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SEQUENCE OF SELECTED QUALITY MANAGEMENT TOOLS TO ANALYZE QUALITATIVE PROBLEMS OF PRODUCTS

Identification of causes of incompatibilities of the products treated with the powder method allows their elimination or minimization of those differences, which contributes to the improvement of the powder coating method and thus to the development of processes in the field of metallurgy. The aim of the article is to analyze the corrosion problem on the ventilator cover with the use of the sequence of selected quality management instruments (Ishikawa diagram and the 5Why method) and proposed actions to eliminate or minimize the problem and improve the powder coating process and organization within the workplace place of the selected company. The analysis was carried out at the request of the management of the Podkarpackie fan producer. The management wanted to analyze some of a problems in the simple and cheaper way, and thus in the enterprise this using the types of the method was not practiced. The management were wanted to analyze the problem with using these types of method because, in this enterprise, this was not practiced yet. The analysis of corrosion using the new sequence – Ishikawa diagram and 5Why method allowed, i.e.: appropriate analysis of the problem, identified the root cause of adequate problem and proposed the actions for the problem, thanks to which is possible to improve the powder coating process and a good organization workplace in the selected company. The sequence used and the proposed improvement actions can be used to analyze quality problems in other production and service companies.

Keywords: Ishikawa diagram; 5Why method; quality management tools; improving of product; production engineering; mechanical engineering.

1. INTRODUCTION

Quality management is a key action of enterprises to improve product quality. Usually, it is supported by quality management tools (Pacana, Siwiec, 2021). A typical problem is

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an increase in the demand for high-quality paint coatings, which are obtained by the powder method. It requires prevention of incompatibility, such as corrosion on the paint cover. To increase resistance to corrosion, the cast iron or steel castings are covered with powder paints. Powder coating is included in ecological methods and does not require large amounts of financial resources. Additionally, powder methods are one of the few methods by which high-quality paint covers are achieved, and, moreover, powder painting is considered a dynamically developing method in the field of metallurgy (Pacana, Siwiec, Bednarova, 2019).

The powder coating process is the method of painting with finely ground paint particles that do not contain solvents. The powder coating process consists of charging electrostatically dry and well ground pigment particles and resin and successively sputtering them onto objects that are electrically grounded (Rustico et al., 2015). The powder, whether charged or sprayed, adheres to the surface of a given item until it is melted in an oven at elevated temperature into a homogeneous coating. In powder coating, the basic types of coating materials are thermoplastic and thermoset coatings. Thermoplastic coatings fuse together with the supply of the right amount of heat and their chemical components remain unchanged after cooling and merging (John, 2015). In the case of thermosetting coatings after melting, chemical reactions occur, in which the cured thermosetting coating has a chemical structure than before the melting process (Naderi, Attar, Moayed, 2004). As a result, the thermosetting coatings are stable and do not react to reheating, which is why, unlike thermoplastic coatings, they do not soften. The advantages of the powder method are that it does not affect the environment (the powder coated coatings do not emit the organic compounds responsible for ozone) and do not increase the economic costs associated with the petroleum solvents used in traditional liquid coatings (Pardo, Aristizabal, 2017).

The development of powder coating materials was caused by the desire to replace liquid solvent-based paints that are not environmentally friendly. One of the first steps was the development of a hot mixing process using a bladed mixer, which contributed to the more homogeneous powder materials. In 1960 the method of spraying thermosetting powder coatings was developed, where with compressed air the decorative covers were sprayed. The development of the powder method resulted in the creation of many other factors that affected its effectiveness (Mozaryn, 2018; Wade, 2002). After analyzing the selected research on powder painting, it was concluded that only the improvement of the products and the machines used for powder grinding will not contribute to the minimalization of the corrosion on the products. For example, the dependences of the thickness of the coating in relation to the four variables of the powder coating process, i.e. oven temperature, curing time, and conductivity, as well as powder yield, have a significant impact on the quality of the paint coating. After selecting the optimal values for the given parameters, it is possible to obtain an average coating thickness (about 80 microns) (Adams, 1989; Boer, Petruta, 2014; John, 2015; Kramer, 1993). The coatings, in particular thermally cured, phenolic or epoxy phenolic, provide corrosion resistance, and the heat-curing coating to protect against corrosion must be stable at elevated temperatures of up to 220°C. In addition, if adequate air conditioning is provided, which also applies the ventilators, the occurrence of corrosion and contamination results in a smaller temperature difference between the liquid or gas and the outside air. This phenomenon can be minimized by achieving a higher condensing temperature that provides the ability to conduct heat (Donelli, Picoltrini, Donelli, 2012; Naderi, Attar, Moayed, 2004). Other factors that may affect the corrosion of the product

are, for example, the poorly prepared cover for powder painting or the poorly performed process of the powder coating.

In the article, the causes of the corrosion of ventilators for external use were analyzed. For the analysis, previously not practiced (in the enterprise in which the problem was identified) were used. Thus, the Ishikawa diagram and the 5Why method were used. In view of the large potential causes of corrosion, to analyze of the problem, the Ishikawa diagram was used. In view of a large number of potential causes of the corrosion to analyze the problem, the Ishikawa diagram was used. Thanks to this method, the main causes were identified, i.e. pollution, inadequate ventilator cover, and lack of periodic training. Next, using the 5Why method, it was concluded that the root cause of the corrosion was the lack of broadening knowledge of the powder painting principles and the lack of implemented Lean Manufacturing instruments. Due to the conclusions which were made and the improvement actions that were proposed, it could be avoided by preventing corrosion on the products and improving the powder painting process.

2. SUBJECT OF RESEARCH AND METHODS

The problem was related to the corrosion that occurred in the ventilators, which was detected after several months of use by the external customer (Figure 1).

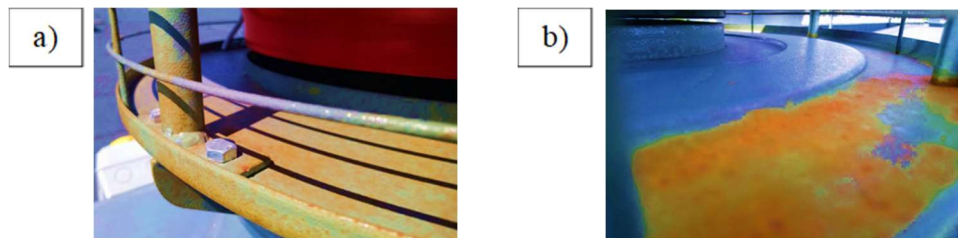


Figure 1. Example of the corrosion identified in the ventilator: a) outside part; b) internal part

Source: Own study.

The ventilators, in which the corrosion was identified were fixed on the building roof (on the free space). These were PFD-200 roof ventilators designed for general use. The temperature at which the ventilator should not be damaged is for the pressed medium from -25°C to 60°C and for the area to 40°C . The ventilator covers were made of steel sheet (TH 1300, 2000) and painted with using the powder painting (called the furnace method).

The powder painting process began with the preparation of the ventilator cover by mechanical cleaning to remove the impurities. Mechanical cleaning included the process of prerinsing and the application of iron phosphates to the cover to protect it from corrosion. Subsequently, the ventilator cover was powder coated with polyester paint for a paint coat thickness of $95\ \mu\text{m}$ and the powder was baked by the furnace method. The sintering was made in a convection oven at about 200°C for about 10 minutes.

The heat in the oven was distributed in the circulation system. After the powder was mixed with a uniform surface in the oven, the coating was cured for about 20 minutes. The simplified scheme of the powder coating process is shown in Figure 2.

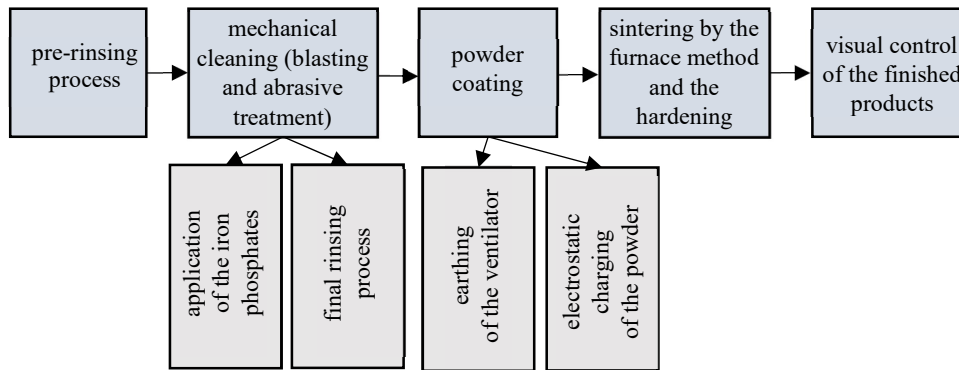


Figure 2. Scheme of the powder coating process

Source: Own study.

In view of a large number of potential causes of the ventilator corrosion, the Ishikawa diagram (called fish bone) was made (Bilsel, Lin, 2012; Braglia, Frosolini, Gallo, 2017; Chokkalingam et al., 2017). In the fish head the problem was put, i.e. the ventilator corrosion. Next, the five categories to analyze this problem were selected, i.e. man, method, machine, material, and environment. These categories allowed us to find the potential causes of corrosion and therefore allowed us to thoroughly analyze individual indirect causes (Lira et al., 2017). Subsequently, the company manager and the quality department chose the main causes of corrosion for the reasons (Salvador, Goldfarb, 2004; Shin, Lee, Son, 2015). To find the root cause of the problem, the 5Why method was used. The analysis was started by defining the problem (coating in the fans) and giving the pre-defined root causes of the problem. The analyze was started from the definition of the problem (conductor corrosion) with the main causes of the problem, which were selected at the previous stage. The analysis was based on the task for every cause of the “why” question until the root cause was identified (Benjamin, 2015; Wade, 2002). The analyses allowed us to propose improvement actions, thanks to which it is possible to minimize the risk of corrosion on ventilators.

3. RESULTS OF ANALYSIS

In the first stage of the analysis, the Ishikawa diagram was made, to identify the potential causes of the corrosion problem that was involved on the ventilators (Figure 3).

The main causes of the corrosion problem were the poorly prepared ventilator cover and lack of periodic employee training. These factors meant that the process of preparing the fans and the process of painting them were not carried out correctly. The poor adhesion of the varnish coat and subsequent corrosion of the ventilators were considered to be directly on the poor surface preparation of the ventilator before painting. The possible impurities that caused the paint to not adhere properly to the ventilator, resulting in damage of the ventilator cover and consequent corrosion as a result of external factors (including atmospheric). The ventilator surfaces contaminated before painting caused deterioration in the protective properties of the coating and corrosion. Impurities were also related to the

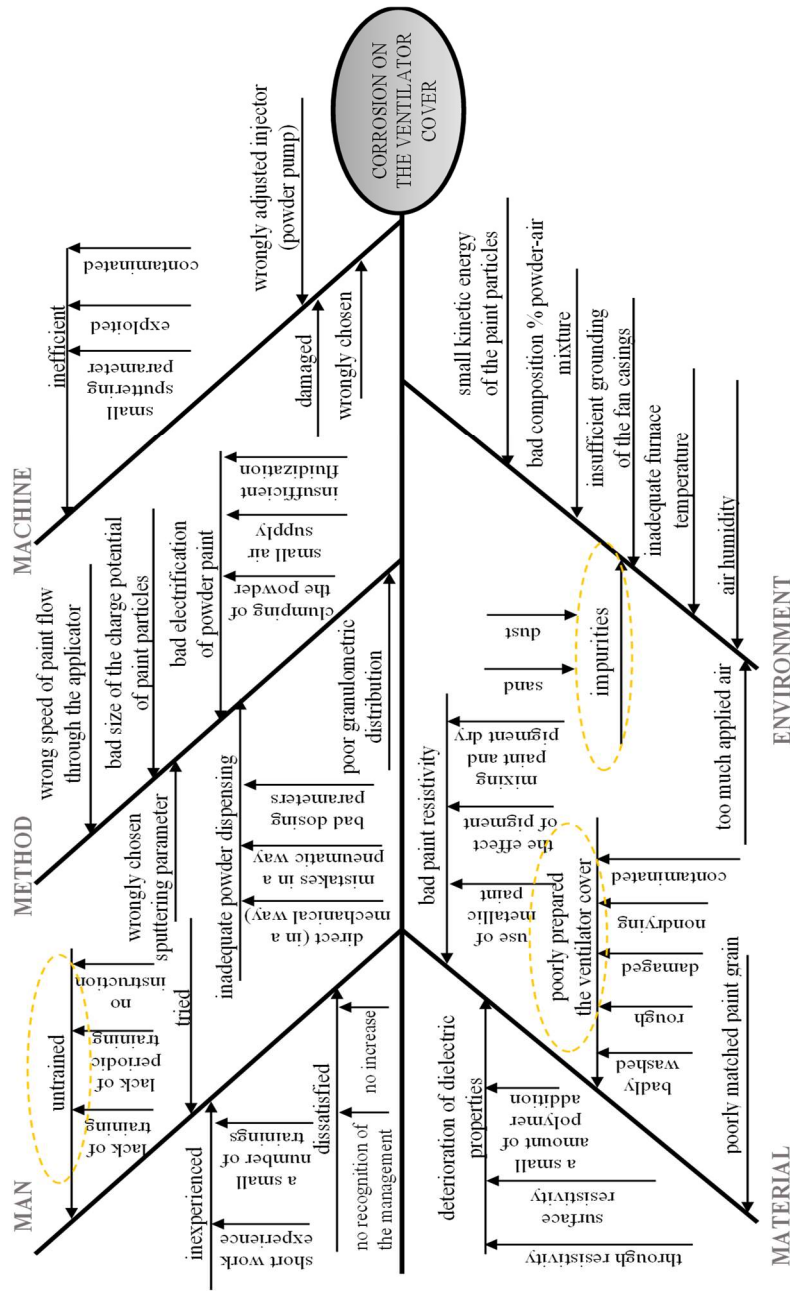


Figure 3. Ishikawa diagram for the corrosion problem on the ventilator cover

Source: Own study.

maintenance of the equipment used during the cleaning and painting of the ventilators, as well as the rooms in which these processes were carried out. The employees were not subjected to periodic training, so their knowledge of the correct implementation of the production processes was not good enough, which led to their mistakes. To identify the root cause of the problem, the analysis was performed with the 5Why method (Figure 4).

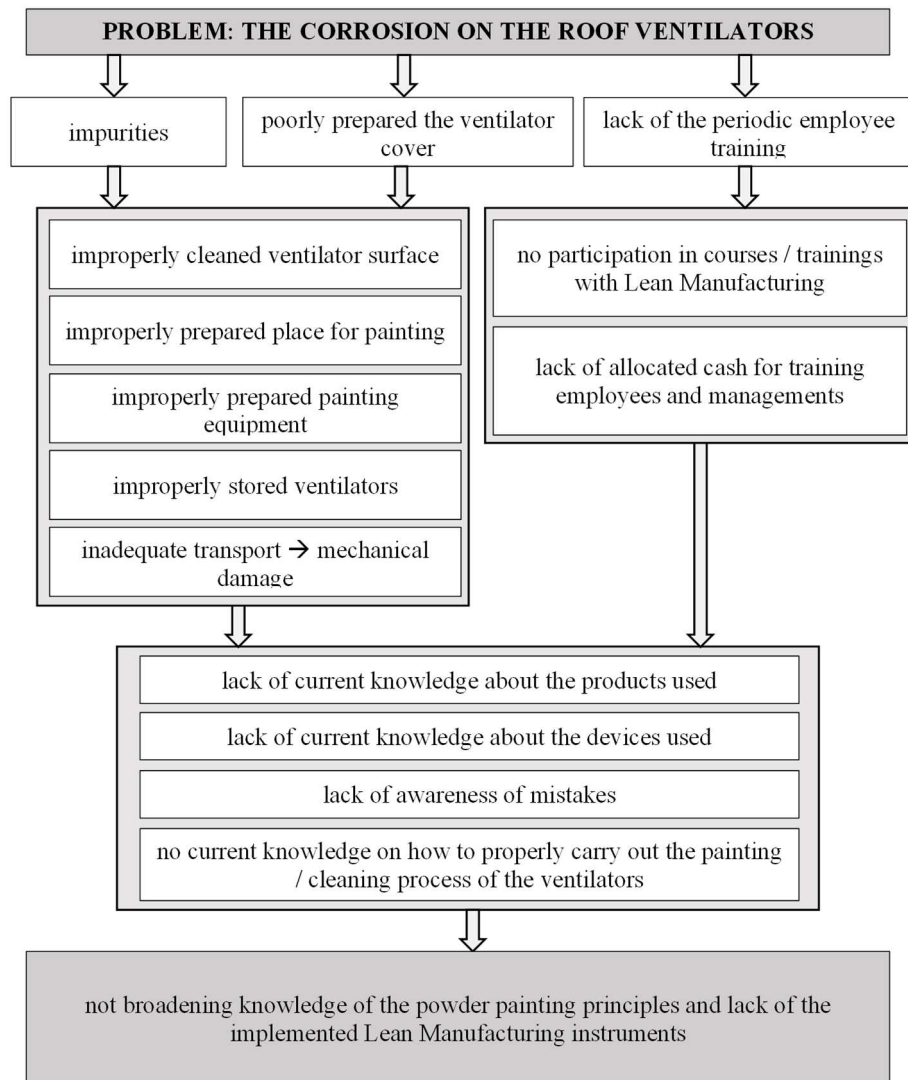


Figure 4. An analysis of the corrosion problem of the ventilators with using the 5 Why method
Source: Own study.

After analyzing the main causes of ventilator corrosion with the 5Why method, it was concluded that the root cause was the lack of broadening knowledge of the powder painting

principles and lack of managements awareness of the benefits of practicing Lean Manufacturing.

4. DISCUSSION AND CONCLUSION

Achieving high-quality products and simultaneously customer expectations are still a challenge (Ostasz, Siwiec, Pacana, 2022; Pacana, Siwiec, 2022; Siwiec, Grebski, 2022; Siwiec, Pacana, 2021). Therefore, it is necessary to use different techniques which will support during achieve a stable production process of products (Siwiec, Pacana, 2022; Siwiec, Pacana, 2021). In this case, it was concluded that the production process should be improved and Lean Manufacturing instruments should be introduced. Improvement actions in the production process that would minimize the corrosion of the ventilators are as follows:

- replacement of the mechanical washing process with the chemical cleaning process, thus introducing the following:
 - surface degreasing,
 - application of zinc coatings, which would be a primer for powder coatings and thus would increase the protection against corrosion,
 - application of painting sets with increased resistance;
- introduction of visual inspection of the products prior to the powder coating process, in which the number of items to be inspected, would be consistent with the technology adopted.

The example of the simplified scheme for the implementation of the powder coating process with the improvement actions presented in Figure 5.

In addition, the improvement of the powder coating process and the functioning of the entire company can be achieved through the implementation of Lean Manufacturing instruments such as: 5S, TPM and standard work. The steel surfaces of the ventilators require careful workmanship, in particular in the case of ventilators whose use is intended for external use. The replacement of mechanical cleaning for chemical washing, together with the degreasing process, and the use of zinc coatings together with phosphate coatings increase the corrosion resistance. The implementation of the selected Lean Manufacturing instruments (5S, TPM and standard work) would allow for, i.e.:

- maintaining cleanliness at work stations,
- maintaining the good condition of the machines and devices used during the production process of the ventilators,
- analysis of individual processes and measure,
- to identify problems on an ongoing basis,
- eliminating or minimizing problems.

Using the 5W2H method sequence, the Ishikawa diagram, and the 5Why method, it was possible to:

- characterizing the problem in a transparent way, including the most important information about the problem,
- identifying the causes of the potential problem and selecting the main causes,
- identifying the cause of the source problem,
- developing improvement actions that are adequate to the identified cause of the source problem.

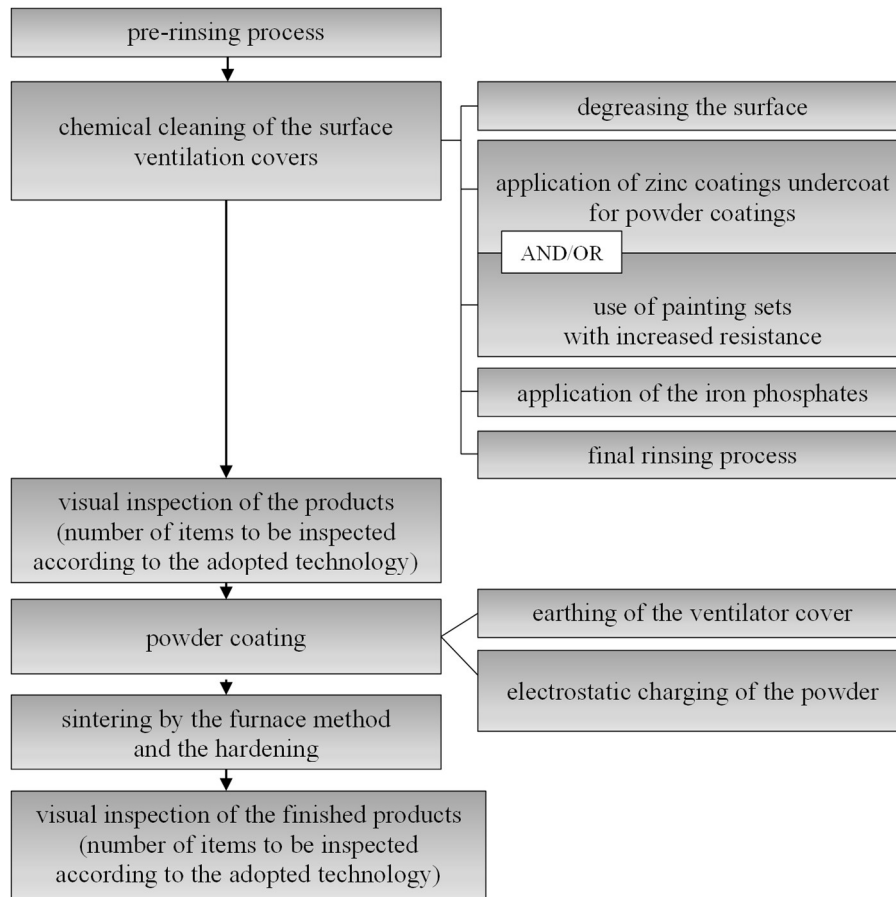


Figure 5. Simplified scheme of the powder coating process with suggested improvement measures

Source: Own study.

Quality management tools used to solve the problem of ventilator corrosion and the proposed improvement actions can be practiced in the case of other problems in the field of metallurgy.

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