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QUALITY ASSURANCE PROCESSES IN SERIES PRODUCTION OF CAR ELEMENTS

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Abstract: The paper presents partial results of qualitative analyzes conducted on the production line in the automotive industry. The subject of analyzes is the safety element for motor vehicles and meeting the quality requirements. The quality requirements that the manufacturer must meet are based on customer guidelines (automotive concern) for components manufactured for first assembly. The presented analyzes relate to the identification of production discrepancies and the results of statistical analyzes for the cutting process and component control for one type of cable.
This work contains basic issues in the field of production management for elements intended for the automotive market, detailing the basic applicable rules and standards in this field. It also contains the results of the analysis and evaluation of the production process of the company operating on this market. A preliminary analysis of the causes of production problems and statistical analysis for the indicated process was presented.
Keywords: quality assurance, automotive industry, statistical control, process quality indicator

1. INTRODUCTION

Today's car companies no longer resemble typical manufacturing companies, which include many branches (e.g. painting, electricity, tires, etc.). For economic reasons, today, a car manufacturing company relies primarily on cooperation with many subcontractors and suppliers. In order to ensure the high quality of their products, car companies place requirements on suppliers of assembly parts and appropriate production quality indicators, which are the basis for establishing cooperation. This is because in the automotive industry for the customer the most important are reliability and safety of use, and thus the high quality of the car that they decide to buy. Therefore, the success of the automotive company is based primarily on the uncompromising quality of all components of the car and on the logistics of cooperation with suppliers to reduce operating costs (Klimecka-Tatar, D. 2018).
Quality has become one of the basic problems of modern management in organizations. Currently, in the era of widespread globalization and high competition on international markets, this concept is of particular importance. There is a lot of evidence confirming the thesis that not the quantity of manufactured products, and also not their

price are the determining factor of the company's brand. In the era of overproduction of everything, the customer is the most important. Therefore, an important element of production is the creation and delivery of such goods and services that will be recognized by customers as “high quality”. The implementation of a quality management system often results from the desire to gain a competitive advantage on the market. This can be achieved by improving the organization management system, improving the quality of your products, or deriving marketing benefits from the obtained certificate. However, a large group of enterprises was forced to decide on the implementation of the QMS by clients (Dziuba, ST., Ingaldi, M., Kadlubek, M., 2016). Regardless of the motives of the enterprise, this decision becomes a necessary condition for functioning on the market (Jagusiak-Kocik, M., 2014).

2. Research subject

The results that are presented in the article are developed on the process analysis of a company that is a manufacturer of car tendons and cables. The automotive industry and customers enforce a documented system ensuring quality, not only ISO 9001 but also a number of industry requirements. The company has and operates according to the guidelines of the IATF 16949 standard and other client guidelines. The product offer includes over 2,500 products, which due to the specificity of the product are designed and manufactured for the customer on special orders. Therefore, the number of products offered is constantly growing through the implementation of subsequent projects for new products. Production is carried out on the basis of the customer's design, but design work is also underway. New solutions arise within the scope of the producer but also in cooperation with the client's project department.
Three basic groups can be distinguished in the product structure:

- products for the demand of the spare parts market,
- products intended for first assembly in automotive production plants,
- products not intended for the automotive market, these include links for controlling hospital beds or bicycle links.

The first two product groups are elements with the same technical parameters, but with different requirements documenting the results of quality control on the production line. The design and quality of the product is the same, and only the documentation of the quality assurance process varies in relation to each other and to the customer. The last group accounts for only 11% of production, however, it is a segment with high development dynamics. These products are made in production series of very different sizes, depending on market needs and individual customer orders. An important element of ensuring quality in production is full traceability of the product on the production line and development of a control plan according to customer guidelines for a given product group.
The company also conducts a different division of the product range, due to the type of device to be controlled by a given tendon. In this case, you can distinguish:

- details for window lifters,
- hand brake control rods,
- rods for controlling the gas pedal,
- rods for controlling the clutch pedal,
- speedometer drive cables,
- pull rods for seat control,

- pull rods for controlling the setting of a specialized medical bed,

and other tendons, including for newly designed cars.

In the enterprise, based on the construction drawing, a technology department employee prepares a production order "W - for the manufacture of a product”, which contains all information about the materials and components of the product. Along with the production order, a Product Control Card is issued, on which quality control tests of the cable according to the construction documentation are designated. Each product that is ordered by the customer is implemented on the basis of a contract that contains characteristics of special importance. Important parameters for the client are marked on the construction drawing and are subject to mandatory control during the technological process. To this end, process control is carried out using selected statistical methods, i.e. pre-control card and statistical control card. The results of card controls are supplemented with the development of quality capacity indicators for individual technological processes.

Figure 1 shows an example of a product that is offered by the company. Gear shifting cable, which is used to connect the gear lever to the gearbox, through which the gearshift takes place. The cable consists of armor, a base grommet, a rubber bellows, two steel-rubber silencers, two ends and a steel cable. The basis of this tendon is a steel cable (1x19) with a diameter of Ø 2.6 braided from a steel wire covered with electrolytic zinc coating and coated with plastic Tarnamid T-27. The cutting length of this cable is 1345 ± 1 mm, at both ends of the cable a tarnamid coating of 17 mm should be removed. According to the construction drawing, another component is applied to the rope thus prepared.

Fig. 1. Gear shift cable - research company product (company internal material)

The basic characteristics of the manufacturing process are presented in Figure 2 and include the following stages:

1. Storage of details.
2. Transportation of details from the warehouse (600s, 900m).
3. Damper assembly of components I + Visual Inspection (20s).
4. Damper assembly of components II + Visual Inspection (22s).
5. Intraoperative transport for the next operation (1s).
6. Armor grommet assembly with mufflers (20s).
7. Clamping mufflers on the armor + Visual Inspection (20s).
8. Transport for cable assembly (1s).
9. Armor cable assembly + Visual Inspection (22s).

10. Transport for crimping cable ends (1s).
11. Crimping tips + control of cable length (20s).
12. Transport to the final inspection post (1s.).
13. Final inspection + packaging (25s).
14. Transport to the finished goods warehouse (600s, 900m).
15. Finished product storage.

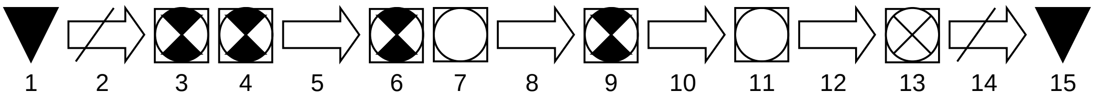

Fig. 2. Basic stages for the process of manufacturing a gear shift cable

3. Guidelines for ensuring quality in production

The key to success in solving quality problems is to properly diagnose of the problem. That is why the company conducts analyzes of the causes of non-compliance in both quantitative and qualitative terms (Dziuba, ST., Ingaldi, M., Kadlubek, M., 2018, Menn, J.P., Sieckmann, F., Kohl, H., Seliger, G. 2018). Quality tools such as Ishikawa Diagram, dependence diagram and taxonomy diagram are used in this regard. The quantitative summary of production problems was estimated on the basis of summaries from the following months of 2018. These data show that 63% of non-compliant products are internal deficiencies, i.e. those that arise in technological processes on the production line. 29% of all non-conformities are component errors, and therefore problems arising from the company's suppliers, which are the result of initial control of the supply of production materials. The remaining 7% of non-compliance are products damaged in technological and quality tests.
Qualitative analyzes of errors arising are based on internal incompatibilities, i.e. those that are the result of processes implemented on the production line (Pacana A., Czerwińska K., Siwiec D. 2018.). The results of the risk analysis related to internal incompatibilities based on FMEA analysis are presented. Table 1 summarizes these analyzes.

Tab. 1. The results of the FMEA analysis for production incompatibilities

P	The effects of defects, restriction of functions	Potential incompatibility	Causes of the defect mechanism	NOTE			RPN	Recommended remedies
				Z	W	R		
1	Customer assembly difficult	Cable length defect	Cable out of tolerance - down	8	4	4	128	Training for the fitter
2	Rough cable operation	Damaged guide bushing	Damaged by machine and operator	5	9	3	135	machine review; introduction of manual control
3	Hard work - load	Incompatible armor diameter	Wear of pins - pushers	4	9	3	108	entering the diameter of the pin into the process; introduction of 100% manual control during assembly

4	Machine jams	Optical barrier damage	Pollution - leakage of the optical barrier	2	3	3	18	Barrier repair; order
5	Blocked armor	An obstacle inside the armor	Pin connecting armor spools	6	7	3	126	Adding control
6	Incorrect marking	Setter error	Qualifications	3	7	3	63	Setter training; control 4 times a shift
7	Cable jams	Machine defect	Machine defect	5	7	3	105	Inspection of the machine once a month + first and last item
8	Waste	Setter error while setting the machine	Qualifications	2	6	3	36	Team Leader setter training
9	Calibration	Setter error	Qualifications	3	3	3	27	Setter training
10	Impossible to screw	Component fitting	Screw defect	2	2	3	12	Screw check

Table 1 presents the FMEA analysis for non-compliance in the tendon production. As a result of the analysis, it was found that the greatest threat - the highest LPR value was calculated for damage to the guide bushing (material defect) and defect in the total length of the cable. The length of the cable causes difficulties in the assembly of the cable on car components, which completely eliminates the cable for further assembly despite the correct installation of all its rock elements. Corrective actions were proposed, consisting in additional training in the field of manual control at the workplace, which allow immediate identification of the error and its elimination during the export process.

Matrix analysis was also performed, the input data of FMEA was used to perform it, and so the matrix supplemented the results of FMEA. This analysis has identified process parameter points that contribute the most to non-conformities. Table 2 presents the results of these analyzes.The causes and effects contained in the FMEA analysis were additionally used in the matrix diagram, which showed the most important relationships and what more important - the strength of their joint interaction.

Tab. 2. Matrix diagram of non-compliance analyzes in production

Production process factors	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	**Impact Group**	
Causes of defects											Sum of effects	Number of effect items
Armor length	10	0	0	0	0	0	0	1	1	0	12	3
Machine - defects	5	10	1	10	0	5	0	1	5	5	31	8
Dimensions of components	10	1	5	1	0	0	5	5	5	0	32	7
Pin	5	1	10	1	1	0	0	1	5	0	24	7
Armor inner diameter	5	1	10	0	10	0	1	5	5	0	37	7

Employee Errors		10	10	10	1	0	10	0	5	5	0	50	7
Other component defects		0	5	5	1	5	1	0	1	1	5	24	8
Cause Group	Number of items	6	6	6	5	3	3	2	7	7	2		
	Sum of Causes	45	28	41	14	16	16	6	19	27	10		

The matrix diagram shifted the FMEA results to the non-compliance analysis number P1, i.e. the cutting process. This allowed us to indicate our plans for statistical analyzes developed at the cutting station. The results of this analysis confirmed the large impact of operators on qualitative results in processes, and a training plan for employees and workplace analysis was prepared (Ingaldi M. 2017, Ulewicz, R., 2018).

4. Statistical control of the cutting process

Control of the cutting process includes taking and measuring every hour a sample, which consists of five elements. The presented analyzes relate to 1 business day, and then they were extended to the period of the week and the following week. The rules for sampling and measuring remain unchanged. MATLAB was used to develop the collected results, in which the distribution of numerical data was determined and index values were calculated (Knop, K., 2015). Normal distribution of numerical data over the course of 1 week has been preserved and shows the stabilization of the process. However, the results of the following week do not allow us to conclude about a continuous improvement of the process. Cp indicators improved, however, a clear change in the dominant value and a shift to the lower tolerance point indicate a further problem with the repeatability of results.
Figure 3.4 and 5 present detailed results of statistical analyzes and a picture of the distribution of numerical data for subsequent periods (1 day, 1 week and following week).
The calculated indicators show that the process is potentially qualitatively Cp> 1, for the automotive industry the indicator of 1.66 is also maintained. However, the process is clearly shifted towards lower tolerance, however, this fact does not increase the number of non-compliant products yet.

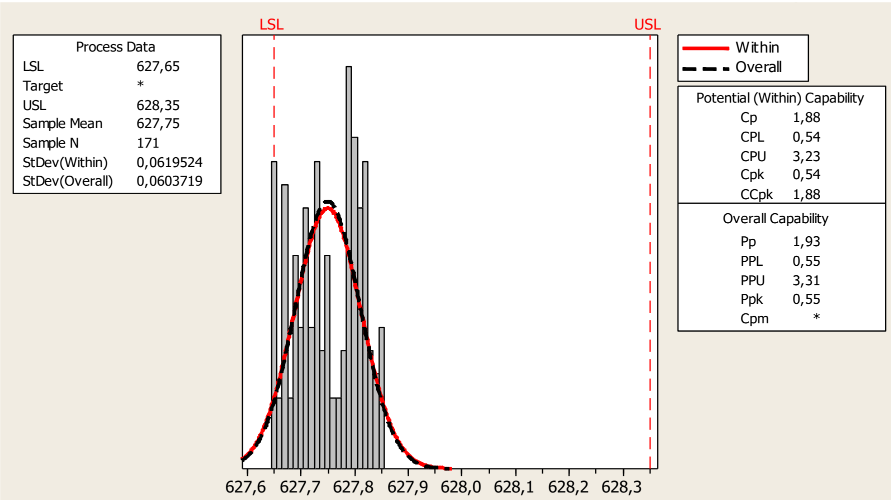

Fig. 3. Statistical analysis results for a period of 1 day

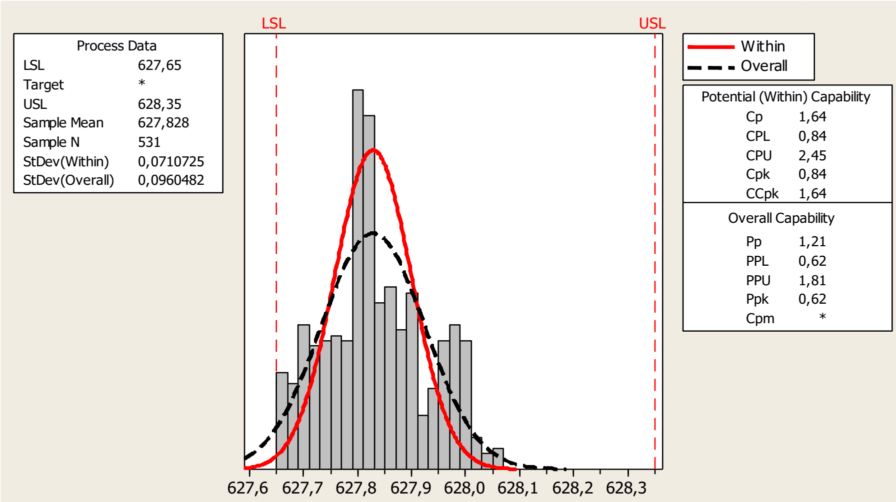

Fig. 4. Statistical analysis results for a period of 1 week

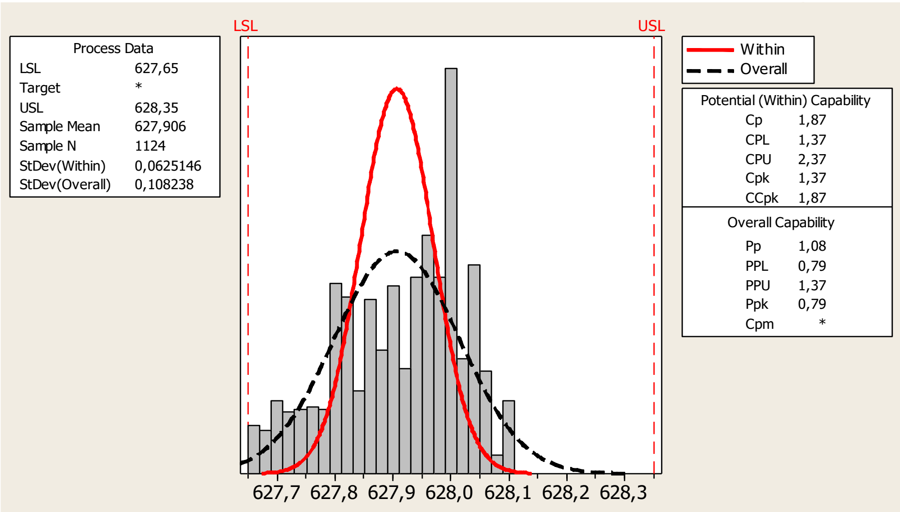

Fig. 5. Statistical analysis results for the 2nd week period

5. CONCLUSION

The presented analyzes contain the basis for actions towards quality assurance. Qualitative analyzes using the Ishikawa diagram and systematics distinguished three groups of incompatibilities: "Internal deficiencies", "Defects in components from suppliers" and "Destructive tests". Due to the quantitative diversity of these groups, an analysis was made of the causes and effects of FMEA errors for production paroblems. Risk analysis has identified two major problems: incompatibility in cut length and internal defect in the sleeve. The internal defect of the sleeve resulted from the material used and the result was the definition of material control guidelines at the process entrance and at work stations. In the further part of the study, quantitative and statistical analyzes were made for inconsistencies in cutting length.
In order to analyze the problem more closely, a matrix diagram was used using preliminary information from the FMEA analysis to create a list of causes and a list of effects. After comparing these two indicators, logical relationships and their dependence strengths were determined. In the "cause group", due to dependence

strength, all elements of the "cause" group were linked to the full list of effects. This allowed the identification of the most important reason, the one most strongly affecting the effects of non-conformity. On this basis, all further analyzes were directed to the length cutting process. In this regard, statistical analysis was used and based on regular measurements, a statistical analysis of process stability was carried out for a period of 1 day, one week and following week.

The qualitative capacity test was conducted for the first day of analyzes, then the data was extended to the whole week and the following week. The results show a high quality ability of the process, but due to the lack of operator experience, setting the process in the lower tolerance limit caused a weak Cpk coefficient. During the 1 week period, the Cp index slightly decreased to 1.67 but at the same time the Cpk index resulted in centering the process. However, the next week of analyzes again indicates that the results are so very shifted to the lower tolerance threshold. As a result, a larger number of employees from all working shifts were directed to the trainings.

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