TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 67, Issue Special I, February, 2024

IMPLEMENTATION OF THE QUALITY MANAGEMENT SYSTEM IN THE PRODUCTION OF A COMPONENT IN THE AUTOMOTIVE INDUSTRY

Damián PETI, Jozef DOBRÁNSKY, Martin POLLÁK

Abstract: *The article deals with the implementation of the Computer Aided Quality (CAQ) management system in the technological process of cataphoretic painting of parts of an electric charging station used in the automotive industry. The goal was to describe the technological process of cataphoresis painting (KTL) and to choose a suitable method for monitoring the quality of the production process. The thickness of the dry layer was chosen as a qualitative parameter for monitoring the capability and performance of the production process. The statistical process control (SPC) method was used to evaluate the process. Process capability, performance indices and control charts were used for evaluation. The main task of the research was the implementation of the quality management methodology according to the International Automotive Task Force (IATF) 16949:2016 standards in the production process of cataphoretic painting in the production company. So far, the company has not used such a form of quality control.*

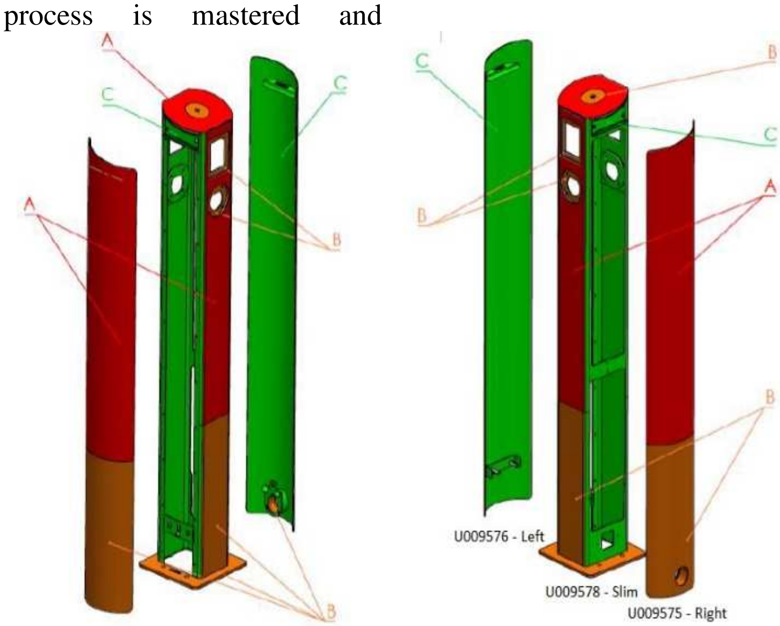
Key words: *Quality, process, cataphoretic painting, capable indices*

1. INTRODUCTION

From the point of view of the automotive industry, the computer aided quality management system and its implementation in production processes represent an inseparable component of quality control. Assessment of process capability is among the basic requirements of the end customer for confirmation of stable production conditions that ensure compliance with the prescribed criteria. Currently, the aforementioned criteria are subject to the recognized international standard according to IATF 16949:2016, which supplements the standard ISO 9001:2015 with expanded requirements in the industry. The aim of the given technical specification is to process and set requirements for possible suppliers of the automotive industry and the subsequent implementation of the quality management system in companies with a guarantee of continuous improvement, with the reduction of variability and losses in the supply chain. [1,2]

According to the model situation, there was a request for the implementation of the quality management system with the parts of an electric charging station. The supervision of the control of production process was accompanied by the measurement of the thickness of the dry layer of cataphoretic painting and the evaluation of the correctness of the final product. Ensuring appropriate analysis is accompanied by work in the PalstatCAQ program, which is characterized by the effective construction of a quality management system in enterprises of various specializations. The use of the mentioned program provided space for the creation and establishment of the measured parts of the electric charging station, the creation of a control-technical procedure, analysis of possible errors and their consequences – Failure Mode and Effect Analysis (FMEA) and Statistical Process Control - SPC analysis. By defining the requirements, there was an effort to directly focus on quality, which helps to differentiate from the competition and by setting up a suitable production cycle of the mentioned parts. [3]

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 KTL technological process to packaging and shipping. The very conclusion of the work is the evaluation of the measurements of the selected parts and the subsequent assessment of whether the given technological process is mastered and sustainable in its current state from the point of view of short-term and long-term quality capability. [4]



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. MATERIAL AND METHODS

2.1 Cataphoresis painting

Cataphoresis or in other words cathodic immersion painting (KTL) is classified as an economical and extremely ecological method of painting automotive and engineering parts. It is also possible to include it among the most modern technologies, the characteristics of which are given by the surface treatment of metals. In practice, it is possible to use the given surface treatment of the material as the only one - final painting or in combination with other surface treatments, where the cataphoretic painting acts as a primer. [5]

Cataphoretic painting is one of the methods of electrophoretic painting, which is characterized by the use of cationic soluble coating materials. Coating materials can be described as substances soluble in water with a structure that is composed on the basis of epoxies or acrylates. These substances are specified by the low content of organic solvents containing varnish particles, which are found in the form of polymer cations. [6]

During the painting, the parts are immersed in the paint bath, where they act as a cathode after being connected. Further insertion of a direct current of copper and the anode guarantees the creation of an electric field under the influence of which the polycations move towards the cathode. The formation of a reaction with hydroxyl ions causes the decomposition of water and the excretion on the surface of painted parts is guaranteed. With the gradually increasing thickness of the coating, the resistance of the layer also increases at the same time, where the excretion rate has a decreasing character, and this happens especially in places where the applied layer is not sufficiently thick (shielded places, cavities, etc.). [7]

2.2 FMEA analysis

The main task of the Failure Mode and Effect Analysis methodology is the targeted identification of all possible errors that are found either in the product or in the process itself, where, in the case of their consequences, the effort is to prevent, reduce and limit the possible causes and their errors, which are accompanied by the documentation of the given process itself. In the case of using the FMEA method, 70% - 90% of possible errors in the production process of automotive components are ensured to be detected according to the QS 9000 methodology or the methodology of the German automotive industry association VDA.

By using this method, it is possible to minimize or avoid the risks that arise when:

- Development of products.
- Process development.
- Development of new technologies.

The use of this method must be considered justified not only in the automotive industry, but also in the engineering industry, since the percentage of possible error removal given in % is determined at all stages of the process from product development to its use in practice. [8]

2.3 SPC analysis

The statistical process control (SPC) system can be described as a returnable system of statistical tools, the task of which is to manage process parameters with an effort to create the minimum number of faulty or inconsistent outputs in the production process. [9-12]

Basic objectives of SPC:

- Achieving the required state in the form of a statically managed process.
- Striving to maintain the process at a defined stable level.
- Prevention of non-conforming final products.
- Creation of such conditions that serve to evaluate the capability of the process.
- Creation of such conditions that serve for the subsequent improvement of the process.
- Striving to achieve the fastest possible intervention in the process in the event that there are special causes.
- Process management documentation. [13-16]

2.3.1 Process performance and capability indices

The process performance and capability indices C and P have the task of assessing the scope of the process with the scope of the specification and subsequently expressing the error rate of the process. They also compare continuous data with a normal distribution. The expression is given using equations (1, 2, 3, 4):

$$C_P = \frac{USL-LSL}{6\sigma\ Short\ term} \quad (1)$$

$$P_P = \frac{USL-LSL}{6\sigma\ Long\ term} \quad (2)$$

$$C_{pk} = Min\ \{\frac{USL-\mu}{3\sigma\ Short\ term}; \frac{\mu-LSL}{3\sigma\ Short\ term}\} \quad (3)$$

$$P_{pk} = Min\ \{\frac{USL-\mu}{3\sigma\ Long\ term}; \frac{\mu-LSL}{3\sigma\ Long\ term}\} \quad (4)$$

• Capability Indices C = Capability - Used to assess a short-term process where there is a certain allowable range/specification. The deviation is given in the subgroup.

• Capability Indices P = Performance - Used to assess a long-term process where there is a certain allowable range/specification. The deviation is given in the whole process.

• Indices p - The full width of the specification is used. It does not consider the location of the process.

• Indices pk - The full width of the specification is used. It takes into account the location of the process. It consists of at least two USL values – x, x-LSL.

Table 1

Established conditions in the production process when assessing quality capability

Cp, Cpk	≥ 1,33
Pp, Ppk	≥ 1,50

2.3.2 Statistical control diagrams

They act as a graphic means for displaying the development of process variability over time, in which the principle of statistical hypothesis testing is used. When evaluating processes, a distinction is made between diagrams for quantitative (use of control diagrams when checking by measuring the thickness of the applied layer, length and diameter) and qualitative data (use of control diagrams when checking the comparison with the help of an assessment of the type: pass/fail). The most frequently used control charts are the charts for mean (X), range (R), individual values (I) and sliding range (MR), the use of which can be observed in the control performed by measurement. The use of diagrams based on the principle of non-conforming products, such as e.g. p, np, c and u – diagrams. [17,18]

In the evaluation and subsequent assessment of statically mastered processes, the central straight line – X, the lower regulatory limit –

LCL and the upper regulatory limit UCL – act as basic criteria. The X value acts in the structure of the control diagram as a reference value, which is defined in different ways:

a) Possible estimation from the values that are given by the regulated variable and are obtained from the conditions of the statically managed process.

b) The output value appears as a nominal value (nominal value or value entered by the customer's technical regulation).

c) Output value, which is entered based on possible experience with the given production process. [19]

2.3.3 Distribution tests

Distribution tests are used to assess whether a variable comes from the distribution that is assumed. With the help of the given tests, it is advisable to examine the course of the entire distribution function and verify the assumption of a normal distribution.

• X2 test – a chi-squared test (symbolically represented as a X2 test) is basically a data analysis on the basis of observations of a random set of variables. Usually, it is comparison of two statistical data sets.

• Kolmogoorov-Smirnov test - statistic quantifies a distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution, or between the empirical distribution functions of two samples.

• Shapiro-Wilk test – is a hypothesis test that evaluates whether a data set is normally distributed. It evaluates data from sample with the null hypothesis that the data set is normally distributed.

• Anderson-Darling test – is a statistical test of whether a given sample of data is drawn from given probability distribution. [20-22]

Table 2

The established conditions of the distribution tests when assessing the results of the analyzed data

✓	Meet the conditions
X	Does not meet the conditions

3. EXPERIMENTAL PART

In the production process of cataphoresis painting of the electric charging station and their parts (U009575 – Right, U009576 – Left, U009578 – Slim), it was necessary to make 2850 measurements of the surface of the dry layer of cataphoretic painting to ensure a suitable statistical analysis and subsequent assessment of the process itself from the point of view of quality capability. By choosing sample values, i.e. of average values from individual measurements, it was necessary to subsequently upload them to the information system of the PalstatCAQ programme.

Before applying the Statistical Process Control, it was necessary to perform an analysis of the measurement system analysis (MSA) in the selected PalstatCAQ program in order to assess the measurement system and determine the suitability of the measuring device with the help of statistical and metrological quantities. The aim of the given analysis was to determine the possible influence of various factors that caused variability in the process of measuring the observed parameter, to evaluate the quality of the measured data and to try to deliberately avoid the production of non-conforming pieces during the process of cataphoretic painting. The MSA analysis was carried out by a group of operators who monitored the impact of repeatability (evaluation of the resulting measured values) and reproducibility (comparing the resulting measured values) on the total dispersion of the KTL production process and measuring device.

When displaying the results in the distribution test of the analyzed data, it is possible to observe the plotting of the distribution function of the measured data, the distribution function of the distribution and the level of significance. In the end, there was a need to assess the process capability of selected parts with the help of established quality capability indices and subsequent comparison of the results from the distribution tests for individual parts.

Table 3

Results from Measurement of the dry layer of cathaforesis painting for electric charging station

Indices	U009578	U009576	U009575
Cp	2,74	1,83	2,45
Cpk	2,54	1,53	2,16
Pp	1,95	1,59	1,48
Ppk	1,83	1,33	1,30

Table 4

Results from the Distribution tests of dry layer of cataphoresis painting of electric charging station

Tests	U009578	U009576	U009575
X2 Test	0,9735	1,0000	0,3309
K-S Test	0,9961	0,6340	0,1081
S-W Test	0,7139	0,1294	0,001638
A-D Test	0,8584	0,1417	0,0009147

Table 5

Results from Calculated characteristics of dry layer of cataphoresis painting of electric charging station

Characteristics	U009578	U009576	U009575
$\bar{X}$	21,934	21,257	23,408
Median	22,03	21,40	23,15
R	6,52	4,97	6,84
σ	1,262	1,573	1,693

Fig. 2. Statistical control diagram – U009575 - Right

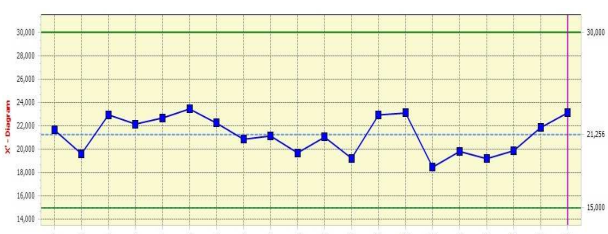


Fig. 3. Statistical control diagram – U009576 - Left

Fig. 4. Statistical control diagram – U009578 – Slim

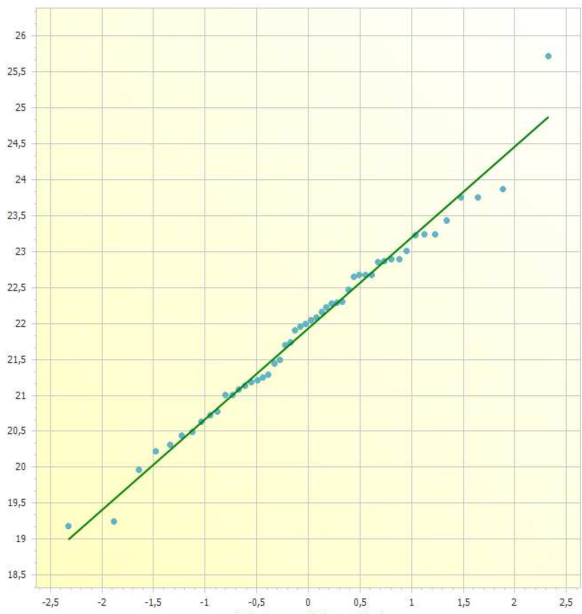
By determining the short-term capability of the process, i.e. capability of the process, it can be concluded that the obtained values $Cp = 2.45$, $Cpk = 2.16$, $Cp = 1.83$, $Cpk = 1.53$ and $Cp = 2.74$, $Ckp = 2.54$ from the parts U009575, U009576 and U009578 are higher than the specified common indices $Cp \geq 1.33$, $Cpk \geq 1.33$ and the cataphoresis painting process is sustainable for all specified parts in the current state. With the resulting ability of the process to persist within the set regulatory limits, it is possible to demonstrate that the process is mastered and meets the criteria of the required production and the end customer.

By determining the long-term capability of the process, i.e. performance of the process, it can be concluded that the obtained values $Pp = 1.98$, $Ppk = 1.83$ from the part U009578 are the only satisfactory ones within the given common indices $Pp \geq 1.5$ and $Pkp \geq 1.5$. Parts U009575 and U009576 and their resulting values $Pp = 1.48$, $Ppk = 1.30$ and $Pp = 1.59$, $Ppk = 1.33$ were accompanied by possible influences that characterize the production equipment used in the KTL line. The influence on the resulting characteristics it could have been caused by the action of other factors, such as: workers, measurement method, environment or faulty mounting. For these reasons, there was a demand for increased attention to the characteristics of the selected parts and a possible re-evaluation of the control plan.

With the help of the given distribution tests, it is advisable to examine the course of the entire distribution function. From the point of view of the evaluation of the results from the tests of the distribution of the analyzed data for the X2 test, the Kolmogoor-Smirnov test, the Shapiro-Wilk test and the Anderson-Darling test, it is possible to determine that the parts U009576 and U009578 of the electric charging station comply with the given hypothesis. In the case of part U009575 and the resulting values for the X2 test = 0.3309 (measured values in class intervals with the corresponding frequency) and the Kolmogoor-Smirnov test = 0.1081 (verification of the monitored variable of the assumed distribution), it can be determined that they do correspond to the specified hypothesis.

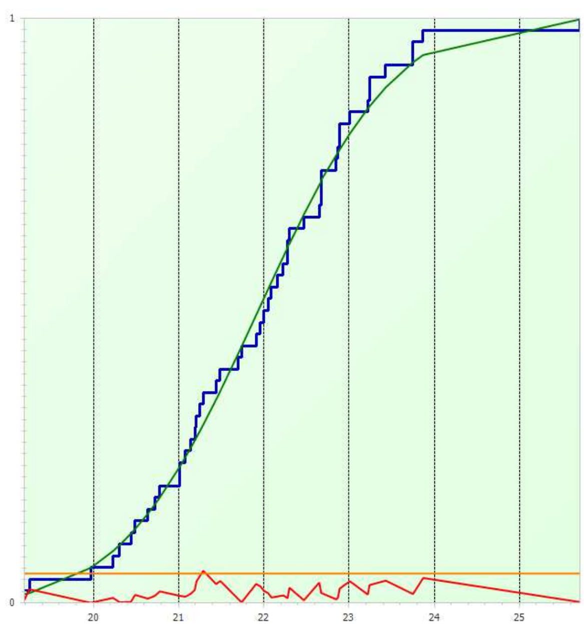
Recommended measures:

- isolation of non-conforming products or products suspected of non-conformity after the KTL process.



- Ideal data
- Measured data

Fig. 5. Distribution test – Normal distribution value (U009578 – Slim)



- Measured data
- Ideal data
- Difference
- Level

Fig. 6. Distribution test – The value of the quantity (U009578 – Slim)

- Analysis of possible causes and non-conformities with mandatory adoption of immediate corrective measures.
- Acceptance of control and test measures guaranteeing the supply of exclusively identical products for the following cataphoretic process.

4. CONCLUSION

In order to meet the specified goals, it was necessary to establish and develop a methodology that serves to determine the capability of the short-term and long-term production process of cataphoresis painting and then assess the distribution tests from the analyzed data.

When evaluating the measurement results, it was necessary to use the established conditions of the qualitative capability indices Cp, Cpk and Pp, Ppk, to develop control diagrams and distribution tests that examine the course of the entire distribution function.

The analysis of the KTL production process itself proved that the resulting ability of the process to persist within the regulatory limits meets the criteria of the required production. From the point of view of the short-term capability of the production process, i.e. process capability, the entered parts complied with the specified conditions of the quality capability indices $Cp \geq 1.33$, $Cpk \geq 1.33$ and comply with the cataphoresis painting process. In the issue of long-term capability of the production process, i.e. performance of the process and the set conditions of the quality capability indices $Pp \geq 1.5$, $Ppk \geq 1.5$ it was possible to determine that the part U009578, which is placed as the most supporting part of the electric charging station, is suitable for the cataphoresis painting process. The unsatisfactory parts U009575 and U009576 may have been affected by various factors that are partially beyond our control.

The process of cataphoresis painting of selected parts of the electric charging station is sustainable in its current state due to the stated results and reasons.

5. ACKNOWLEDGEMENTS

This paper has been elaborated in the framework of the project KEGA 063TUKE-4/2021 and project VEGA 1/0488/23.

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IMPLEMENTAREA SISTEMULUI DE MANAGEMENT A CALITĂȚII ÎN PRODUCȚIA UNEI COMPONENTE ÎN INDUSTRIA DE AUTOMOBILE

Rezumat: Articolul tratează implementarea sistemului de management al calității asistate de computer (CAQ) în procesul tehnologic de vopsire cataforetică a pieselor unei stații de încărcare electrică utilizate în industria auto. Sarcina a fost de a descrie procesul tehnologic de vopsire prin cataforeză (KTL) și de a alege o metodă adecvată pentru monitorizarea calității procesului de producție. Grosimea stratului uscat a fost aleasă ca parametru calitativ pentru monitorizarea capacității și performanței procesului de producție. Pentru evaluarea procesului a fost utilizată metoda controlului statistic al procesului (SPC). Pentru evaluare au fost utilizați indici de capacitate de proces și de performanță și diagrame de control. Pe baza indicilor, procesul de producție a fost evaluat ca capabil. Sarcina principală a cercetării a fost implementarea metodologiei de management al calității conform standardelor International Automotive Task Force (IATF) 16949 în procesul de producție a vopsirii cataforetice în compania de producție. Până acum, compania nu a folosit o astfel de formă de control al calității.

Damián PETI, MSc., PhD. student, Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Automobile and Manufacturing Technologies, damian.peti@tuke.sk, +421-55-602-6368, Štúrova 31, 080 01 Prešov. Slovak Republic.

Jozef DOBRÁNSKY, assoc. prof. Eng. MSc. PhD., associate professor, Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Automobile and Manufacturing Technologies, jozef.dobransky@tuke.sk, +421-55-602-6350, Štúrova 31, 080 01 Prešov. Slovak Republic.

Martin POLLÁK, MSc. PhD., assistant professor, Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Computer Aided Manufacturing Technologies, martin.pollak@tuke.sk, +421-55-602-6460, Štúrova 31, 080 01 Prešov. Slovak Republic.