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THE ANALYSIS AND IMPROVEMENT OF PRODUCT QUALITY USING SELECTED METHODS AND TOOLS IN AUTOMOTIVE INDUSTRY ENTERPRISE

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Abstract
The work included a qualitative analysis of a product installed in passenger cars of a selected make and model. The product is an airbag module manufactured for one type of passenger car. This product is produced by an international production company with its plant in the northern part of the Silesian province. The initial analysis covered six calendar months, of which the month chosen for further analysis was the one in which the percentage of nonconforming products in the total production exceeded the assumed acceptable value. The analysis used four basic quality management instruments: the Pareto chart, the FMEA method, Ishikawa chart and the 5 Whys technique. After the analysis, improvement actions were also proposed.

Keywords
quality, quality analysis, quality tools, improvement, airbag module.

1. Introduction

Each product is the end result of a certain process, therefore it can be anything that the company is able to offer to consumers and what can satisfy their needs. Products are called goods that are located at the producer and have not yet been sold, while after purchase by the customer they become commodities [15]. For each customer, the quality of these products is of fundamental importance during the selection and purchase process.

Quality can be perceived depending on the nature of the product, therefore the product can fulfill the following functions: service, material object, i.e. an article, intellectual product or processed material. The characteristic features of the product are: material form, countability, reproducibility of properties - measurement of each property can take place many times and the possibility of acquiring property rights to the product [2].

Each product consists of many features that can be called qualitative features. They have the task of distinguishing products for the same purpose from each other. A person who makes decisions regarding the production of a specific product analyzes particular features. For everyone, another characteristic will be more important: functionality, price, appearance or reliability of the product. Therefore, it is not easy to define this concept because it means something different for everyone. Today's perception of quality develops with the development of management science and increasingly demanding human needs.

There are many definitions defining quality. One of them, included in the international standard ISO 9000: 2015, explains it as follows: "Quality is the degree to which a set of inherent features meets requirements" [5], where it should be added that [5]:

- the term "quality" can be used with adjectives such as low, good, excellent,
- "inherent", as opposed to "assigned", means existing in itself, especially as a permanent property.

Based on the available literature, one can cite another definition: quality is providing the client with what he needs at a given moment, at a price he is willing to pay, at a cost which the company is able to bear. The definition of quality can also be defined as the degree of correspondence between expectations and reality [16].

The Japanese Association of Quality Standards has distinguished three quality characteristics: required quality (required by the customer), target quality (the company's management wants to achieve it) and adjusted quality (currently delivered) [18].

Differences between the interpretation of quality were also presented by Ishikawa indicating narrow quality, where it is understood in the dimension of product quality, and broad quality, which concerns the quality of work, enterprise, departments, processes, goals, etc. [7].

Summing up, all the above-mentioned considerations regarding quality, one can say that: 'quality is the object's ability to create satisfaction for the recipient" [14].

In order to assess the quality level of a product, one should not be guided only by the qualitative features that the product possesses but also by the quality characteristics of the product. They include [8]:

- functionality – defines what functions the product can perform and to what extent,
- safety – this characteristic helps to determine whether the product does not directly or indirectly threaten the life and health of people and the environment,
- emotional usefulness – this characteristic mainly refers to aesthetics, product appearance, current trend or fashion. These features affect the emotions that a product raises in the user,
- ergonomics – determines the degree of its adaptation to the anatomical, physiological and psychological characteristics of users of the product.

All the qualitative characteristics of the product can be divided into two basic groups [2]:

- time-dependent,
- independent of time.

From the point of view of product quality, "time-dependent" features are those where the opinion can only be expressed in variants of probabilities and often when the designated period of product usage elapses. It should be specified [2]:

- repairability – it is the estimated cost and sometimes the tendency to restore the destroyed product its utility value,
- durability – is determined by the length of time of use in which the product has not lost its use value,
- time between damages (failures) – the average period of time of using the product between damages that cause its functionality to disappear.

Subsequently, characteristics independent of time, i.e. those that can be specified at the moment of acquiring goods, that is [2]:

- option of use, so-called functionality,
- appearance – shape, diligence in and way of finishing,
- percentage of nonconformity – is determined by the degree to which the product does not meet the requirements,
- ergonomics, otherwise ease of use.

Maintaining a satisfactory level of quality in enterprises is guaranteed by the implementation of quality management system. Standard system are currently based on the requirements of ISO 9001:201. However, there are branches of industry for which such system is not sufficient and additional requirement should be implemented. On of such branch is automotive industry [10]. This industry includes companies producing passenger cars, trucks, vans, buses and motorcycles as well as suppliers and sub-suppliers of parts of these vehicles throughout the supply chain [7]. Such enterprises are obliged to meet stricter quality expectations. Automotive corporations increasingly cooperate with numerous suppliers of automotive components. Therefore, the quality of the produced car depends on the quality of all individual parts, what is connected with the need to assess and verify suppliers [11].

One of the factors that guarantee the fulfillment of quality requirement for this industry is the certification to the quality management system in accordance with the global standard IATF 16949:2016. This standard combines the requirements of existing American, German, French and Italian management systems within automotive industry [12]. This standard was issued on October 1th, 2016, this time these requirements are not issued by The International Organization for Standardization (ISO), but the International Automotive Task Force (IATF) – the organization bringing together car manufacturers and associations of manufacturers of automotive industry, whose main task is to provide better quality of automotive industry products [7].

This automotive standard applies to all internal and external suppliers of [3]:

1. Production or service parts.
2. Production materials.
3. Assemblies.
4. Heat treating, welding, painting, plating or other finishing services directly relating of automotive related parts.

IATF 16949:2016 shares the same section headings and clause structure as ISO 9001 and, after its 2015 update, follows the same high level structure (Supplement SL) with 10 clauses dedicated to ensure alignment with standards governing other management systems (such as ISO 14001 and the ISO 27000 series) [1].

The instruments used in quality management, including product quality assessment in automotive industry, are characterized by division into techniques, principles and methods, but the subject literature also distinguishes tools. The difference between them is primarily related to the scale of their activity [9].

In general, such instruments are divided according to the purpose (designation), in which they will be used. Literature allows division into three categories [17]:

- the principles are the most general and mean the attitude of the company's employees with its manager at the forefront to the general problems related to quality,
- the methods are less general and therefore are characterized by a logical and science-based procedure; in more detail, it is the integration of procedures for dealing with models when executing projects based on quality management,

Table 1
Three-component classification of quality tools [15].

Traditional quality tools	New quality tools	Statistical quality tools
a) Error detection: • Histogram. • Control cards. • Control sheet.	a) Problem analysis: • Affinity diagram. • Interrelationship diagram.	a) Data collection: • Sampling.
b) Error analysis: • Ishikawa chart. • Pareto chart. • Correlation diagram. • Block diagram.	b) Making decisions: • Systematic diagram. • Matrix diagram. • Matrix data analysis.	b) Parameters estimation: • Descriptive statistics. • Schedules. • Confidence intervals.
	c) Scheduling tasks: • Arrow diagram. • Process Decision Program Chart.	c) Inference: • Testing hypotheses. • Variance analysis. • Regression analysis. • Correlation analysis.

- tools, especially used in practice, help gather and modify acquired data, related to various views of pro-quality products; It can be said that they answer the question: ”how should it be done?”.

Such a division was adopted by tradition and the ISO 9000 standard.

Over the years, based on observation, analysis and practice, many principles have been developed that help improve processes in terms of quality. They are philosophies that have won recognition in many countries in small, medium-sized and large enterprises. Their thoughtful and conscious use helps to achieve success, improve processes, and especially to improve the level of quality at all levels of the company. The principles of quality improvement include: the Deming concept, the “0 defects” principle, the Poka-Yoke principle, the Kaizen concept, and the principles of quality management according to the ISO 9000 standard.

Quality management methods include, among others the following methods: the FMEA method, 5S method, 5 Whys technique, QFD method, SPC method, DOE method – experimental planning, and the 8D method.

Classification of quality tools is presented in Table 1.

The criterion which categorizes quality tools and is most often used, is to define the designation and purpose. They are then used to examine specific processes in the enterprise. These tools have been extended on the basis of Japanese quality clubs and divided into two basic groups: traditional tools, as well as the so-called new tools [15].

Arranging traditional tools, i.e. the classic seven, was introduced by Japanese engineer Kaoru Ishikawa. They are based mainly on elements in the field of mathematics and statistics. The role of these tools is to collect quantitative and qualitative information about the observed process, as well as to present them graphically [2].

In parallel with the speed of development of quality management, the “classic seven” has been expanded by a further seven new tools. They complement the old tools and are qualitative in contrast to the old tools that contained a quantitative description. In the literature one can find a three-fold classification of quality tools (Table 1).

The article uses selected quality management methods and tools to assess the quality of the airbag module manufactured for one type of passenger cars. This product is manufactured by an international manufacturing company of the automotive industry, having its plant in the northern part of the Silesian province. The causes of nonconformities were identified and improvement actions were proposed.

2. Characteristics of the tested product

The paper analyzes the product, the airbag module used to ensure safety at the time of a collision. Such a module is mounted in the steering wheel of passenger cars. It consists of several basic elements [4, 6]:

- Airbag – the size of the airbag depends on the type and its purpose. It is covered with a silicone coating, because when deployed the temperature is about 600°C. It prevents burning or damage of the airbag.
- Inflator – its task is to fill the airbag with gas. There are two types: thermal and gas. An appropriate type of inflator is fitted in each airbag, matched exactly to the volume of the airbag. The inflator must fill the airbag so that it fills its entire volume. It is mounted on the back of the airbag.
- Frame – it is a metal part that allows connection of the inflator and the airbag.
- Housing – this part is plastic and is located on the back of the module.
- Cover – there is already a folded airbag module between the housing and the cover. The cover is the outer part, or the front of the module. Only this element is visible after mounting in the car. In the case of the driver module, this is the central part of the steering wheel.

The quality control system in the enterprise producing analyzed products is one of the elements of the quality management system operating inside the enterprise. Such system operates based on ISO 9001:2015 standard. In addition, due to the fact that the enterprise operates in automotive industry, is has also implemented the system that meets special requirements for this kind of products. At present, the enterprise has certificate of such system compliant with the IATF 16949:2016 standard [4].

The work includes qualitative analysis of the product installed in passenger cars of a selected make and model. The initial analysis covers six calendar months, of which the month chosen for further analysis is the one in which the percentage of nonconforming products in the total production exceeded the assumed acceptable value. The analysis uses 4 basic quality management instruments: the Pareto chart, FMEA method, Ishikawa chart and the 5 Whys technique. After the analysis, improvement actions are proposed.

3. Quantitative and qualitative analysis of the production of the tested product

A quantitative analysis of the production volume of the tested product was made. Figure 1 shows the volume of monthly production in six consecutive months of one calendar year.

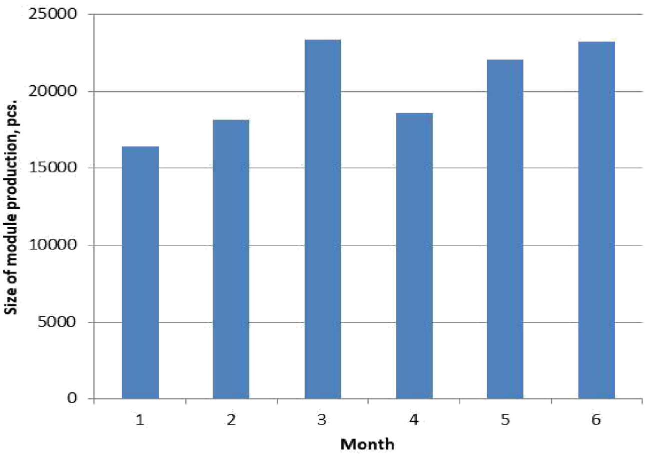

Fig. 1. Module production volume in individual months. Source: Authors' own study based on [4, 6].

Figure 2 shows the percentage of nonconforming products in the total module production. For this type of module, the acceptable number of nonconformities in production is 0.2% of the total production.

The results presented in Fig. 1 and 2 clearly show that the production volume of the tested product undergoes certain fluctuations (about 16.5–23.3 thousand items), however, it cannot be said that the trend of changes in this phenomenon is more pronounced. Changes in the production volume are strictly due to the size of orders entering the examined company because a specific product only fits the cars of a specific make and model. It can be noted that the number of nonconformities identified is not dependent on the production volume. In the month of March, the acceptable number of nonconformities was exceeded, in the remaining months the share of defective products was within the admissible standards. Further analysis of nonconforming production was carried out for month 3 (March) due to the maximum acceptable value being exceeded.

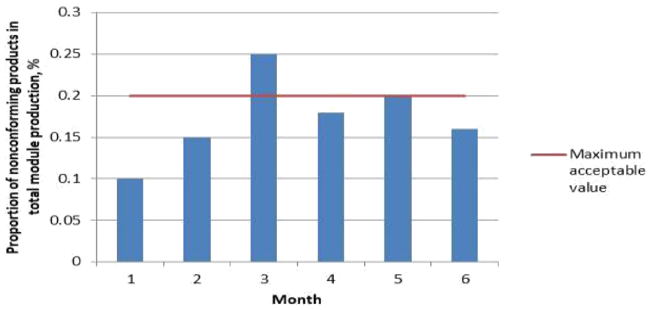

Fig. 2. Proportion of nonconforming products in total module production in individual months. Source: Authors' own study based on [4, 6].

3.1. Quantitative analysis of nonconforming products using the Pareto chart

Information was collected on the types of nonconformity and the number of nonconforming products broken down by type. In the analyzed period, 9 types of nonconformities were identified, which are presented in order of frequency:

1. Hole drilling errors.
2. Damage to the plug.
3. Damage to the fabric during assembly.
4. Faulty label.
5. Use of wrong component.
6. Incorrect horn function.
7. Initial winding error.
8. Final label error.
9. Omitted operation.

Accurate quantitative analysis using the Pareto chart is shown in Fig. 3.

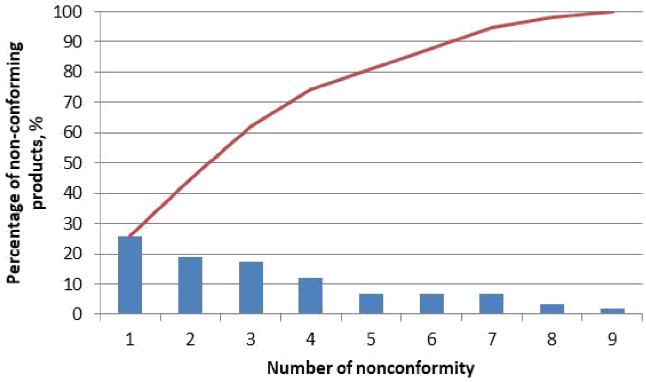

Fig. 3. Pareto chart of nonconformity of module production in examined month. Source: Authors' own study based on [4, 6].

From the data presented in Fig. 3, it can be deduced that:

- The most common nonconformities are: no hole drilling (25.8%), damage to the plug (18.9%), damage to the fabric during assembly (17.2%) and faulty label (12%). Therefore, during the production process, special attention should be paid to the operations in which these elements are mounted. During these operations, mistakes are made that cause these nonconformities.
- 81.03% of nonconforming products include five types of nonconformity: hole drilling error, damage to the plug, damage to the fabric during assembly, faulty label, use of the wrong component.
- The analysis clearly shows that the statistical relation "20–80" has not been observed. It is rather rare situation that may be influenced by various factors. Probably, in this case the main factor is relatively short period of time taken into account, thus the number of result taken to the analysis might have been insufficient.

3.2. FMEA analysis of the causes of product nonconformities

FMEA analysis allows the causes and effects of nonconformities to be determined. Using this analysis allows factors that affect the occurrence of nonconformities to be identified. FMEA analysis of the nonconformities that occurred in the products was performed. The results of this analysis are presented in Table 2 (P – probability, S – severity, D – detection, RPN – risk priority number).

The values of the risk priority numbers for individual nonconformities determined in the FMEA analysis are presented in Fig. 4. For comparison, the critical value of the risk priority number is marked at 100 on the graph.

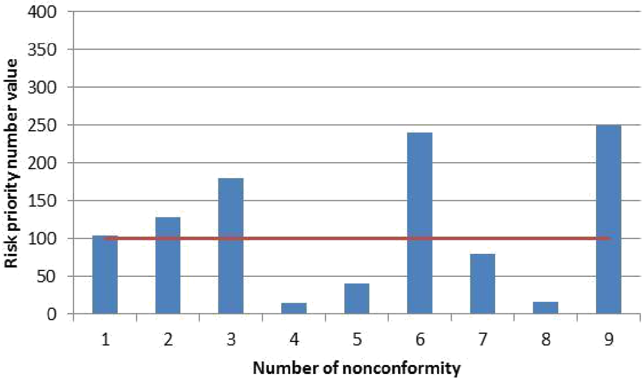

Fig. 4. Risk priority number values for particular nonconformities of module production and critical value in analyzed period. Source: Authors' own c study based on [4, 6].

Table 2
FMEA analysis for nonconformities that occurred in products. Source: Authors' own study based on [4, 6].

No.	Name of nonconformity	Potential consequences of defect	Potential reasons for defect	P	S	D	RPN	Preventive measures
1.	Hole drilling error	Poor hole dimensions.	Drilling machine failure.	5	7	3	105	More frequent drilling machine inspections, as well as its adjustment.
2.	Damage to plug	Risk of short circuit. No possibility of current flow.	Damage could have occurred during production process.	8	8	2	128	Visual inspection of plug installed in finished product.
3.	Damage to fabric during assembly	Tearing of airbag.	Mechanical damage caused during transport or production process.	6	10	3	180	Avoid use of sharp elements during airbag operations, e.g. folding blades in folder, should not have sharp tips
4.	Faulty label	Difficulty scanning lead label.	Fuzzy bar code.	5	3	1	15	Printer to print an additional label should be placed next to the machine. This will save time.
5.	Use of wrong component	Product cannot be operated according to its intended use.	Failure of person taking the component.	4	10	1	40	Minimize working movements of assembling persons. Appropriate management of assembly area.
6.	Incorrect horn function	No possibility to use horn for its designated purpose.	Poor installation of horn wire.	6	10	4	240	Conduct tests to check horn function on few random pieces from given order.
7.	Initial fastening error	Damage to bolt thread.	Use of wrong nut.	8	5	2	80	Nuts with individual component numbers should be located in places designated for them, as well as in containers that prevent them from spilling or mixing up.
8.	No final label	Limited possibilities of introducing finished product to system. Additional time spent on printing subsequent label.	Failure of person who glues label on finished product.	8	2	1	16	Use labels with stronger adhesive.
9.	Omitted operation	Finished product may be useless or dangerous.	Machine operator failure.	5	10	5	250	Additional training of employees and machine operators.

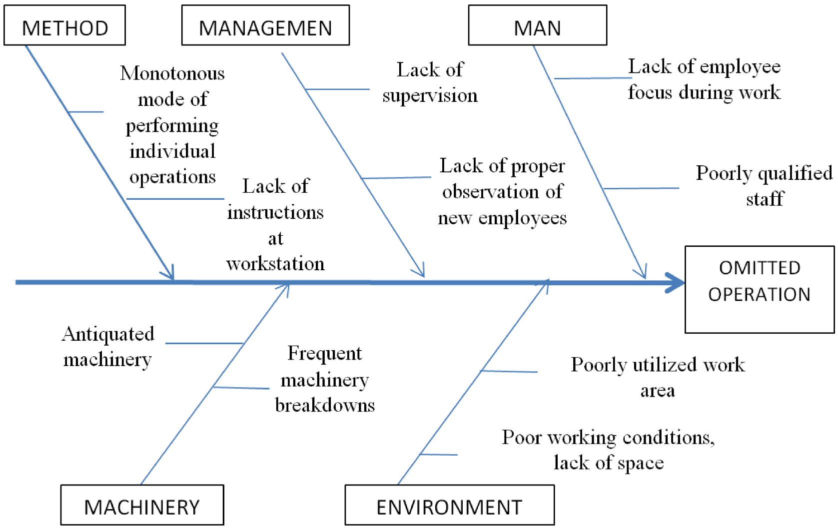

Fig. 5. Ishikawa chart for nonconformity omitted operation occurring during module production.
Source: Authors' own study based on [4, 6].

The FMEA analysis carried out for nonconformities concerning products (Table 2, Fig. 4) proved that the leading and the most important nonconformity that should be eliminated is the omitted operation (9). The priority number of the risk of this nonconformity reached the highest value. However, three other defects also exceeded the critical line: incorrect horn function (6), damage to the fabric during assembly (3) and damage to the plug (2).

3.3. Ishikawa chart of causes of nonconformity of the selected module

The Ishikawa chart is a cause and effect diagram that allows the areas responsible for the occurrence of problems to be determined, including nonconformities in components as well as in products. In the area in which there are the most factors responsible for the problem, it should be must be examined as a priority and efforts should be made to eliminate the detected problem. The most significant nonconformity for products which was identified during the FMEA analysis, omitted operation, was used to construct the Ishikawa chart (Fig. 5).

The cause and effect graph, which was made for the key nonconformity of products – omitted operation (Fig. 5) – showed that many areas in the enterprise are responsible for the occurrence of this nonconformity. There is no main leading area responsible for this problem.

3.4. Using the 5 Whys technique for the causes of nonconformity of the selected module

The 5 Whys is one of the techniques which allows the underlying causes of a nonconformity problem or defect to be detected. This technique consists in asking five "why?" questions. This allows the cause of the problem to be divided into factors, as well as reach the original cause and determine the area responsible for its occurrence. By asking further questions, the problem becomes simpler and easier to solve. Figure 6 presents an analysis of the problem with the 5 Whys technique, which was carried out for the nonconformity detected in products – omitted operation.

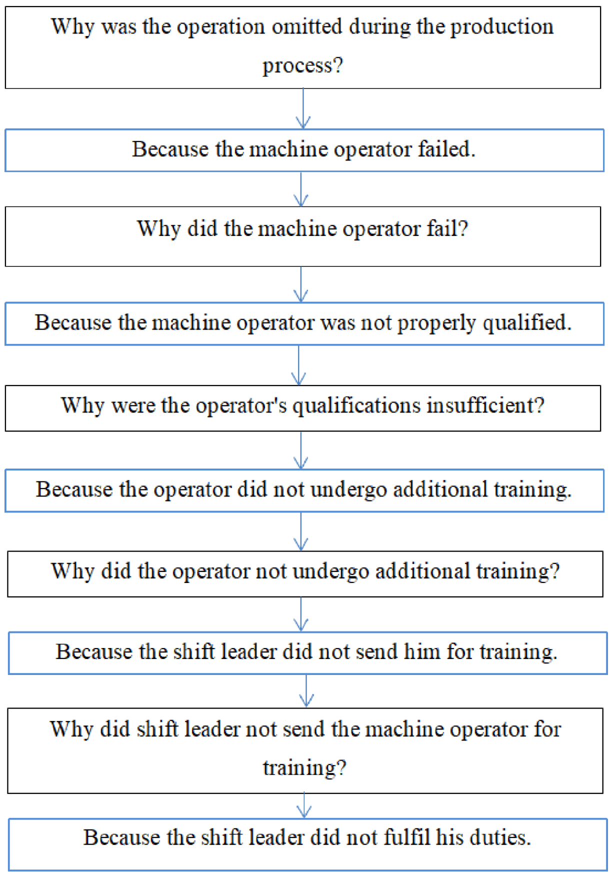

Fig. 6. Application of 5 Whys technique for nonconformity of omitted operation occurring during module production.
Source: Authors' own study based on [4, 6].

The 5 Whys analysis carried out for nonconformity of the omitted operation showed that the main reason for the nonconformity was the transgression of the shift leader, who did not ensure proper training of the machine operator.

4. Possibilities of improvement of the selected product

The analyses showed areas of problems as well as the reasons for their occurrence. Thanks to these results, corrective actions can be applied to minimize the identified problems, which results in continuous improvement of the product quality. The following statements and conclusions can be made on the basis of the analyses:

1. *Pareto chart* – the analysis carried out for the products shows that the most frequently occurring nonconformities are: lack of holes drilling (25.8%), damage to the plug (18.9%), damage to the fabric during assembly (17.2%) and faulty label (12%). Five nonconformities account for 81.03% of nonconforming products: hole drilling error, damage to the plug, damage to the fabric during assembly, faulty label, and use of the wrong component. Based on the observation of the production process and products, it can be concluded that:
   - The lack of hole drilling prevents the assembling individual components with each other. This may be due to frequent drilling machine failures. The machine should be inspected or completely replaced.
   - Damage to the plug is a mechanical nonconformity that could have arisen in transport or during the production process. In order to eliminate damaged plugs, it will be necessary to visually check the quality of the plugs.
   - Damage to the fabric during assembly is an nonconformity that could have occurred during transport, but also during the course of the production process. The whole process, as well as the elements and tools should be examined because the fabric may have been damaged by the blades in the machine or by the operator. None of the components in the machine or the operator's tools must pose a risk of damaging the airbag fabric.
   - A faulty label is a nonconformity that hinders the pairing of components and introducing them to the system as a whole. The problem causing the nonconformity is a printer failure or use of the wrong ink. It will be necessary to inspect the printer and possibly send it for an overhaul.
2. *FMEA analysis* – the analysis showed that the leading and the most important nonconformity, which should be eliminated the fastest, is the omitted operation. The risk priority number of this nonconformity reached the highest value. However, three other defects also exceeded the critical line: incorrect horn function, fabric damage during assembly, damage to the plug.
   The omitted operation is an extremely serious transgression and neglect by the person occupying the given position on the production line. The omission of any operation creates a very high risk for the subsequent user of the car, e.g. if the operator omits fastening the component with the specified number of bolts listed in the instructions placed at the workstation, individual components that make up the module will not be secure. When the airbag is deployed, the components can pose a serious threat to the user's life, which completely fails to fulfil the premise and function of the product.
   In order to completely eliminate this nonconformity, additional training of employees will be necessary, making them aware of the danger and responsibility which risk and danger entail. It is possible that the person on the selected production line has too many operations to perform. In this case, his working movements should be limited and a less complicated scheme of operation should be created.
3. *Ishikawa chart* – Five areas are responsible for the nonconformity "omitted operation": method, management, man, machine and surroundings.
   The omitted operation may have been caused by the lack of instructions at the workstation. The employee may have been unaware of the order of individual operations or forgot to perform it. Instructions at the workstation are a necessary requirement. Before starting work, the employee should become familiar with them.
   The cycle of executing work movements of a given operation could be too monotonous. The worker at the workstation could fall into monotony and boredom. He fell into a routine and did not focus on the work he was doing. An operator's work should not be complicated, that is, it should not be composed of many operations but it should not be too monotonous. Employees should be sent for training, made aware of how important an omitted operation is, and how responsible the work is that they perform.
4. *The "5 Whys" technique* – Omitting the operation by the machine operator is the main reason for the nonconformity. The source of this reason lies in the lack of employee supervision by the shift leader and the lack of employee participation in additional training. The lack of proper qualifications and competences of the operator led to the omission of the operation. A shift leader should observe his team, and on the basis of these observations, send team members for training that will expand their qualifications. This training would make employees aware of the seriousness of the situation and suggest methods, tools and principles that prevent the occurrence of such nonconformities.

5. Summary

In the production process, nonconformities of the product have been identified. The percentage of identified nonconformities is variable, and the determined critical level on the production line was exceeded periodically. Exceeding the critical level of identified nonconformities was not dependent on the production volume.

In the products the most important identified nonconformity was the omitted operation. It achieved the highest LPR value in the FMEA analysis. This failure is extremely important because it makes the product incomplete and the components in it incorrectly attached. To avoid the occurrence of this nonconformity, additional training for employees, increased supervision by the shift leader as well as constant awareness of employees about the responsibility of their work will be necessary.

During production process, many problems caused appearance of nonconformities were not avoided. It should be emphasized that the main factors affecting this situation were related to the people: poorly qualified staff, lack of employee focus during work, monotonous made of performing individual operations, lack of supervision, poor working conditions affecting the comfort of performed activities. These problems are connected with both production workers and managements staff. On of ways to improve such situation would be training of employees or improving working conditions what positively affect the quality of their work. It is also important to make all employees aware that their work affects the quality of products, and hence the safety of car use, that is, health and life of people.

Analysis and improvement of product quality are important processes, especially when it comes to the automotive industry. In order for the analysis and improvement of the product to yield the desired effects, it is necessary to use the tools, methods and techniques designed for that purpose. Thanks to them, the problem, the frequency of its occurrence, the importance of the problem can be determined, and to eliminate the problem as well as improve the entire process.

References

[1] Gruszka J., Misztal A., *The New IATF 16949:2016 Standard In The Automotive Supply Chain*, Research in Logistics and Production, 7, 4, 311–318, 2017.

[2] Hamrol A., *Quality management with examples*, Printing House PWN, Warsaw 2013.

[3] IATF 16949, *The International Automotive Quality Standard. An Executive Overview*, Perry Johnson Consulting, Inc., Detroit, 2016.

[4] *Information materials from Company X.*2017.

[5] ISO 9001:2015: *Quality management systems – Requirements.*

[6] Kipigroch M., *The analysis and imrovement of quality of products in the selected production company*, Eng. Thesis, Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Częstochowa, Poland, 2017.

[7] Komarnicka A., Sąsiadek M., Nahirny T., *The challenges of the automotive industry in the light of the introduction of IATF 16949:2016 standard*, Innovations in management and production engineering, Knosala R. (red.), Publishing House of the Polish Society for Production Management (PTZP), 2, 251–260, 2018.

[8] Kowalczyk J., *Basic concepts and regulations in the field of impact on quality*, Library of Quality Guides – Training Materials, Bydgoszcz 1985.

[9] Mazur A., Gołaś H., *Principles, methods and techniques used in quality management*, Printing House of Technical University of Poznan, 2010.

[10] Mazur M., *Analysis of production incompatibilities and risk level in series production of assembly elements for the automotive industry*, MATEC Web of Conferences, 183, 03011, 2018.

[11] Mazur M., *Quality assurance in the manufacturing of automotive*, Archives of Engineering Knowledge, 2, 1, 63–67, 2017.

[12] Mazur M., Ulewicz R., *Quality in the Manufacture of Safety Components in Cars, Advanced Manufacturing and Repair Technologies in Vehicle Industry*, Romankiewicz F., Romankiewicz R., Ulewicz R. (red.), University of Zielona Góra, pp. 225–237, 2018.

[13] Prussak W., *Quality management. Selected elements*, Printing House of Technical University of Poznan, 2006.

[14] Słowiński B., *Systematic evaluation of the quality of ceramic wheels*, Printing House of Technical University of Koszalin, 2004.

[15] B. Słowiński, *Management and quality engineering*, House of Technical University of Koszalin, 2011.

[16] Stadnicka D., Pacana A., *Budowa i rozwój skutecznych systemów zarządzania jakością*, Printing House of Technical University of Rzeszow, 2016.

[17] Starzyńska B. *Quality tools and techniques relationship matrix as the element of manufacturing improvement methodology*, Scientific Papers Technical University of Poznan, Machine Construction and Production Management, No. 13, pp. 97–108, 2010.

[18] Stoma M., *Models and methods for measuring the quality of services*, Q&R Polska Sp. z o.o., Lublin, 2012.