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Solving Critical Quality Problems by Detecting and Eliminating their Root Causes – Case-Study from the Automotive Industry

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Abstract. The article presents the results of using selected quality tools to detect and analyze critical quality problems of low-pressure hoses for car radiators and their root causes for their elimination. The research aims to analyze the nonconformities of the tested product, identify critical nonconformities in terms of frequency of occurrence, and analyze potential causes of their creation to propose effective corrective and preventive actions. The paper presents the use of such quality tools as the Pareto-Lorenz diagram, Ishikawa diagram, and 5 WHY analysis. It was identified that the critical nonconformities of low-pressure hose that should be addressed first are nonconforming insert mounting depth and crooked cut detail. It has been shown that most of the factors causing critical nonconformances are in the "man" and "machine" type of problem areas. They identified the root causes of the quality problems, which were the incorrect setting of the machine by the operator and a lack of frequent inspections of the machine's technical condition. It was proposed corrective actions to eliminate the possibility of critical nonconformities due to their root causes.

Introduction

Effective satisfying customers' needs and requirements is one of the most critical objectives in any manufacturing enterprise, conditioning its success in the market [1]. The goal of any enterprise should be to make money by their meeting and even exceeding [2]. The processes of continuous globalization and the dynamics of change have established new challenges for enterprises. Changes in the perspective of quality perception are a consequence of its development. Quality is interpreted as perfection or excellence [3]. However, in reality, quality measurement is complex and focuses on the process of reaching it [4]. Quality is defined as a set of product features that determine how the product will meet customer expectations [4]. Product features, in turn, are its functionality, which carries a specific utility for the customer. One of the essential product features is its durability and reliability over time [5]. Companies strive to gain the highest level of quality, understood as offering products of higher quality at a cost-effective price for the consumer, focusing attention on not making mistakes and errors during production, producing products of higher quality than the competing company, and preventing the emergence of non-compliant products, which are associated with higher costs for the organization, introducing the process of improving the way of performing the assigned tasks and the product for all employees to involve them in the process of continuous improvement, planning and organizing the work of employees for comprehensive quality management [5, 6]. The basic tool for achieving these goals has become a quality management system, whose elements are methods, tools, rules, procedures, job descriptions, people, and the relationship between these elements. The effective implementation of these system elements increases the company's ability to satisfy customer needs and requirements [6].

Methodology

The study analyzes quality problems in manufacturing low-pressure hoses for car radiators. The analysis was conducted using selected quality tools such as the Pareto-Lorenz diagram, Ishikawa diagram, and 5WHYs.

The research object is a plant of a leading international manufacturer of fluid flow systems, seals for car bodies as well as anti-vibration systems located in the Silesia voivodeship in Poland. The analyzed plant is engaged in the production of hoses: cooling, turbocharger, vacuum, and air transfer. The subject of the research is a low-pressure hose used for the cooling system in automobiles.

A Pareto-Lorenz diagram was used to identify the most critical quality problems in terms of the frequency of occurrence in relation to low-pressure cooling system hoses. A 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 [7]. In order to significantly reduce the likelihood of quality problems, the most frequently occurring nonconformances should be addressed first [8]. The remaining nonconformities should not be underestimated; they are less important but not invalid [7].

For the most frequently occurring nonconformity of the analyzed product, an analysis of the causes of its occurrence was carried out using the Ishikawa diagram. The analysis is based on five main areas of the problem, namely: man, machine, tools, materials, and method, within which there are looking for probable causes of the problem [9, 10].

For the second, most frequent occurring nonconformity of the analyzed product, an analysis of its root cause was carried out using the 5 WHY method. Its primary goal of using is to find the exact, fundamental reason that causes a given problem by asking a sequence of "why" questions [9, 10]. It is one of the most effective tools for root cause analysis in the Lean management concept [11].

Results

10000 pieces of the low-pressure hoses were inspected, and certain nonconformities were found, such as scratches on the hose (N1), too short hose (N2), too long hose (N3), illegible print (N4), crooked cut hose (N5), deformations (N6), under-bottomed overmoulding (N7), hose leakage (N8), incompatible insert mounting depth (N9), broken hose end (N10). The Pareto-Lorenz diagram (Fig. 1) was built based on the data on the frequency of occurrence of these nonconformities.

The Pareto-Lorenz diagram showed that 20% of the nonconformities (2 out of 10) were responsible for 52.4% of all hoses quality problems. The remaining 8 nonconformities are responsible for only 47.6% of the quality problems. The critical nonconformities in terms of frequency of occurrence were, therefore: nonconforming insertion depth (N9) and crooked cut hose (N10).

The most frequent nonconformity, i.e. incompatible insert mounting depth (N9), was addressed first. All possible causes of this nonconformity were identified using brainstorming and plotted on the Ishikawa diagram (Fig. 2).

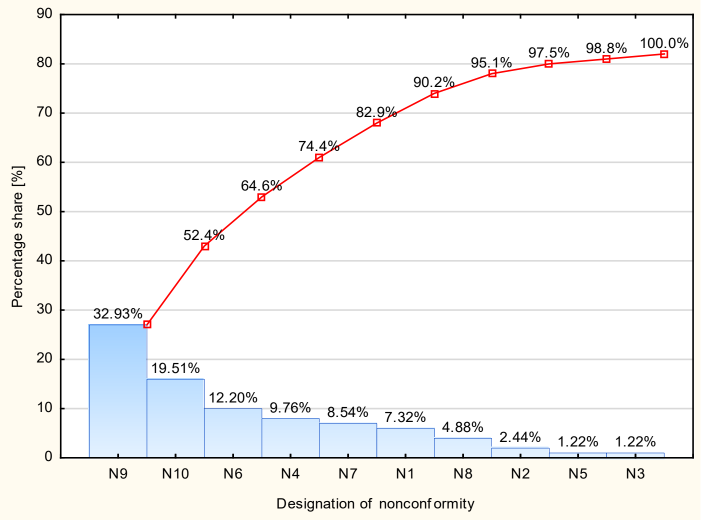


Fig. 1. *Pareto-Lorenz diagram for the analysis of the frequency of low-pressure hose nonconformities [own study with the use of Statistica 13.3 software]*

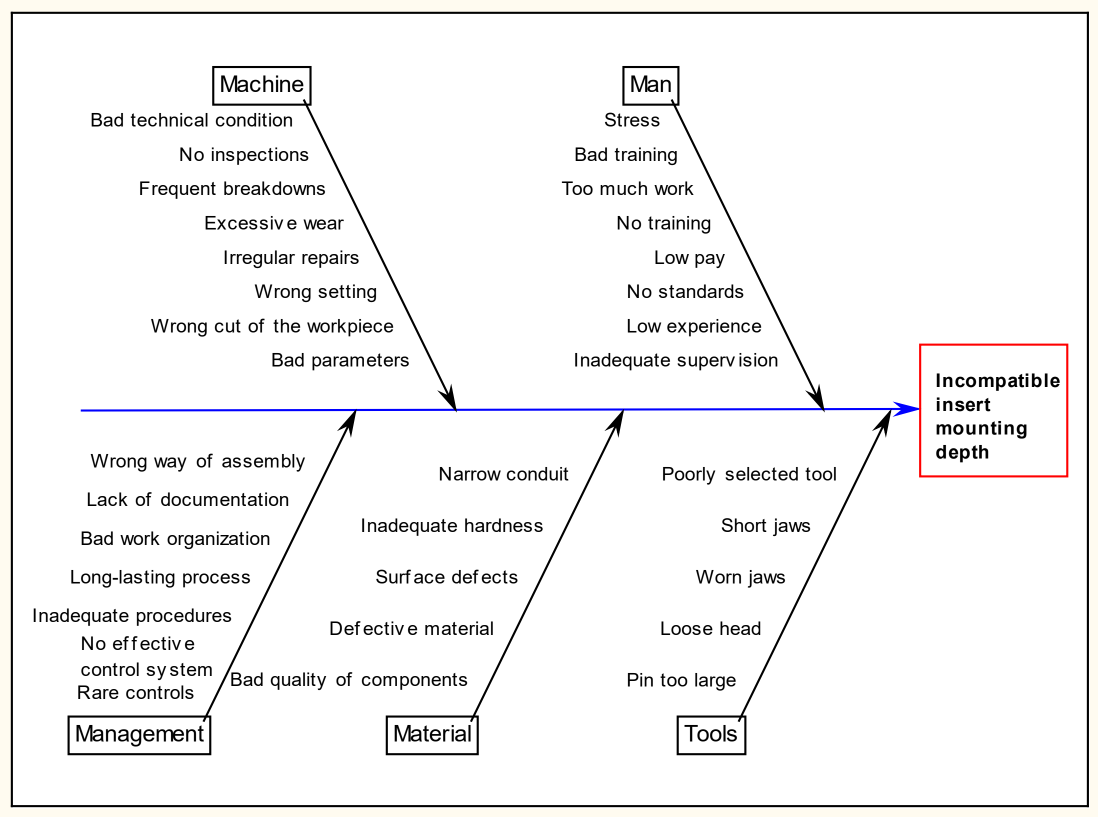
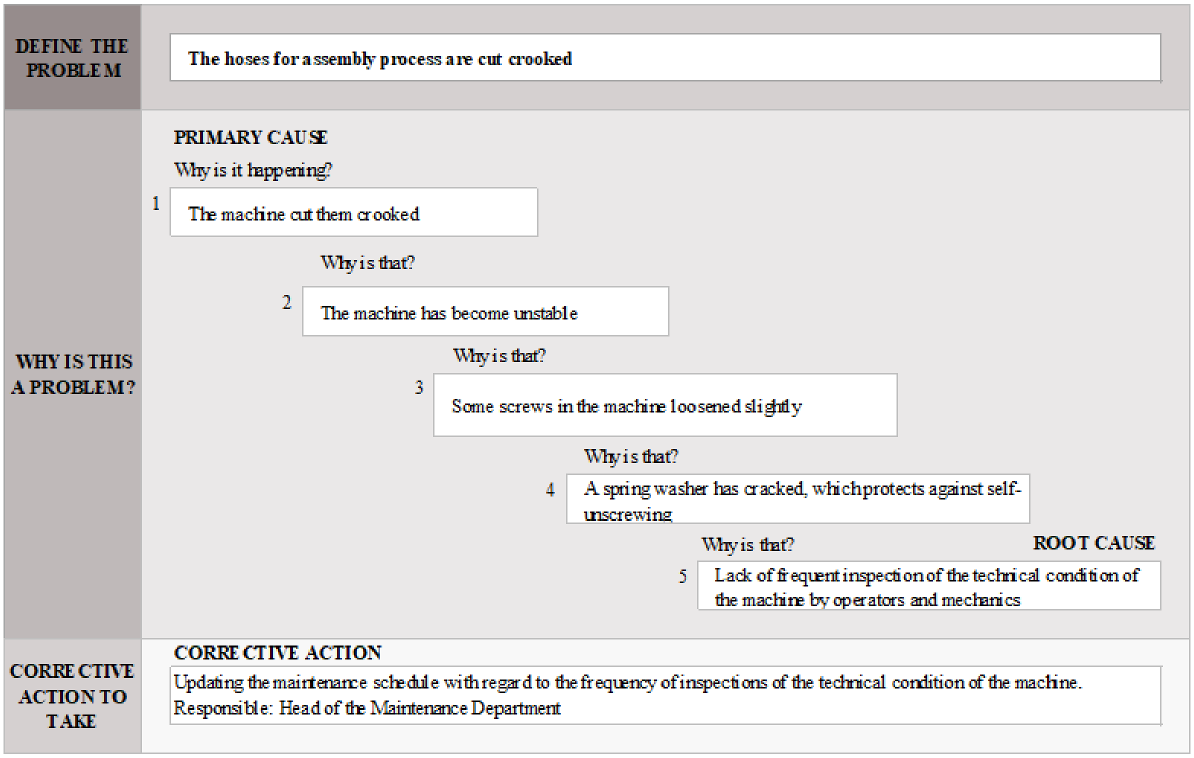


Fig. 2. *Ishikawa diagram for root cause analysis of critical low pressure hose nonconformance [own study with the use of Statistica 13.3 software]*

It can be seen from the diagram that most of the factors causing nonconforming insert mounting depths appear in the "human" and "machine" type areas. The poor condition of machine parts resulted in lower qualitative capability and turned into incomplete or improper insert mounting. Many "hard" and "soft" factors related to humans affected the formation of nonconforming products, such as lack of appropriate knowledge and experience, lack of adequate motivation, low wages, and lack of training. Also, improper management so bad organization of work, lack of work standards, not-effective control systems, rare inspections, or lack of current documentation at the workplace affected the critical nonconformance occurrence. In the effect of this last situation, the customer after making corrections on the workpiece still receives the hose before the corrections, because the employees are unaware of the corrections made and continue to produce a workpiece that does not meet the current requirements of the customer. Poor quality of materials and tools led to the production of poor-quality details or rapid wear of parts such as jaws, which are to compress the hose. Worn jaws posed a risk of producing a non-conforming product or perforation of the conduit during assembly.

A 5 WHY analysis was used to identify the root cause of the second most common low-pressure hose nonconformance, namely, a crooked cut workpiece (Fig. 3).

The root cause of the problem was the lack of frequent inspections of the machine's technical condition, and its parts, which was caused by too long a defined time between such inspections in the maintenance work schedule. In the analyzed case, the machine work became out of control because of a broken washer. Its absence resulted in backlash at the washer location, as well as the slow loosening of the nut, which increased disc movement. To solve this problem in a permanent way machine inspection intervals should be increased. Thus, the maintenance inspection schedule should be updated. Mechanics should inspect the machine at least once a month (the best twice a month), while operators should inspect the machine each time before starting and after ending work on the machine. This corrective action will minimize the possibility of the machine malfunctioning due to its poor technical condition.



DEFINE THE PROBLEM

The hoses for assembly process are cut crooked

WHY IS THIS A PROBLEM?

PRIMARY CAUSE

Why is it happening?

1 The machine cut them crooked

Why is that?

2 The machine has become unstable

Why is that?

3 Some screws in the machine loosened slightly

Why is that?

4 A spring washer has cracked, which protects against self-unscrewing

Why is that?

ROOT CAUSE

5 Lack of frequent inspection of the technical condition of the machine by operators and mechanics

CORRECTIVE ACTION TO TAKE

CORRECTIVE ACTION

Updating the maintenance schedule with regard to the frequency of inspections of the technical condition of the machine.
Responsible: Head of the Maintenance Department

Fig. 3. *5WHY analysis for a crooked cut detail [own study]*

In order to reduce errors caused by human work (operators, mechanics), it is necessary to introduce further remedial measures aimed at raises for employees that will motivate them and give them a desire to develop; development of visual work standards in workplaces (visual controls & management tools [12]), which will allow the production of uniform, standardized parts and also allow rapid assessment of their quality by a glance. It is important to provide job training for employees to increase their awareness about the impact of their work on quality, and increase knowledge, and skills. The greatest attention should be paid to poor machine alignment. In order to eliminate this cause, it is necessary, first of all, to train people who will set up and changeover machines to a new workpiece; pay attention to excessive loading of the machines because it leads to rapid wear or overheating of its parts; more often diagnose the technical condition of machine parts so that the process carried out by them is not disrupted; conduct training for employees on machine diagnostics, so that they can react immediately if they notice a problem on a machine; develop documentation with pictures of correct and incorrect functioning of a machine (One Point Lessons - OPL cards in a version of "basic knowledge" and "problem" [13], boards and KAMISHIBAI cards [14]). In the event of detected non-compliance with requirements, the person using these types of visual control tools will have to report the problem immediately in order to implement necessary corrective actions.

Summary

The article presents the method of identifying the most important quality problems of low-pressure hoses for car radiators, the results of their analysis in order to discover the root causes, and the methods of eliminating the possibility of their occurrence - preventing the critical nonconformities. For this purpose, selected, popular quality tools were used.

Using data that was collected during the manufacturing process of a low-pressure hose for automotive radiators, 10 major nonconformities were listed that contributed to nonconforming products. The most common nonconformities were a nonconforming insert depth and a crooked cut hose. In order to eliminate the first main nonconformity, the Ishikawa diagram was made, which allowed identifying the basic cause of its occurrence, which is poor alignment of the machine by the operator. In order to eliminate this nonconformity, it was proposed to conduct periodic training for employees responsible for setting up and changeover of machines, to introduce more frequent inspections of the technical condition of machines, and to develop visual documentation of the correct operation of the machine. Using the 5 WHY method, the root cause for the crooked cut hose was identified, which was the lack of frequent machine maintenance. This caused the machine to become out of adjustment, which resulted in this nonconformance. It was suggested that the maintenance schedule should be updated and that in addition, a machine job card should be developed for employees to fill out before and after work, allowing for quicker detection of worn parts by which failures and quality problems can arise.

In conclusion, the application of quality tools to analyze low-pressure hose nonconformities was intended to prevent the possibility of their occurrence in the future by paying attention to their root, fundamental causes. In order to have a lasting effect of eliminating analyzed critical nonconformities of the tested product, defined and listed corrective and preventive actions must be implemented in an effective way and quality analyses focused on investigating potential causes of nonconformities must be generally conducted in an anticipatory manner. Success in the permanent elimination of nonconformities is a combination of employee involvement (a necessary condition), the use of appropriate methods and tools for detecting and analyzing their root causes, and the implementation of effective ways of preventing them (good first time).

The presented analysis may inspiring in many branches of the industry interested in high quality e.g. service [15], automotive [16-19], BIM [20], biotechnology [21, 22] and quality general management [23]. Such approach leads to desirable sustainable production [24-26], increases the trend for automation [27, 28] and gives new ideas for analysis methods [29, 30], both parametric [31, 32] and non-parametric [33-35].

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