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MEASUREMENT SYSTEM ANALYSIS IN THE SURFACE TREATMENT OF A PART FOR THE AUTOMOTIVE INDUSTRY

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Abstract: *The article deals with the implementation of innovative methods used in quality control in the automotive industry. The task was to design and develop an analysis of the measurement system for variable and attributive quality features. The parts of the charging station that are surface-treated by cataphoretic painting were used for analysis. Dry layer thickness was used as a quality variable. The overall appearance of the surface varnish was used as an attributive sign of quality. For the analysis of the measurement system, the method of repeatability and reproducibility, indices of the feasibility of the measure and the attributive method were used. The repeatability and reproducibility method has been shown to be unacceptable for this product. Therefore, the attributive method was subsequently used, which proved that the analyzed measurement system is in order.*

Key words: *Measurement system analysis, charging station, repeatability, reproducibility.*

1. INTRODUCTION

The IATF 16949 standard was developed as the fourth version of the standard and serves to harmonize the diverse assessment and certification systems worldwide in the supply chain for the automotive industry. [1]

Authors Dan and Prica prepared a study based on a review of professional literature over the past 7 years, focusing on the main problems that occur in connection with the quality of the automotive industry at its intersection with aspects of economic and technological development, current sustainability, identifying and analyzing specific solutions, opinions and case studies relevant to industry practice. [2]

In their study, the authors of Laskurain Iturbe et al. analyzed the added value of IATF 16949 with respect to ISO 9001. They analyzed its use in several companies. Multiple internal and external sources of documentation were analyzed. The findings show that IATF 16949 adds value to a more flexible ISO 9001 in five main areas: market, customer service in the supply chain, operational performance, staff, and technology. [3,4]

Other authors in their articles describe the appropriate use of statistical tools, with statistical process control (SPC) according to the IATF 16949 standard being a common choice. SPC is a methodology used mainly for monitoring and controlling the behavior of a production process. The main purpose of SPC is to prevent non-conforming products from leaving the manufacturing floor and being delivered to the end customer. Statistical process control, part of the core tools of IATF 16949, which is an analytical decision-making tool. [5-7]

Authors Bozola et al. have investigated the identification and analysis of elements added in the evolution from ISO/TS 16949 to IATF 16949. The main elements added to IATF 16949 with the update of the standard are the use of process failure effects analysis (PFMEA) for risk analysis; developing a communication channel for employees to report cases of misconduct and disagreements; procedures for checking repaired/remanufactured products and temporary changes; and the inclusion of autonomous maintenance for a full implementation of Total Productive Maintenance (TPM). [8]

Authors Makkar et al. write in their study that there are many production control procedures, each procedure is suitable for a different type of product in production. Therefore, it is necessary to understand the procedure and choose the method that will best suit the inspection of the given product. Nowadays, software is used in the inspection. There are many softwares and they are constantly being updated due to the rapid development of technology. The software must be adapted to the development of technologies so that it is able to thoroughly and correctly control the process. Inspection is important for continuous improvement of production. [9,10]

Trofimova and Panov describe in their paper that correct techniques of and approaches to the analysis of production stability and measuring systems and management of products quality are significant for the tasks of development and improvement of a mechanical engineering enterprise quality control system. More opportunities arise for production quality managers enabling their dealing with claims and defects, elaboration of corrective actions and application of statistical methods for the analysis of quality of products. [11, 12]

The article monitors and describes necessary controls of the cataphoretic painting process at the Company. Mainly the thickness of the dry layer is checked, but also the production process itself. Data from the production process were further processed in PalstatCAQ programme by the standards of the IATF 16949. [13]

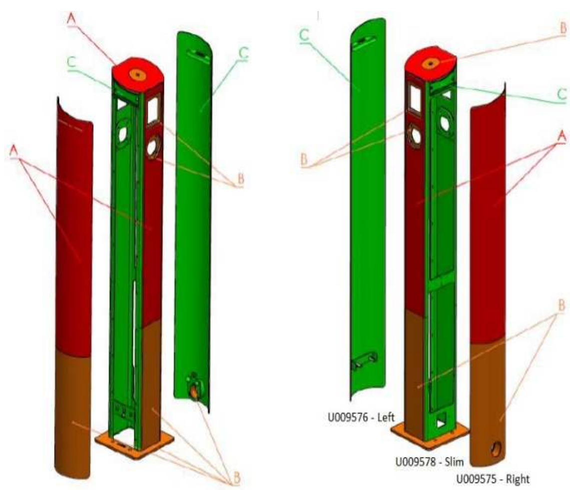
The aim of this article is to implement innovative methods in the automotive industry, specifically focusing on the creation of MSA analysis procedures for variable and attributive measurement system evaluation. [14]

2. MATERIAL AND METHODS

2.1 Analyzed product

The individual components of the charging station for electric cars were used as the analyzed product for developing the MSA analysis. The parts are surface treated using cataphoretic painting technology. Variable and attributive quality control features were evaluated on the parts according to the IATF 16949 standard.

The selected parts and their subsequent division was given by a unique design with a specific designation (U009575 - Right, U009576 - Left, U009578 - Slim), which served to identify the parts from the process of receiving from the customer through the cataphoretic technological process to packaging and shipping.



A – Red color (Directly visible surface) – repairable defects/errors on the surface must be sanded with fine sandpaper. The repair must cover the subsequent powder coating.
B – Orange color (Partially visible area) – the need for a preventive approach to the given area in the same way as for the red color (directly visible area).
C – Green color (Invisible area) – there is no need to correct the errors created after cataphoretic painting.

Fig. 1. Display of inspected surfaces by importance and subsequent division of the parts of electric charging station

2.2 PalstatCAQ

PalstatCAQ is a quality management software that allows you to build an effective quality management system in all companies, regardless of the size and focus of the company. The modular design is convenient for its easy display to use. It fulfills the selected requirements of all customers and standards in the field of quality management, metrology, maintenance and others. System is intended primarily for the implementation of standards:

- STN EN ISO 9001 (engineering industry)
- IATF 16949 (automotive industry)
- ISO/IWA 1 (health care industry)
- APQP 2110 (military industry)

The CAQ system offers professional quality management solutions, stability and software development using the most modern information technologies. [15]

2.3 Cataphoresis painting

Cataphoresis painting is a type of surface treatment, where the main principle is to immerse the part in a bath, to which the cathode is subsequently connected. Therefore, conductive materials, especially metals, are varnished using this method. Cationic, water-soluble coating materials based on epoxies or acrylates with a low content of organic solvents (around 2%) are used, which contain paint particles in the form of polymer cations. During the painting process, the part serves as a cathode. By connecting a direct current, the painted part with the anode creates an electric field, due to which the polycations move towards the cathode. By reacting with hydroxyl ions, which are formed by the decomposition of water, they lose their solubility and are excreted on the surface of the part. As the thickness of the layer increases, the discharge rate decreases and the resistance of the layer increases. Cataphoretic varnishing is one of two methods of electrophoretic varnishing. The process is modern and in most cases fully automated. [16]

Thanks to the dipping method of the painted material, it is possible to paint even hard-to-reach places, such as various cavities, inner parts of pipes, corners, edges and the like. Surface treatment with this method is advantageous primarily for the quality of painted parts. Metals modified by the cataphoresis process excel in their resistance to corrosion and resistance to mechanical damage. The paint does not crack or peel, even with thinner layers of paint. The technology enables the regulation of the thickness of the varnish layer, according to the customer's requirements. The thickness of the final varnish depends primarily on the magnitude of the applied voltage, it usually ranges from 15 to 30 micrometers. High productivity, efficiency and reasonable costs are also advantageous. Cataphoresis is beneficial both for the final layer of painting and as a base for further surface treatment. Cataphoresis painting is increasingly used in practice and is preferred over other methods of painting materials. [17]

The application of cataphoretic painting is possible on a wide range of materials such as: rolled steel, galvanized steel, forged parts, zinc, brass, copper, aluminum. It is also possible to paint chrome or stainless steel parts. Given the wide range of materials for which this technology is applicable, the process can be considered universal across various industrial sectors. Another plus of this technology is the ecological side, thanks to the use of organic based varnishes epoxy resins. Also, after soaking the painted part and subsequent removal, where the excess paint is returned and thus almost 100% of the paint is used. [18]

Table 1

Technological process of cataphoretic painting and inspections for the charging station

Process n.	Position	Technological process
1.	-	Acceptance from costumer
2.	-	Input inspection of parts
3.	1.	Hanging the parts up
4.	2.	Chemical degreasing No.1
5.	3.	Chemical degreasing No.2
6.	2. 3.	Interoperation control – temperature measurement
7.	4.1	Technological rinsing No.1
8.	4.2	Technological rinsing No.2
9.	8.	Activation before phosphating
10.	9.	Phosphating
11.	9.	Interoperation control – temperature measurement
12.	10.1	Technological rinsing No.1
13.	10.2	Technological rinsing No.2
14.	11.	Rinsing with demineralized water
15.	12.	Cataphoretic painting - KTL
16.	13.1 13.2	Rinsing in the ultrafiltrate
17.	14.1 14.2 14.3	Burning in furnace
18.	15.1 15.2	Cooling
19.	16.	Hanging the parts down
20.	-	Output inspection – visual inspection + additional inspection of the dry layer of cataphoretic painting
21.	-	Output control – measurement the thickness of the dry layer
22.	-	Packaging and shipping

Disadvantages of the cataphoretic painting:

- Complexity of line setup.
- Limitation of the size of the painted object.
- Material must withstand high temperatures.

2.4 Specification of Measuring device

Elcometer 456 is a non-destructive thickness gauge of dry coating layers that you can use to measure thickness quickly and accurately.

Specifications of the thickness gauge Elcometer 456C XH22928 and the probe used (probe for steel):

- Range: 0-1500 µm
- Accuracy: ±1 – 3% or ±2.5 µm
- Resolution: 0.1 µm: 0-100 µm; 1 µm: 100-1500 µm

Fig. 2. Digital Elcometer 456C

The Digital Elcometer 456 thickness gauge complies with the following standards: AS 2331.1.4, AS 3894.3-B, AS/NZS 1580.108.1, ASTM B 499, ASTM D 1186-B, ASTM D 1400, ASTM D 7093, ASTM D 7093, ASTM , ATSM G 12, BS 3900-C5-6B, BS 3900-C5-6A, BS 5411-11, BS 5411-3, BS 5599, DIN 50981, DIN 50984, ECCA T1, EN 13523-MSC1. (82), IMO MSC.244(83), ISO 1461, ISO 19840, ISO 2063, ISO 2360, ISO 2808-6A, ISO 2808-6B, ISO 2808-7C, ISO 2808-7D, ISO 2808-12, NF T30 - 124, SS 184159, SSPC PA2, US Navy PPI 63101-000, US Navy NSI 009-32. [19]

Table 2

Specification of the calibration plate

Part number	4910
Serial number	XJ06167

Table 3

Specification of the etalon

Elcometer	24,1 µm
Tracking number	TXG90344

3. EXPERIMENTAL PART

The experimental part of the article is dedicated to the development of individual analyzes in the Company. Specifically, developing analyzes of the MSA measurement system using ARM, Cg/Cgk and MSA methods for visual inspection.

3.1 Evaluation of the MSA ARM analysis

• GRR [%] - expresses what percentage of the total variability is attributable to the combined repeatability and reproducibility.

Table 4

The result of GRR [%]

GRR [%]	GRR [%] > 30%
78,516 %	Unacceptable measurement system, the measurement system does not reliably inform about what is happening in the process

GRR indicator, which is 78.516% - the analysis evaluated the measurement system as unacceptable and as unreliable information about what is happening in the process.

• NDC - induces the number of categories into which the measurement process can be divided.

Table 5

The result of NDC

NDC	NDC **< 5**
1,112 = 1	Unacceptable measurement system

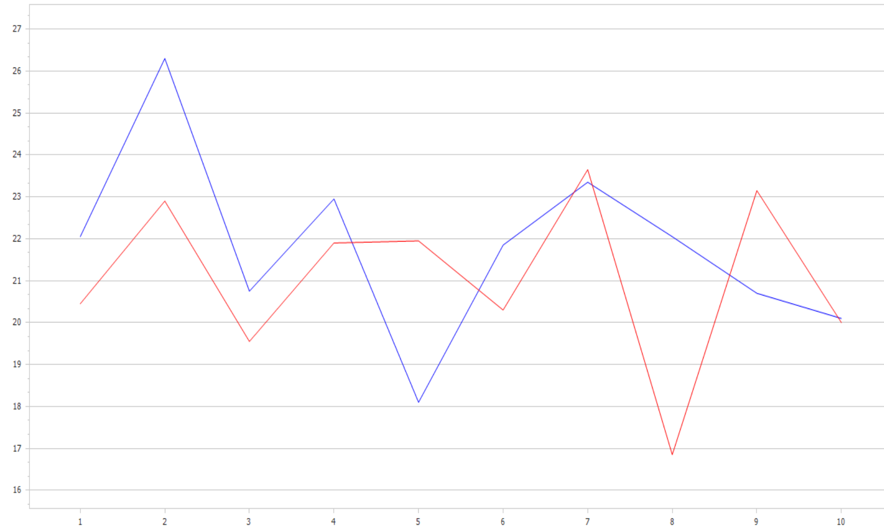
The NDC indicator was recorded as 1.112, effectively rounding to 1, leading to the evaluation of the measurement system as unacceptable and unreliable for monitoring the process

Table 6

Other indicators of the MSA ARM analysis

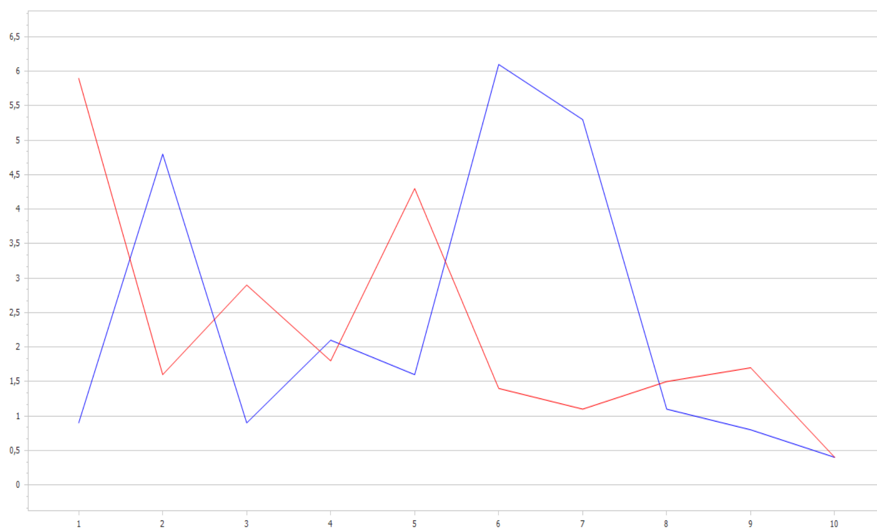
EV [%]	77,825 %
AV [%]	10,396 %
PV [%]	61,929 %

EV - percentage repeatability value.
AV - percentage value of reproducibility.
PV - percentage value of variability.



Controller n.1
Controller n.2

Fig. 3. Dependency graph of MSA averages



Controller n.1
Controller n.2

Fig. 4. Dependency chart of MSA spreads

There can be several reasons for bad results:

- An appropriate control method was not selected.
- The quality of the process in the Company is not sufficient.
- Either the device used was faulty or it was incorrectly configured.
- Errors, inaccuracies of operators.
- Other reasons.

3.2 Evaluation of the Cg/Cgk method

Conditions for fulfillment without measuring error:

$$Cg/Cgk \geq 1{,}33$$
$$Cgk \leq Cg$$

Table 7

Capability indices and their results

Cg	Cgk
1,50 ≥ 1,33	1,38 ≥ 1,33
1,50 ≤ 1,38	

Cg – Cauge Capability Index
Cgk – Corrected Scale Capability Index
S0 – The total dispersion band of the measuring device (0,499 mm).
X0 – Average measured value (24,224 µm).

The conditions are met and the Elcometer 456C is suitable for measurement of the dry layer thickness of the cataphoretic painting.

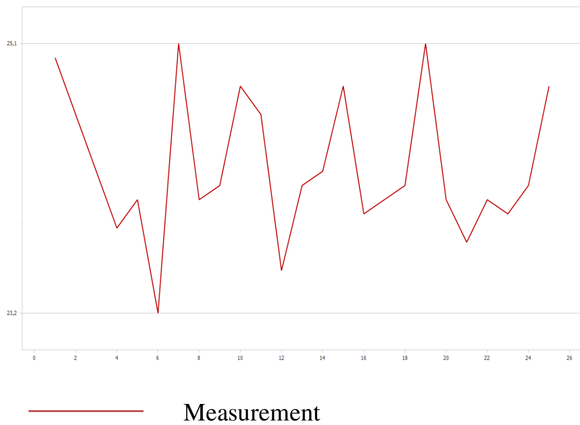


Fig. 5. Graph of the course of the measured values of MSA Cg/Cgk

3.3 MSA analysis for visual inspection

During the visual inspection, the numerical values will not be worked with, but the human senses, namely vision and touch will be the most relevant. During the visual inspection, it is important to compare a specific part with a part that is flawless.

At the Company, a visual inspection was carried out for the stand and side parts of the electric charging station. An important factor in the inspection was compliance with the principles described in the visual inspection instruction. Cataphoresis varnishing was used as a base layer. Parts after cataphoresis are still varnished with a final coating, therefore some defects were permissible, such as surface scratches or abrasions.

Table 8

Evaluation of the MSA visual inspection

	System	System x REF
Total number checked	20	20
Number of matches	20	20
95% UCL	100 %	100 %
SCORE	100 %	100 %
95% LCL	86,1 %	86,1 %

4. CONCLUSION

The IATF 16949 standard is the main requirement for the automotive industry. Its goal is constant progress, improvement of production quality, access to employees, environmental aspects and the like. Every manufacturer that wants to comply with this standard must comply with the requirements contained in this standard.

CAQ quality control systems are used to check quality requirements. Software used to evaluate production data and assess whether the production, product, equipment, machine or operator is suitable for production. Tools are used to control individual aspects of production. In this article, we focused on MSA analysis, which assesses the measurement system in production. Ishikawa diagram that evaluates the possible causes and effects of the measurement system and the production process. The main task of the article was to implement innovative methods used in the automotive industry by creating procedures for developing MSA analyzes for variable and attributive assessment methods, developing ishikawa diagrams for the production process and measurement system on a specific case in the KTL.

MSA analysis by the ARM method is the most widely used method of MSA analysis, therefore this control method was used. However, even with repeated measurements and analyzes in the PalstatCAQ program, the results were negative. In search of the cause of this problem, an MSA Cg/Cgk analysis was performed, the results of which showed that the meter was fine. After repeated measurements of the parts, it was found that the ARM method is not suitable for this type of parts due to the fact that the surface is very fragmented and even with repeated measurements in one place, the values differed, this is the reason for the unfavorable results. The %GRR indicator evaluates the repeatability and reproducibility of the measurement, which was not met due to the impossibility of measuring the same or very similar value at the same place of the part. The NDC indicator indicates the number of distinguishable categories of measured values of the measurement system, which is again impossible in this case.

The indicator EV>AV, which means that the variability of the inspected parts is high. The thickness of the dry layer of those pads is not the same everywhere, therefore it was impossible to make measurements so that the data met the conditions of the analysis.

This means that even though the results of the MSA ARM analysis were negative, it does not change the fact that the measurement process is flawed. The reason is a poorly chosen MSA method, other methods of MSA analysis were also tried, which are not so strict or evaluate the process according to other criteria. According to the measured values, it is impossible for cataphoretic painting and specific parts of the electric charging station. Although the results were somewhat better, they were still not satisfactory. Therefore, a visual inspection method was chosen, which was successful and the results of the MSA analysis meet the specified conditions. For a given type of parts of an electric charging station, inspection procedures have been proposed in the way of visual inspection, which makes much more sense. However, checking with the Elcometer 456C gauge is also necessary to maintain the dry layer thickness tolerances specified by the customer.

5. ACKNOWLEDGEMENTS

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ANALIZA SISTEMULUI DE MĂSURARE ÎN TRATAMENTUL DE SUPRAFATĂ A UNEI PIESE PENTRU INDUSTRIA DE AUTOMOBILE

Rezumat: Articolul tratează implementarea metodelor inovatoare utilizate în controlul calității în industria auto. Sarcina a fost de a proiecta și dezvolta o analiză a sistemului de măsurare pentru caracteristicile calitative variabile și atributive. Părțile stației de încărcare care sunt tratate la suprafață prin vopsire cataforetică au fost utilizate pentru analiză. Grosimea stratului uscat a fost folosită ca variabilă de calitate. Aspectul general al lacului de suprafață a fost folosit ca semn atributiv al calității. Pentru analiza sistemului de măsurare s-au utilizat metoda repetabilității și reproductibilității, indici ai fezabilității măsurii și metoda atributivă. Metoda de repetabilitate și reproductibilitate s-a dovedit a fi inacceptabilă pentru acest produs. Prin urmare, s-a folosit ulterior metoda atributivă care a demonstrat că sistemul de măsurare analizat este în regulă.

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