Use of Selected Tools of Quality Improvement in a Company Producing Parts for the Automotive Industry – Case Study

KNOP Krzysztof [a *]

Department of Production Engineering and Safety, Faculty of Management, Czestochowa University of Technology, Al. Armii Krajowej 19b, 42-218 Czestochowa, Poland

[a]krzysztof.knop@wz.pcz.pl

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Abstract. The article is a case study on the use of selected quality management tools in a company from the automotive industry for the purpose of improving the basic production process carried - the assembly process. Quality tools such as Pareto-Lorenz diagram, Ishikawa diagram, and 5WHY method were used. The analyses carried out with the use of quality tools made it possible to identify non-conformities that most often occurred during the assembly process of the tested products, indicate the causes of these non-conformities, and develop suggestions for improvement. The most frequently found non-compliance of products was the disconnection of an element during assembly, due to damage to materials in the warehouse. The root cause turned out to be the lack of control of the state of materials available in the warehouse according to the control plans in force at the plant. The need to introduce changes in the organization of warehouse work, in particular, to increase supervision over the control of the condition of materials and to introduce 100% control of products manufactured in the plant, was indicated as improvement measures.

Introduction

A company that wants to meet market challenges must get to know customers, their needs and expectations, and then, on this basis, develop and manufacture products that will satisfy them [1]. This requires proper quality management. It covers a wide spectrum of issues related to planning, organizing, coordinating and controlling quality assurance activities [2]. Quality management is one of the concepts of broadly understood enterprise management. In the most general sense, it means planning and organizing the enterprise management system in such a way that it covers everything that affects the fulfillment of quality requirements [3]. Quality management is also understood as continuous improvement of products and activities related to their production [4]. In other words, it is the management of resources and processes carried out in the company through the prism of effects directly related to quality [5].

Commitment to quality requires not only a well-designed system that will be implemented in accordance with applicable procedures, but also orientation towards external and, above all, internal customers [6], because they are responsible for the quality of their work, and thus the quality of manufactured products and implemented processes in the company. Thanks to their knowledge, skills and experience, each of the company's employees contributes to the quality of the entire organization [7, 8]. The aim of the article is to present the use of selected quality management tools in a company producing components for the automotive industry in order to improve the main production process in this company – the assembly process. The methodology presented in this article can be similarly applied in other industries. Quality improvement issues are common in the industry [9-11], and correctly identifying the causes of disruptions allows for the reduction of necessary resources [12].

Usually, quality problems originate either in the organizational area or in the material and technological aspect. In the latter case, they are usually related to environmental factors [13,14], excessive tool wear [15,16], or defects in structural joints [17,18]. To counteract these issues, appropriate selection of materials [19-21] can be made, which either directly meet higher requirements or can be enhanced through the application of coatings [22], including electrospark methods [23-25], or modification of the technological characteristics of the coating [26]. Additionally, the morphological features of the coating can be modified [27-29], influencing its friction and hydrodynamic parameters. Separation from undesirable factors [30,31] is also possible. Complex technological methods primarily require a reduction in the number of analyzed factors [32,33], after which optimization and stabilization of the process can be achieved using statistical tools, in classical form (factorial, RSM, Taguchi) [34,35], or nonparametric methods [36]. The result of such actions is more reliable machinery and equipment [37,38], vehicles [39], and BIM elements [40,41]. High-quality solutions also become attractive to military customers, who have very high-quality requirements [42-44].

Methodolodgy

The aim of the work was to present the results of the analysis of nonconformities in the production of axle shafts for drive systems of passenger cars. The article is a case-study from a company producing products for the automotive industry. The nonconformities analysis was carried out using selected quality tools, such as the Pareto-Lorenz diagram, Ishikawa diagram and 5WHY method.

The analyzed company is a manufacturer of products for the automotive industry. The plant mainly produces driveshafts for passenger cars, which were the subject of the nonconformity analysis. During the performance of individual assembly operations of the driveshafts, nonconformities occur, lead to the fact that the assembly process ends with the production of a defective product. In the automotive industry, accuracy and precision are of particular importance. They determine the safety of the driver and other road users. With this in mind, the analyzed company pays special attention to ensuring high quality of all products manufactured in the plant. For this purpose, the company uses appropriate tools and methods of quality improvement. A Pareto-Lorenz diagram was used to identify the most common nonconformities during the assembly operations of the axle shafts for drive systems. The Pareto-Lorenz diagram is a tool that allows data on emerging problems to be recorded and analyzed so that the most significant problem areas are highlighted [45,46].

Ensuring the high quality of driveshafts required by customers requires also identifying the reasons for the nonconformities found. For this purpose, it is necessary to conduct a cause-and-effect analysis using, for example, a Ishikawa diagram. The analysis is based mostly on five main areas of the problem, such as: 1. Man, 2. Machine, 3. Material, 4. Method, 5. Management, within which there are looking for probable causes of the problem [47,48]. In the cause-and-effect analysis in the company, the following six main areas of the problem were used, such as: 1. Man, 2. Machine, 3. Environment, 4. Material, 5. Method, 6. Measurement. The result of this analysis allowed to indicate the main - root cause of nonconformities, which most often occur during the assembly process and, based on the obtained results, enabled the implementation of corrective actions.

Determining the root cause of nonconformities when installing halfshafts to drive systems requires identifying the source of the problem and the reasons why the problem was not previously diagnosed. For this purpose, the 5 Why method was used in the analyzed company. Its primary goal of using is to find the exact, fundamental reason that causes a given problem by asking a sequence of "why" questions [49,50]. It was carried out in the company in three stages, namely: 1. Determining the reasons for the identified nonconformities, 2. Determining the frequency of nonconformities, 3. Determining why the problem had not been noticed earlier.

Results

The results of the nonconformities analysis for the selected driveshafts with the use of Pareto-Lorenz diagram are presented on Fig. 1. The analysis covered a period of three months of the selected year. The analysis covered 112 driveshafts manufactured in the plant. The results constituting the basis for the analysis were collected during the quality control process carried out after the completion of individual assembly operations and the quality control of the finished product. Most of the nonconformities were found during the quality control of components produced after the completion of individual assembly operations. Most of the problems involved disconnecting one of the mounted elements. Others related to damage to one of the assembled elements. Finished product quality control showed that the complete driveshaft is too loud, the vibration level is too high, or the sensor is too loud. During the assembly of driveshafts for drive systems, 88.76% of defective products identified are caused by one type of nonconformity - disconnection of one of the elements during the assembly operation of the subassembly. The remaining five types of diagnosed nonconformities were the cause of only 11.24% of the identified assembly defects. As a result, measures have been taken to reduce nonconformities related to component detachment during assembly operations of the driveshaft subassemblies. This required identifying assembly operations where such nonconformities most often occur, determining their causes and introducing corrective actions that will allow for their elimination or at least limitation. The results of the Pareto-Lorenz analysis showed that in the analyzed plant, during the assembly of half-shafts for drive systems, the most frequently found nonconformity is the disconnection of one of the elements during assembly operations, which results in the creation of a specific subassembly. This disconnection is not caused by an incorrect implementation of the assembly operation, but by a large amount of damage to the materials used for assembly. Therefore, an attempt was made to determine the main causes of this problem. First, using a teamwork and brainstorming technique, all potential causes that could lead to quality issues from the warehouse's point of view were identified. The identified, probable causes of nonconformity were divided into six categories, specifying the reasons resulting from: 1. People's work, 2. Machines used, 3. Work environment, 4. Material used, 5. Method used, 6. Measurements used. Subsequently, all identified potential causes causing the identified nonconformity were assigned to six categories. Assigning all diagnosed causes to individual categories allowed to develop the Ishikawa cause and effect diagram. It was presented in Fig.2. The analysis of the diagram made it possible to identify the main cause of damage to the materials used in assembly operations.

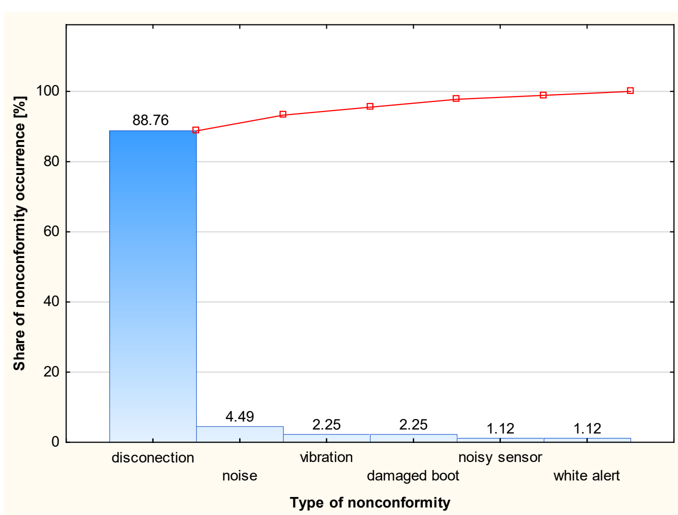

Fig.1. *Pareto-Lorenz diagram for nonconformities found in the process of assembling half shafts to drive systems.*

The conducted Ishikawa cause and effect analysis allow concluding that the damage to the materials used to assemble the axle shafts is mainly due to environmental causes. They relate to the conditions prevailing in warehouses where materials used in assembly operations are collected. It was found that the reasons for these are: improper lighting, and thus poor visibility during transport, high air humidity in the warehouse causing corrosion of materials used in assembly operations, slippery surfaces in the warehouse due to sub-zero temperatures, and high humidity causing rapid wear of wooden containers.

As previously emphasized, damage to the materials used to assemble the axle shafts causes the most common error, which is the detachment of the component during assembly. Therefore, an attempt was made to explain why this nonconformity occurs. Damage to the materials used for assembly is indeed a significant cause, but it should be noticed by employees preparing materials for assembly operations. An in-depth analysis of each of the reasons for disconnecting a component during assembly has shown that the use of such materials during assembly is the responsibility of employees who do not check the condition of materials in warehouses by the control plans in force at the plant, and in the course of performing their duties (picking containers from warehouses) are not focused on their work (conduct phone calls). This results in the fact that very often containers with link shafts are placed in the wrong storage area. This is the main cause of nonconformities during the assembly process of driveshafts for drive systems. They were highlighted in the Fig.2.

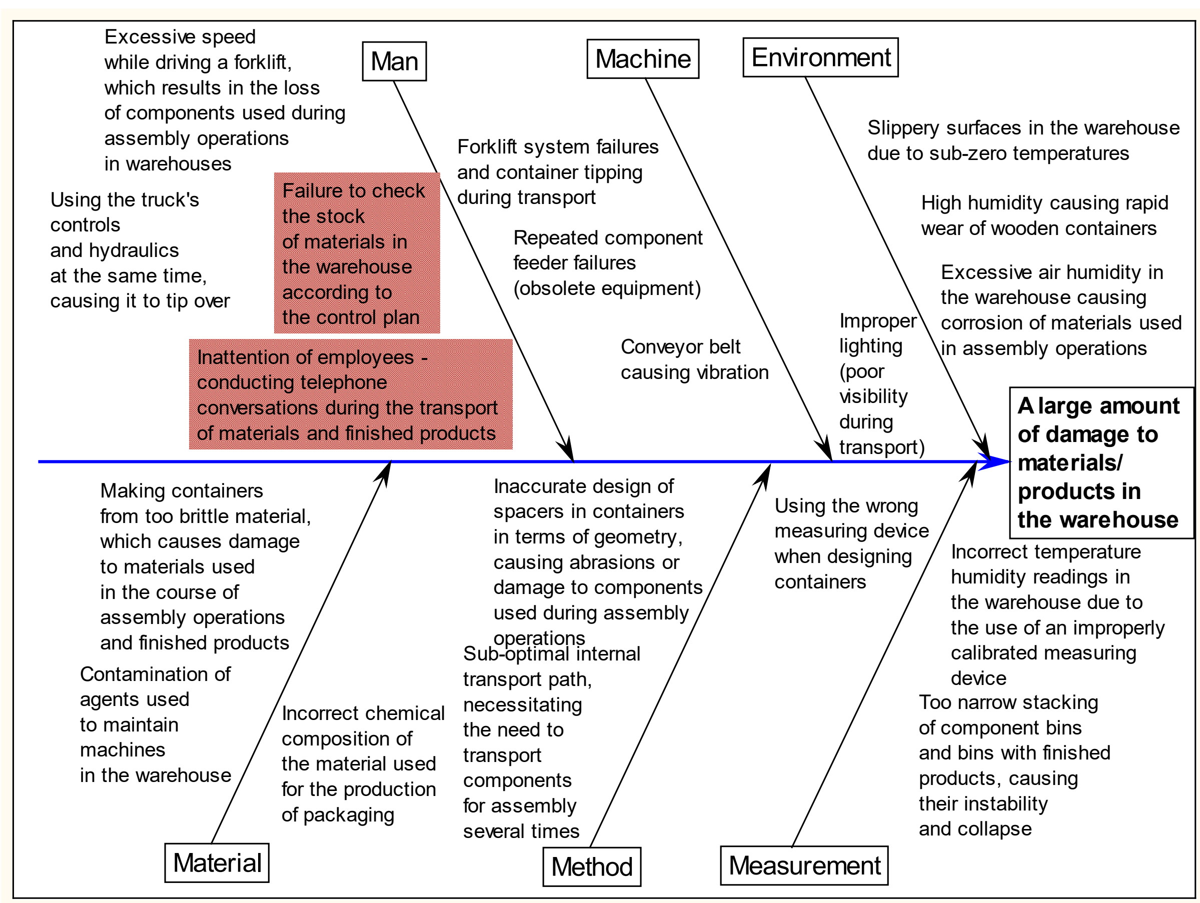

Fig.2. *Ishikawa cause and effect diagram for nonconformities arising during the process of assembling half shafts to drive systems, with an indication of the main causes causing the element to detach during assembly (highlighted in the figure).*

The development and implementation of corrective actions to eliminate the indicated causes of nonconformity during assembly require determining the reasons for the control of the condition of materials in warehouses in accordance with the control plans in force at the plant.

The root cause of the nonconformities during the assembly of driveshafts to drivetrains was identified using the 5 WHY method, based on three stages.

The first stage of the analysis consisted in identifying the causes of nonconformities that were found during the assembly of the driveshaft. At this stage, it was determined what happened in the plant, that the stock of materials in the warehouse was not inspected. Solving this problem required the appointment of a team of employees. It consisted of two warehouse employees, a forklift operator collecting materials from the warehouse for the assembly of axle shafts, and three employees involved in the implementation of individual stages of the assembly process. The team in this composition undertook work on the analysis of nonconformities occurring during assembly. It showed that during assembly operations, the element is most often disconnected. It should be noted that this may be due to a defect in the material used for assembly, and not an error during the assembly operations. The team then began work on determining the possible causes of this problem. There are 18 possible reasons why the material used to assemble the axle shafts are damaged. The condition and quality of deliveries of individual materials as well as the method of their storage and transport to assembly lines were analyzed. The analyzes carried out showed that the main reason for the most frequently found problem, i.e. disconnection of the element, is damage to the materials, which in turn result from the fact that the plant does not carry out inventories of materials by the applicable quality control plan. Carrying out such inventories would avoid the use of inappropriate materials that do not meet quality requirements during assembly.

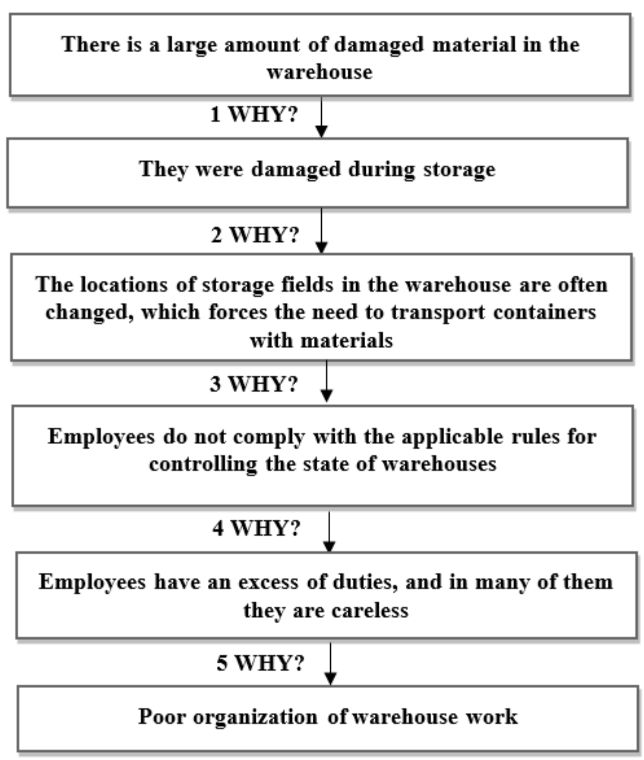

Fig.3. *5WHY analysis for the occurrence of a large amount of damage to the materials used in the assembly process of half shafts for drive systems.*

The second stage of the analysis was to determine the frequency of nonconformities found. The analysis of the quality control cards for the finished product and the quality control cards for the subassemblies made after the completion of the individual stages of the assembly process, carried out by the appointed team of employees - the pressing of the cross, the assembly of the cover and the pressing of the joint, showed that in 79.46% of cases, this nonconformity was found. It was recognized that the problem required an immediate solution, the more so that the disconnection of any element causes the finished product to be defective and cannot be used.

The third stage of the analysis was to determine why this problem had not been identified earlier. After analyzing all possible causes, the appointed team concluded that the control of the stock of materials in the warehouse is not carried out properly, i.e. according to the quantity and quality of materials in force at the plant. This required finding the source of this cause. For this purpose, the 5WHY analysis was carried out. By asking the question "why?" five times the main reason for the occurrence of the most frequently found nonconformities was indicated. This analysis is presented in Fig.3. It showed that the root cause of the identified problem is the poor organization of the warehouse work. This applies both to non-compliance with the applicable rules of quality control of materials in the warehouse, as well as the improper performance of the employees' work.

To eliminate or at least reduce the identified nonconformity, it is proposed to increase supervision over employees. First of all, it is necessary to supervise the control of warehouse stock, especially the quality of materials used for assembly processes. It is proposed that the quantity control of materials and the correct location of containers in the warehouse be controlled before the end of each work shift, i.e. three times a day by appropriately selected employees. These employees should take full responsibility for the implementation of the control plans. It is equally important to introduce supervision over employees employed in the warehouse and transporting materials to assembly lines. There should be a ban on using the plant from private mobile phones. Conversations made by employees during work cause them to be inattentive, which results in making numerous mistakes, especially incorrect placement of containers with materials in the warehouse. Implementation of the proposed changes can significantly contribute to reducing damage to materials in the warehouse, and thus the use of materials that meet quality requirements in assembly processes. This will reduce the number of the most common nonconformities, i.e. detachment of the element during assembly.

Summary

The qualitative analysis carried out with the use of selected quality tools showed that there were many nonconformities during the implementation of assembly processes in the analyzed company. It has been shown that the most common error found is the disconnection of the element during assembly. This makes it impossible to carry out further assembly operations, and in the worst case, it even leads to the production of a defective product, inconsistent with the recipient's requirements. As a result of the cause-and-effect analysis, it turned out that the reason for this nonconformity is damage to the materials used for assembly. The conducted analysis also showed that these damages were most often caused by reasons inherent in the working environment. These were: improper lighting, and thus poor visibility of components during transport, high air humidity in the warehouse causing corrosion of materials used in assembly operations, slippery surfaces in the warehouse caused by sub-zero temperatures, and high humidity causing rapid wear of wooden containers. In-depth analyzes allowed to identify the most important cause of the largest number of nonconformities arising during the assembly process. It was the lack of control of the state of materials available in the warehouse according to the control plans in force at the plant. The lack of these controls results in the use of incorrect materials during assembly, which leads to the production of a defective product. Elimination or at least limitation of identified nonconformities requires the implementation of improvement actions. On the basis of the analyzes carried out, it was concluded that they should include changes in the organization of warehouse work, in particular increasing supervision over the control of the condition of materials. In order to increase the productivity of the production plant, highly effective quality control should be implemented [51]. This control should be carried out by competent employees, in accordance with the control plans in force at the plant. It was also recognized that the elimination or at least reduction of nonconformities that occur during assembly requires increased supervision over employees both in the warehouse and those responsible for the internal transport of materials and employees performing assembly operations. It is also essential to carry out 100% inspections of the driveshafts produced in-house. Implementation of the proposed actions can significantly contribute to improving the quality of products manufactured by the analyzed plant. One way to improve the assembly process can also be the use of optimization tools, such as the FlexSim discrete event simulation software package [52].

To sum up, quality management in assembly processes refers both to the correct implementation of assembly operations, as well as to the use of appropriate materials, as their incorrect selection or damage during assembly may cause inconsistencies that cause the final product to be defective.

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