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Chapter 12

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IDENTIFICATION OF SIGNIFICANT DISCREPANCIES OCCURRING IN THE PROCESS OF CABLE PRODUCTION USING SELECTED QUALITY MANAGEMENT TOOLS

Abstract: Tools and methods of quality management are used in many pro-quality oriented organizations. Adequately and comprehensively used, they promote the improvement of production processes and proper functioning as well as growth of the company. In the longer term their use will have a real impact on company's revenue and image. Skillful use of the quality management tools can be considered to be a duty in certain branches of economy, since implementation and following the norms, that are in line with industry standards, is one of the requirements that are laid down by the consumers. An example of such industry is the automotive industry, governed by the international ISO / TS 16949 standard, which specifies teamwork conditions, conditions for the use of quality management methods within the framework of activities related to the defective product, both corrective and preventive actions, as well as the process of continuous improvement of quality management system. The following study is aimed at identifying significant non-conformity in the process of cable production using the Pareto-Lorenz analysis. The following analysis is a starting point for finding solutions that aim at reducing the occurrence of quality related problems.

Key words: Quality, Pareto-Lorenz analysis, cables

12.1. Introduction

The researched company X applies, in its business activity, the guidelines enclosed in the automotive industry standard ISO / TS 16949.

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The norm is both rigorous and detailed, as it concerns the matters of safety of consumers who will be using the final product. It imposes certain requirements, which, besides the problems concerning effectiveness and efficiency of the already operating quality system, also refers to engineering related matters. It also provides a number of pro-quality techniques and methods such as SPC, FMEA, Pareto-Lorenz and the like. Keeping paperwork regarding these tools, as well as applying them in practice, allows implementing the requirements of consumers (MAĆKIEWICZ E. 2006; LUCZAK J. 2008; PIEKARA A. DZIUBA S.T., KOPEC B. 2012).

It was found that most problems are due to several causes, namely 80% of discrepancies are the result of 20% of the causes. This regularity was used in the field of quality management, where the expenses generated by the repairs or defects are in 80% due to 20% of the possible reasons. It is an important rule, since most of the errors result from a relatively small number of causes. If this rule is applied to production, it can be then assumed that 80% of discrepancies are due to 20% of production materials, machines and operators. All data regarding the production related problems require special attention and thus, they can be presented in the form of a Pareto chart in relation to all costs incurred in relation to the production of the product (HAMROL A. 2008; INGALDI M., JAGUSIAK-KOCIK M. 2013).

Pareto chart is often used during the analysis of the information gathered using the check sheet. It illustrates the histogram of the data starting from the highest frequency and ending with the lowest. The Pareto chart is a popular tool used to determine the plan for improving quality. A chart that was similar in concept to the Pareto chart that presented the cumulative curve of the participation of specific defects in their total number was applied by Lorenz. Therefore, a quality tool such as Pareto-Lorenz chart helps to prioritize factors influencing, to the greatest extent the phenomenon that is being considered. It presents the absolute and relative distribution of types of defects and their causes. In practice, it makes it easier to see what is the share of particular errors

(Pareto chart) and cumulative values (Lorenz curve) (HAMROL A. 2008; ŁUNARSKI J. 2011).

Pareto-Lorenz chart is a simple bar graph. The data in this chart are presented in descending order. Other values recorded on the chart are the values that are creating the linear graph of the cumulative value. While putting this method into practice, it is necessary to focus on the 20% of the most important causes of non-compliance and implement corrective and preventative measures for them (HAMROL A. 2008; ŁUNARSKI J. 2011).

Said tool is often used in solving quality related issues occurring in the cable production process. In the PN-E-01002: 1997 norm 'The dictionary of electricity related terminology'. Cables and wires', cable is defined as the 'product of manufacture comprising of one or more insulated conductors in the coating or optionally in a protective sheath or armor "while wire is defined as" a product of manufacture comprising of one or more twisted wires, or of one or more insulated conductors without coating or in the non-metal coating (ŁUKSZA J., SKOŁYSZEWSKI A. 2006; GROBICKI J., GERMATA M. 2011).

Cables that are used nowadays must fulfill a number of tasks in many branches of industry. Taking into account the uses of cables, their structure may be very diverse. For example, twisted wires are insulated using various materials in a variety of geometries. A person purchasing the cable expects the product to perform its functions in a particular installation. That is why the methods and tools, introduced in a particular organization, which are aimed at producing a high quality product, are so important (FILEK W. 2011; BORKOWSKI S., INGALDI M., JAGUSIAK-KOCIK M. 2013).

12.2. The aim of the study and methodology

The quality of cable's conductors has a significant impact on the stage of production concerned with insulating the cable. This is important since it is common that the defects of the spiral prevent processing them, in the extrusion process. They are also often detectable only when the cable is already produced, which makes the cost incurred by such errors higher by losses incurred in subsequent stages of production (MATERIALS FROM THE COMPANY X, 2013).

The company in which the research took place, decided to carry out an analysis of the defective products that were produced in the twisting machines section. They also decided to introduce measures that will help to reduce the number and cost of such errors. To do this, an interdisciplinary team, which comprised of seven employees, was created. The team was supposed to make an attempt at solving the occurring problems. The ultimate goal of the team was to reduce or completely eliminate quality related defects. The team that was created in an ad hoc manner was comprised of specialists that are responsible for the production process, operation of the machines and the quality of products. The team members were chosen carefully to aid the purpose of analyzing the non-conformity, considering various sectors of the production process. The individual stages of analyzing the occurring discrepancies took place during regularly held meetings (MATERIALS FROM THE COMPANY X, 2013).

The first challenge was to identify the discrepancies occurring in the cable production process, in the company X, using the Pareto-Lorenz chart as well as an analysis of the most important discrepancies, which have a significant influence on the quality of the final product.

To achieve this objective the following research methods were used:

- inductive method,
- interview method,
- method of technical data presentation.

The study encompassed an analysis of data collected in the company X in the period of time between 01.01.2013 and 31.07.2013.

12.3. Classification of data, analysis of quality related discrepancies using the Pareto - Lorenz chart

Pareto analysis is a tool, the purpose of which is to award each factor, causing a particular problem, with a degree of importance. According to the Pareto principle, the phenomena in which 20% of the examined factors are related to 80% of the resources. Pareto diagram is visualized in a shape of a simple bar graph. The data illustrated using Pareto diagram are presented in descending order. Values that are plotted on the diagram create a line chart of the cumulative value. While putting this method into practice, the focus should be on 20% of the most important causes of non-compliance as well as on implementing corrective and preventative measures for them (HAMROL A. 2008, ŁUNARSKI J. 2011).

In the analyzed company, collecting all the data allowed coming up with the total number of discrepancies, and subsequently it allowed creating the order of discrepancies that was based on the frequency with which they were occurring. Next, a share of each defect (in percent) was calculated along with the cumulative percentage. Table 12.1. presents the classification of discrepancies and defects according to how often they have occurred.

To make the presentation of the data from Table 12.1., concerning the quality related problems, clearer, the data was presented in the form of a pie chart and Pareto-Lorenz chart that is used to signify the importance of each of the factors causing the problem, which reflects all the dependencies that can be otherwise presented numerically (HAMROL A. 2008; ŁUNARSKI J. 2011).

This technique of presenting data allows for a full and complete presentation of gathered information concerning defects of the products produced in the twisting machines section.

Table 12.1. Classification of discrepancies based on the frequency with which they have occurred

Discrepancy No.	Type of discrepancy	Number of defective reels	Relative number (%)	Cumulative number of defective reels	Relative cumulative number(%)
1	loose single wire	65	42	65	42
2	uneven arrangement	29	18	94	60
3	incorrect resistance	13	8	107	68
4	incorrect length of lay	11	7	118	75
5	thickening on the spiral	10	7	128	82
6	discolored material	8	5	136	87
7	tangled material	8	5	144	92
8	improper extension of a single wire	7	5	151	97
9	grease-stained spiral	5	3	156	100

Source: Own elaboration based on the materials received from the analyzed company

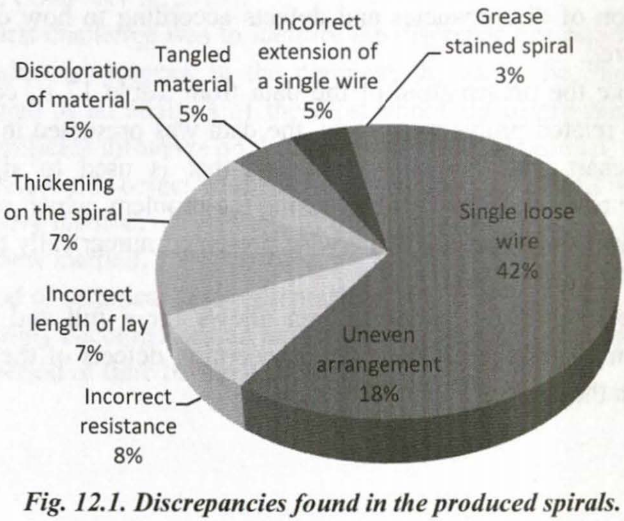

Fig. 12.1. Discrepancies found in the produced spirals.

Source: Own elaboration based on the materials received from the analyzed company

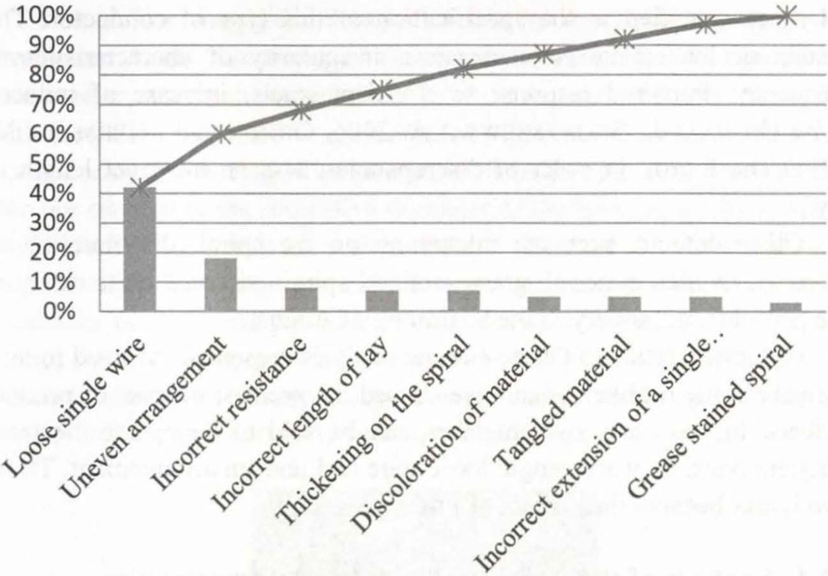

Fig. 12.2. Pareto-Lorenz diagram illustrating quality related defects.

Source: Own elaboration based on the materials received from the analyzed company

The results that can be seen on the graphs 12.1, 12.2, show that the error that was detected most often, in the period from 01.01.2013 to 31.07.2013, was the occurrence of loose single wire, which means that among all the twisted wires in a given conductor, one group of wires is loose, and its concentricity and length of lay is inconsistent. The second most common issue was uneven arrangement. This is a problem which consists of a bulge being created on one or both sides of the reel's flange. The third most common defect was an incorrect resistance, which in this process is defined as a special feature, because this parameter has a significant impact on the features of the final product. Electrical resistance is the opposition of the passage of the electric current through the conductor. The value of electrical resistance in the cable depends primarily on its cross-section, as well as the material and construction. The thinner is the cable the greater is the resistance. Incorrect resistance means that the resistance of the produced material is not within the tolerance specified in the specification of this type of conductor. The results of inadequate resistance are: irregularity of characteristics of frequency, impaired response to transient states, increase of induced noise (ŁUKASZ J., SKOŁYSZEWSKI A. 2006, GROBICKI J., GERMATA M. 2011).The fourth, in order of discrepancies, was an incorrect length of lay.

Other defects, such as: thickening on the spiral, discoloration of material, tangled material, grease-stained spiral, occurred quite rarely in the period from January to the beginning of August.

Compiled data and Pareto-Lorenz analysis presented the need to take care about the problems that have caused the greatest number of product defects. In this case, two mistakes can be said to be by far the most frequent ones, they are: single loose wire and uneven arrangement. These two issues became the subject of further research.

12.4. Analysis of the main quality related discrepancies

Description of the quality problem: "single loose wire"

A single loose wire is a non-compliance which can be described as one wire of the conductor not being properly tight in comparison to the other ones, which results in creation of the thickening on the spiral and leads to creating a slot between the single wire and the other twisted-pair cables. Figure 12.3 illustrates the spiral, that has been affected by the previously described problem.

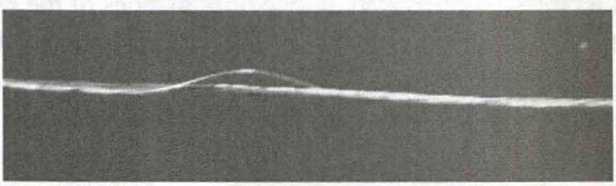

Fig. 12.3. "Loose single wire" discrepancy, illustrated using copper wire.

Source: Own elaboration

This defect can cause serious problems in subsequent stages of production. Local thickening of the spiral can cause the enlargement of its diameter, which, in the next step that is in the step of coating the spiral with insulation may lead to a number of ruptures of material which can occur during processing. The reason for it is that the tools used in this step are adapted to the respective diameter of the spiral and they possibly might not let the spirals of a diameter that is out of the acceptable size pass through them. Figure 12.4 illustrates a piece of the faulty cable conductor that is being processed in the extruder. Single, loose wire that causes the thickening prevents the smooth transition of material through the tool called dorn. Loose group of wires causes an enlargement of the gap before reaching dorn, and subsequently rupture of the wire.

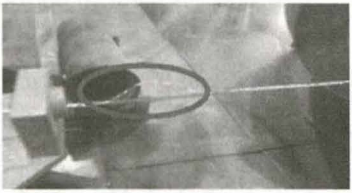

Fig. 12.4. Faulty spiral processed using extruder.

Source: Own elaboration

Not every such occurrence ends with a rupture during processing. There are cases when the loose group of wires does not cause substantial thickening which allows for it to be fully processed. However, this defect causes non-conformity in the finished product that is in the cable. During extrusion, the conductor is coated with insulation, which is in liquid form and is injected under high pressure, as a result of which the insulation manages to get through small crevices which causes deteriorated electrical conductivity. Figure 12.5 illustrates the cross-section of the cable. The illustration on the left, presents a cross-section of the cable with a correctly twisted spiral, the illustration on the right presents a faulty cable, where you can see the insulation between the wires.

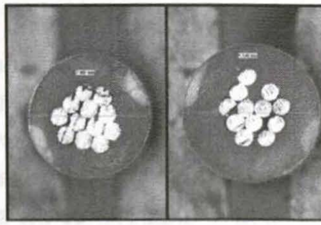

Fig 12.5. The illustration on the left presents a cross-section of the correctly produced cable. The illustration on the right presents a cross-section of a defective cable.

Source: Own elaboration

In the case of cables with thin wall of insulation, the thickening of the spiral may result in a visible deformation of the insulation in the final product (Figure 12.6).

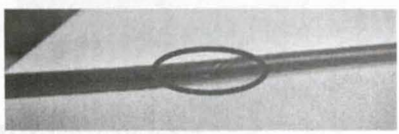

Fig. 12.6. Deformation of the insulation of the cable.

Source: Own elaboration

Description of the quality related problem "uneven arrangement"

"Uneven arrangement" defect is a problem related to uneven winding of the material in the final product. This non-compliance means that a bulge is formed in the middle of the reel or on its sides. Figures 12.7 and 12.8 present the description of the possibilities of this defect occurring, as well as a description of how should the correct arrangement look like.

Fig. 12.7. Even arrangement of the material on the reel.

Source: Own elaboration

Fig.12.8.Improper arrangement of the material on the reel.

Source: Own elaboration

The above illustrations show that the spiral properly wound on the reel can not have any bumps and that the angle between the flange of the reel and a perfectly arranged material should be 90°.It is possible, that despite the improper arrangement of the material the surface of the ready made product will not have visible defects, however they will be noticeable on the inside. This can happen, if during production the material will be wound incorrectly and subsequently the arrangement of the material will be corrected, leveling said defect. A common cause for such an occurrence is a lopsided reel that was used during production. The following figure illustrates such situation.

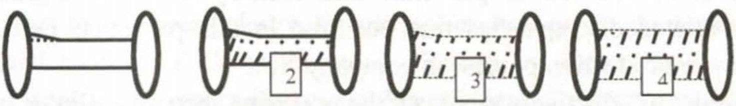

Fig. 12.9. Material arranged incorrectly (on the inside of the product) due to the reel being lopsided. 1. lopsided reel 2. unevenly wound material 3. reduction of bulges during winding, 4.leveling of the bulges.

Source: Own elaboration

Figure 12.9 presents an unevenness caused by the lopsided reel. A defect in the core of the reel results in an uneven winding of the first layers of material. In further stages the arrangement is gradually evened out until it is completely hidden which makes it impossible to detect a defect in a final product.

This defect causes difficulties in processing a particular piece of material because during unwinding of the conductor may get tangled causing rupture at high speed of unwinding, which amount to more than

70 meters per minute. Figure 12.10 illustrates the way in which an unwound spiral becomes tangled (12.10).

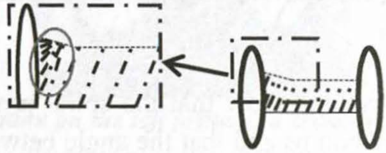

Fig. 12.10. Tangled spiral, the result of uneven arrangement.
Source: Own elaboration

12.5. Conclusions

The research that was carried out served as a preliminary analysis of the existing quality problems. The tool that was used, namely the Pareto-Lorenz chart allowed to prioritize and identify the most significant quality related discrepancies that occurred in this particular period of time, in the production process in company X.

In order to effectively eliminate the occurring incompatibilities it was proposed to prevent the two most common defects - loose, single wire, and uneven arrangement of the material by using the cause-effect analysis that is divided into two parts. The first part should identify the potential causes of the defects, while the second - the reason for not identifying the defect.

For the sake of further research it would be reasonable to create an action plan using the '5 Way' method.

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