research and development in enterprise which is one of the world's largest producers and recyclers of lead-acid batteries.
The authors of the article, being sure of the need for simple and flexible IT solutions facilitating quality management systems in the field of process control, currently are working on application program the aim of which will be to make easier to analyze and evaluation measurement systems with usage of presented new method. It will be developed in Microsoft Excel – thanks to which it will be easily accessible, inexpensive and user-friendly.

5. ACKNOWLEDGMENT

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