Improvement Processes in Materials Engineering and Commodity Science

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Chapter 2

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IMPROVEMENT OF THE MANUFACTURING OF CABLE FOR AUTOMOTIVE INDUSTRY USING ISHIKAWA DIAGRAM

Abstract: There are a number of enterprises where instruments and methods of quality management are used in a proper, comprehensive and professional way at individual levels of maintaining and improvement of production processes. Appropriate application of these processes substantially contributes to development of the organization. It should be noted that the use of quality tools in certain industries is nearly mandatory.

One of the sectors with specific requirements is automotive industry, which introduced normative regulations discussed in the international standard of ISO/TS 16949. The standard concerns the requirements for all the manufacturers of vehicles and its suppliers. The elementary goals of this regulation is striving for ensuring safety for final product, continuous improvement of processes and reduction of costs as well as meeting the customer requirements. This is possible to be achieved by using quality tools such as Pareto chart, Ishikawa diagram, FMEA, SPC or QFD.

This study is aimed to indicate possible causes of defects in the process of cable production using Ishikawa diagram.

Keywords: Quality, Ishikawa diagram, cable.

2.1. Introduction

The enterprise analysed in this study is a manufacturer of cables used in the automotive industry. Therefore, the enterprise is obliged to use the regulations and guidelines contained in the sectorial automotive standard ISO/TS 16949. The use of this standard guarantees presentation of basic

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requirements concerning management system in organization with special requirements of customers and similar approach to quality systems in the automotive sector, both for services and manufacturers that cooperate with original equipment manufacturers (OEMs). An additional benefit of the use of this standard is, on the one hand, avoiding the necessity of multiple certification and, on the other hand, opportunities for continuous improvement with simultaneous reduction in losses, improvement in cooperation with customers and supply reliability (MAĆKIEWICZ E. 2006, ŁUCZAK J. 2008, DZIUBA S.T., JAROSSOVÁ M.A., GOŁĘBIECKA N. 2013). ISO/TS 16949 standard focuses on the whole cycle of manufacturing of a product i.e. from the moment of organization of the enterprise and quality system through activities of market survey, stages in process and product design, production, inspections and testing, implementation of preventive and corrective measures until the dispatch of the final product to the customer. Each stage contains feedback activities which are taken for continuous improvement of the system (HAMROL A. 2008, DZIUBA S.T., GODYŃ M. 2014).

Meeting the guidelines of the standard discussed is achieved by e.g. the whole range of methods and tools used for quality management. The most frequent tools include: SPC, Pareto chart and Ishikawa diagram, which was used in this study.

Ishikawa diagram is also termed cause-and-effect diagram or a fishbone diagram. This tool presents the causes of the problem in an organized form with mutual relationships between these causes. The chart should be prepared by the team composed of the employees of the specific enterprise with high expert knowledge (ŁUNARSKI J. 2011, DZIUBA S.T., JAROSSOVÁ M.A., GOŁĘBIECKA N. 2013).

The quality tool discussed is used to propose hypotheses concerning the causes of defects. This tool is very universal and can be used at all levels, regardless of the type of division. The potential causes are men, material, management, method, machine and environment (DZIUBA S.T., JAROSSOVÁ M.A., GOŁĘBIECKA N. 2013).

One of the conditions for proper identification of the causes of defects by means of Ishikawa diagram during cable manufacturing is in-depth analysis of its manufacturing process.Cables and leads, both isolated and non-isolated, are products which are composed of one or more conductors which can, but do not always have, an individual coating in the form of isolation or shield with twisted strands. Conductors are the basic component of the stranded cable (lead) and are used for conduction of electric current. (ŁUKSZA J., SKOŁYSZEWSKI A. 2006, GROBICKI J., GERMATA M. 2011).

In the case discussed in this study, the cables for automotive industry are manufactured from strands made of copper alloys. Diagram of cable manufacturing is presented in Figure 2.1.

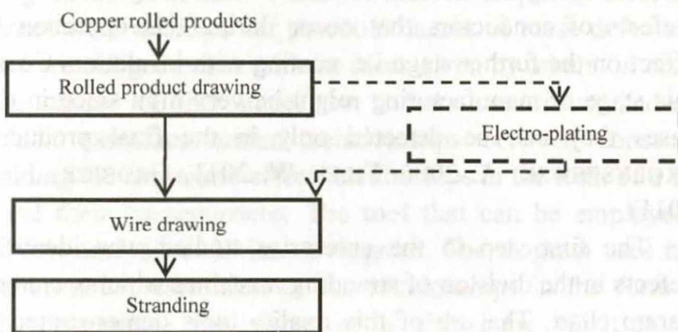

Fig. 2.1. Technological diagram of cable manufacturing.

Source: author's own elaboration based on (FILEK W. 2011, MATERIALS FROM..2013)

As can be seen in Fig. 2.1, there are following stages in cable production: rolled product drawing, wire drawing, drawing wires, stranding, extrusion. Part of cables are obtained from strands coated with tin. Therefore, the material between the stages in rolled product drawing and wire drawing is subjected to electro-plating (FILEK W. 2011, MATERIALS FROM...2013).

The enterprise studied, which is a manufacturer and supplier of cables for the automotive industry, is obliged to meet the requirements contained in the sectoral standard ISO/TS 16949 since they are connected with product safety for final consumer. One of the requirements of the automotive standard is adequate use of quality tools which guarantee continuous improvement in the organization.

2.2. Aim of the study and research methodology

One of the most essential and the most problematic processes in manufacturing of cables and leads is stranding wires into a conductor. Defects of conductors that occur during this operation have essential effect on the further stage i.e. coating with insulation. Costs of defects at this stage of manufacturing might be very high since in the most of the cases they can be detected only in the final product (ŁUKSZA J., SKOŁYSZEWSKI A. 2006, FILEK W. 2011, GROBICKI J., GERMATA M. 2011).

The first step in the enterprise studied was identification of the defects in the division of stranding machines which were organized using Pareto chart. The use of this quality tools demonstrated unequivocally that the most frequent quality problem in the division discussed was "single wire loosening" i.e. among all the wires stranded in a single conductor, one unit is loosened and its concentricity and lay are unequal. Another essential quality defect was "uneven cable laying on a drum", which consists in formation of a belly on one or both sides of the drum flange (DZIUBA S.T., GODYŃ M. 2014).

Identification of the most frequent defects allowed for formulation of the research aim which is determination of potential causes of the defect and pointing to the factors of not detecting the defect. The achievement of this research aim was ensured by cause-and-effect analysis in the form of Ishikawa diagram. The study employed the method of teamwork i.e.

brainstorming, inductive method, interviews and technical data presentation.

2.3. Cause-and-effect analysis of the most important defects

After Pareto chart analysis, the decision was made in the enterprise studied to prevent two of the most frequent defects, i.e. "single wire loosening" and "uneven wire laying" (DZIUBA S.T., GODYŃ M. 2014; KONSTANCIAK M., BORKOWSKI S. 2009).

The examinations were started from organization of a meeting of a team comprising persons responsible for finding solutions to eliminate the defects. A team leader was also appointed. At another stage, the brainstorming method was used to analyse individual quality defects. All the participants were asked to list potential causes of these defects. The participants were obliged not to criticise ideas given by others. In order to facilitate the course of this stage, the authors used cause-and-effect analysis which examines mutual relationships between consecutive events, obtaining the cause-and-effect relationships in the form of a series of causes and their consequences. The tool that can be employed for cause-and-effect analysis is Ishikawa diagram. The diagram uses multi-level deduction and presentation of the relationships in the form of a diagram that resembles the shape of a fish bone (DZIUBA S.T., JAROSSOVÁ M.A., GOŁĘBIECKA N. 2013; BORKOWSKI S., KONSTANCIAK M., JAGUSIAK M. 2010).

The analysis resulted in finding the causes and organization and determination of mutual relations, which can be seen in Figs. 2.2 - 2.5.

Cause-and-effect analysis was divided into two parts during discussion on the problems of "single wire loosening" and "uneven wire laying". The first part was aimed at identification of the causes of defects (Figs. 2.2, 2.4), whereas the second part was focused on detection of defects (Figs. 2.3, 2.5).

Another stage of the study was to assess possible causes of defects through estimation since the fishbone diagrams (Figs. 22 - 2.5) contain possible sources of the problem. Some of them are purely hypothetical and the probability of their occurrence was insignificant. Since taking preventive actions means that some costs have to be incurred, the list was verified and the focus was on the most realistic causes of product defects. At this stage, apart from the team assigned, the shift managers took part in the analysis. The scale of 0 to 2, with 0 meaning insignificant, 1 - medium, and 2 - high likelihood of occurrence of the causes that have essential effect on occurrence of defects. Figures 2.2 - 2.5 present Ishikawa diagrams with evaluation of possible sources of the problem. Among all the above causes, those with two points were considered as priority and were analysed first, followed by the actions taken for those with 1 point, whereas the causes with 0 points were not taken into consideration during creation of the action plan (Table 2.1, 2.2) since the likelihood of their occurrence was considered as insignificant.

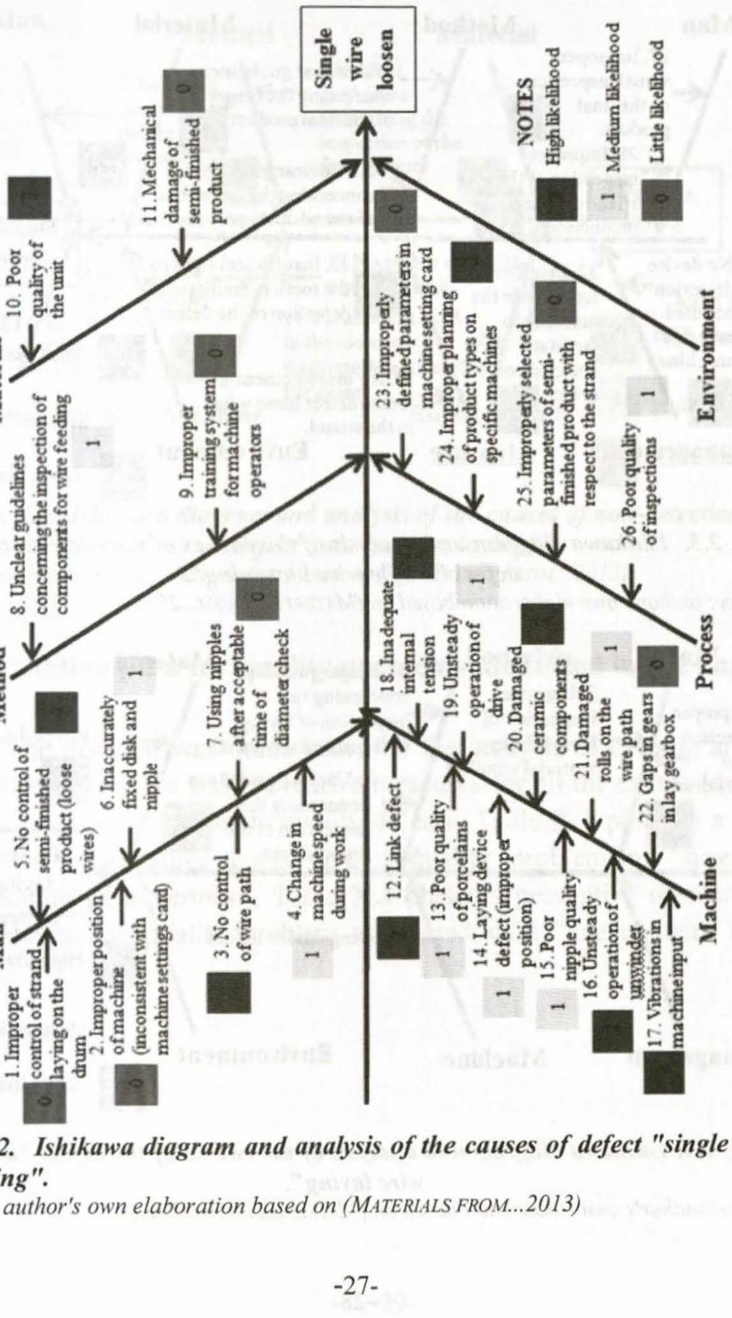

Fig. 2.2. Ishikawa diagram and analysis of the causes of defect "single wire loosening".

Source: author's own elaboration based on (MATERIALS FROM...2013)

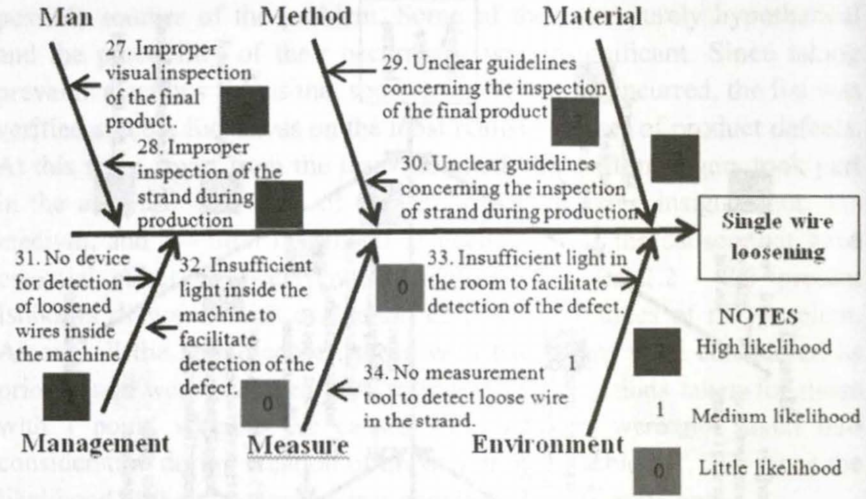

Fig. 2.3. Ishikawa diagram and analysis of the causes of non-detection of the defect "single wire loosening".

Source: author's own elaboration based on (MATERIALS FROM...2013)

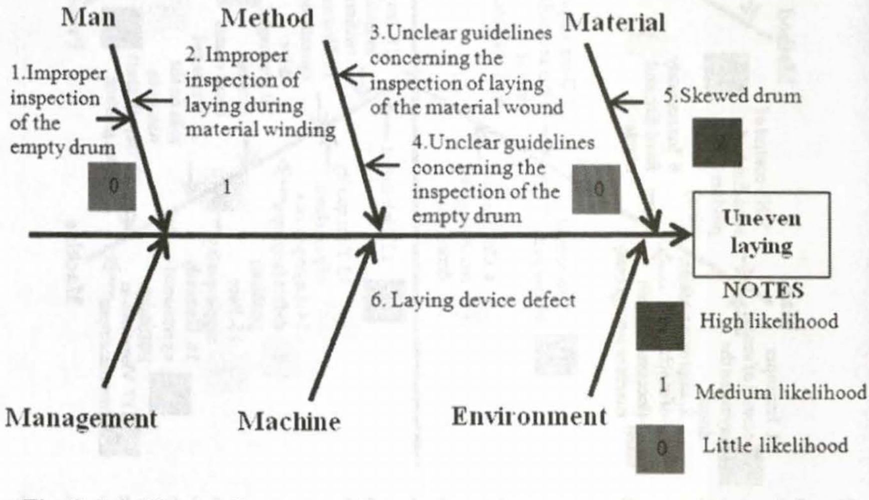

Fig. 2.4. Ishikawa diagram and analysis of the causes of the defect "uneven wire laying".

Source: author's own elaboration based on (MATERIALS FROM...2013)

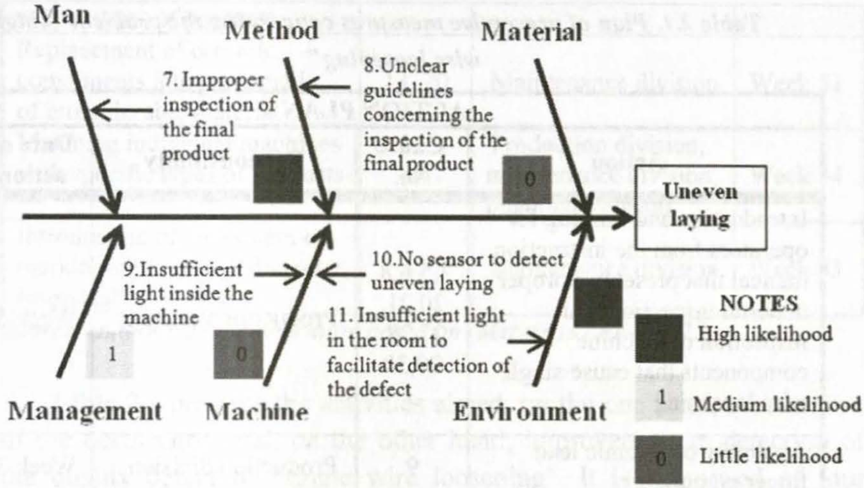

Fig. 2.5. Ishikawa diagram and analysis of the causes of non-detection of the defect "uneven wire laying".
Source: author's own elaboration based on (MATERIALS FROM...2013)

2.4. Action plan for quality problems identified in the analysis

The decision was made based on the analysis to develop an action plan for corrective and preventive measures for all the causes identified. The aim was to eliminate quality defects. Table X.1 presents a plan of preventive measures concerning a quality problem of "single wire loosening". Furthermore, Table X.2 presents preventive measures with respect to the quality problem connected with "uneven wire laying".

Table 2.1. Plan of preventive measures concerning the problem "single wire loosening"

ACTION PLAN			
Action	**Cause No.**	**Responsibility**	**Date of action**
Introduction and training for operators from the instruction manual that presents a proper material inspection and inspection of machine components that cause single wire loosening	3,5,6,8, 20,21, 27,28, 29,30	Production division	Week 33
Assembly of ceramic lead finger on pullers	9	Production division	Week 35
Training of operators concerning proper unit path on the rolls and ceramic components	9	Production division	Week 35
Change in the method of inspection of unit tension in winding machines	9	Production division	Week 36
Preventive replacement of link plates every two weeks	12	Maintenance division	Week 32
Changing the supplier for link plates that offers components with higher quality	12	Purchasing division	Week 35
Creation of templates to distinguish between worn and correct link plates	8,12	Production division	Week 31
Introduction of the obligatory preventive inspection of the wire path during each link replacement	3,12	Production division	Week 32
Replacement of unwinders in selected machines	16, 17	Maintenance division	Week 39
Ordering and testing of new springs for internal tension, matching these springs with	18	Production division, Purchasing division	Week 47

proper types of products			
Replacement of ceramic components into parts made of more durable material	13, 20	Maintenance division	Week 51
Matching individual machines with specific types of products	24	Production division, maintenance division, planning division	Week 34
Introduction of the system of marking nipples with diameter inspected	15	Maintenance division	Week 33

Source: author's own elaboration based on (MATERIALS FROM...2013)

Table 2.1 presents the activities aimed, on the one hand, at reduction of the occurrence, and, on the other hand, improvement in detection of the quality defect of "single wire loosening". It is comprised of four columns: the first column contains the actions, whereas the second column presents potential causes' numbers assigned during assessment in Ishikawa diagrams (Fig. 2.2 and 2.3). The third column contains divisions responsible for the actions implemented. As can be seen from the table, the repeated entity is production division. There is a rule used in the enterprise studied which says it is area where the defect occurred which is responsible for the defects. The fourth column presents the dates for implementation of actions. They are specified as weeks.

The similar method as in the case of "single wire loosening" was used for analysis of the quality defect "uneven laying of cable in the drum", for which a plan of corrective and preventive actions was also developed, presented in Table 2.2.

Table 2.2. Plan of preventive measures concerning the problem "uneven laying"

ACTION PLAN			
Action	**Cause No.**	**Responsibility**	**Date of action**
Introduction of the system of segregation aimed at separation of the drums which cannot be used from those that can be used for production	5	Production division	Week 32
Purchase of new drums	5	Purchasing division	Week 36
Regeneration of skewed drums	5	Maintenance division	Week 34
Introduction of preventive inspection of the laying device.	6	Production division	Week 33
Training for machine operators concerning problems connected with uneven laying.	2, 7	Production division, quality division	Week 33
Assembly of additional lights in machines to facilitate visual inspection of the material.	9	Maintenance division	Week 35

Source: author's own elaboration based on (MATERIALS FROM...2013)

Table 2.2 shows that the most actions were implemented for the cause "skewed drum". Drum segregation was planned in order to eliminate this problem. The drums that could not be used were marked with a red stick and the shift manager made the decision whether this drum should be scrapped or sent for overhaul. The first ones were scrapped, whereas some space for overhauling of skewed drums was spared. Additionally, new drums were ordered to replenish low levels caused by scrapping.

Additionally, the obligation of periodical inspection of laying device was introduced. The cycle of trainings in small groups for machine operators was scheduled; the operators were informed about this problem and the aspects that should be paid particular attention were emphasized. The operators were also taught how to conduct drum inspection.

2.5. Conclusions

After implementation of corrective and preventive measures presented in Table 2.1 and 2.2, the effectiveness of the actions used was carried out.

The effectiveness consisted in inspection of the actions for a month. The examinations showed that the best effects were produced by the actions connected with assembly of additional components, such as e.g. replacement of unwinders in selected machines. The actions concerning preventing low quality of semi-finished products allowed for elimination of the defect of "single wire loosening" caused for this reason. The above actions yielded measurable benefits, but it should be emphasized that the costs of implementing these actions were high. An example of relatively low expenditures was the action aimed at elimination of the use of skewed drums which caused "uneven cable laying". This action turned out to be very effective as no problem caused by this defect was observed over the period of 4 weeks of the study.

A holistic statistics were prepared in the final phase of the study, which showed that, in the case of "single wire loosening" the number of defects declined by 44%, whereas "uneven laying" was reduced by 68%. However, these findings are not entirely reliable since production level in the stranding division increased by 20% in the period studied. Therefore, the additional collected values were computed using PPM (parts per million) index which denotes the number of defects per million products (likelihood of occurrence). Higher PPM values correspond to higher process defectiveness. According to this measure, occurrence of the problem "single wire loosening" reduced by 62%, whereas "uneven cable laying" was reduced by 87%.

The study demonstrated that collecting reliable data followed by the use of proper quality tools allows for finding the causes of defects, implementation of adequate corrective and preventive measures in order to achieve proper quality level of the final product.

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