[1.]Zorana TANASIĆ, [2.]A. JOKIĆ, [1.]Goran JANJIĆ,
[1.]Miljko BOBREK, [3.]Borut KOSEC

BUSINESS PROCESS IMPROVEMENT IN THE AUTOMOTIVE INDUSTRY - QUALITY METHODS AND TOOLS

[1.] Faculty of Mechanical Engineering, University of Banja Luka, Banja Luka, BOSNIA & HERZEGOVINA
[2.] MAHLE Electric Drives Bosnia, Laktaši, BOSNIA & HERZEGOVINA
[3.]Faculty of Natural Sciences and Engineering, University of Ljubljana, Ljubljana, SLOVENIA

Abstract: The development of global economy has forced many companies to introduce and apply modern approaches, models, and initiatives for rapid and long-term business improvement. Achieving business excellence and creating world-class products and services are a basic prerequisite for the survival, growth, and development of the company. It is not the job of just one organizational unit, but the result of synchronized action of all processes in the organization according to clearly defined business goals. This paper includes and elaborates tools and methods of a quality management system in the automotive industry. As statistical process control and the occurrence of non-compliance are indispensable, only organizations that continuously improve the level of product quality and reduce costs survive in the market. Therefore, it is very important to establish an efficient system for managing the quality of processes and products, which means the efficient application of quality tools and the commitment of all employees in the organization.
Keywords: quality standards, automotive industry, quality tools

INTRODUCTION

The automotive industry has made a huge contribution to the overall development of mankind, especially in the area of quality. It was the first to realize that in order to achieve the development and improvement of the competitive position on the market, it is not enough to be good, but it is necessary to be in the group of the best, where those who are equal in terms of technology compete. [1].

In order to assure that the desired quality of the products is achieved, there are several standards that are used in the automotive industry. ISO 9000 defines the quality standards and general rules on quality management for all industries. QMS is based on five pillars of quality, which are [2].

≡ Advanced Product Quality Planning (APQP) and Control Plans
≡ Failure Mode and Effect Analysis (FMEA)
≡ Statistical Process Control (SPC)
≡ Measurement System Analysis (MSA)
≡ Production Part Approval Process (PPAP).

However, ISO/TS 16949 is specific for the automotive industry in terms of quality management systems.

Today, the world's leading companies are increasingly using the term “business excellence“, which claims that providing high quality is a unique and right path to efficiency and effectiveness.

APQP is a structured method for defining and executing the steps necessary to ensure that the product meets the requirements of the customer /consumer. APQP is a team approach required of all systems, subsystems, production processes, and suppliers. This method was first applied by Ford, to be later integrated as a major element of ISO / TS 16949. Compared to earlier systems, the progressive quality plan covers several influencing factors, systematizes them and prescribes clear rules.

The goal of the quality system according to ISO / TS 16949 is the development of a quality management system that provides continuous improvement, failure prevention, and reduction of variations and defects in the supply chain. It is applied in the design (development), production, assembly, and servicing of products in the automotive industry and represents the harmonization of the requirements of the European (German, French, and Italian), American (GM, Ford, and Dodge / Chrysler) and Japanese automotive industries [2, 3].

Figure 1 shows the historical development of the quality management system (QMS) standard from 1970, until the establishment of the ISO / TS 16949: 2002 standard and its revision in 2009.

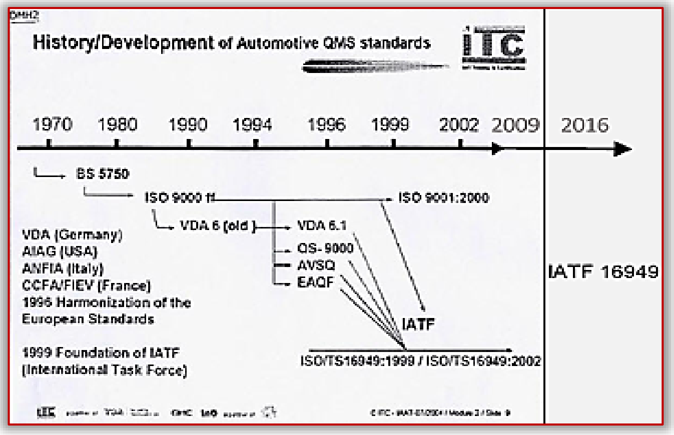

Figure 1. Development of standards for the quality management system in the automotive industry

From October 2016, ISO / TS 16949 became IATF 16949, based on the ISO 9000 standard. Nevertheless, IATF declares in the History chapter of IATF 16949:2016 that „The IATF maintains strong cooperation with ISO by continuing liaison committee status ensuring continued alignment with

ISO 9001" (IATF, 2016). IATF 16949:2016 is linked with ISO 9001:2015, and cannot be considered a standalone QMS standard. It is a supplement to ISO 9001:2015 and must be used in conjunction with [3].

METHODS AND TOOLS OF THE QUALITY SYSTEM

Tools for improving quality in the automotive industry are known as: concepts, techniques, methods, studies, tools, or, more generally, all efforts aimed at improving quality. Quality policy covers the basic directions and goals of the organization in terms of quality, so it is one of the elements of the general policy of the company and must be in accordance with the strategy, goals, and mission of the organization. Also, the full effect of the application of quality tools (the tools of the quality management system), requires the correct choice of tools and their mutual coordination.

This paper presents only some of the quality tools used in the observed company, namely:

1. PPAP analysis,
2. Process flow chart,
3. FMEA analysis,
4. Control plan, and
5. MSA/SPC analysis.

— PPAP and MSA/SPC analysis

PPAP in the automotive industry represents a process that is required to ensure mutual trust between the customer and the supplier. The buyer / customer is the one who sets out his requirements, and the supplier needs to find the most favourable and easiest way to meet the requirements set by the customer.

Every supplier aims to conquer new markets and make a profit in the most competitive way possible. Therefore, the proper process of approving the first samples is paramount for ensuring deliveries for serial production with risks, in terms of quality, minimized, but also ensuring the delivery of the required quantity of products.

The customer submits to the supplier the technical documentation of the requested product / part, with defined dimensions and permitted deviations. The key characteristics and potential places (positions) where the risks of failure may occur are the positions that are processed in MSA/SPC analysis. According to the customer's requirements, the supplier must submit the first samples, DFMEA analysis, flow chart as well as control plans with MSA / SPC analysis. PPAP ensures that the supplier can meet the customer's requirements in terms of production and quality, engineering design as well as the requirements and specifications defined in the technical documentation. Also, the analysis shows that the selected technological process of production can produce a part that complies with all the set requirements. Through PPAP analysis the customer requires a detailed process of analysis of his requirements and needs from the supplier. This analysis involves making the first samples and sending them to the customer for approval.

The PPAP analysis process is quite complex and long lasting, but, as such, it defined requirements that must be provided in order to confirm that the production process will produce a quality product. The elements that are required depend exclusively on the customer, which is most often defined in the offer for the production of a certain product [4].

The PPAP process is detailed and time consuming, but, as such, it provides customers with adequate information and confirmation that all processes from design to production and control will be inspected in detail and, thus, ensure that only high quality products will always be delivered.

— FMEA analysis

The FMEA methodology was developed to systematically monitor and analyze process failures. This method belongs to the methodology of building business processes, and was developed in the 1950s. FMEA is one of the most reliable methodologies for monitoring and analyzing failures in management systems and it includes many factors to identify failures and their causes.

Today, many methodologies are used in business process management and construction systems, for example: IDEFO (International Definition for Function Modelling), SIPOC (Supplier Input Process Output Customer), UML (Unified Modelling Language) and others. All of the above methodologies are useful for a quality management system. The FMEA was first used in the U.S. military industry and at the NASA. Due to good results it has shown, it has started to be applied in other areas of industry as well.

— The Control plan

The control plan defines the method of assessing functional characteristics throughout the entire process of manufacturing semi-finished products and products, in order to meet the specific requirements of the process.

The process of making a control plan implies a detailed analysis of the process and place of occurrence of risks that affect the quality of products through the definition of control characteristics (control-points). Defining control points implies:

≡ Determining the type of quality characteristics (numerical or attributive), the form and specifications of failures, the availability of means and methods for measurement as well as the importance of quality characteristics,
≡ Defining the scope and frequency of quality control,
≡ Determining the holder of control (worker, process controller, or leader).

The results of the measurements are entered in the form "Taking over the process" on the basis of which it is possible to identify the deviation of the controlled measure from the measure prescribed by the control plan.

APPLICATION OF QUALITY METHODS AND TOOLS – a case study

The company was founded in 1994, and its main activity is the production of stator windings for motors and starters for customers of the automotive industry, Figure 2. The production line combines winding elements with soldering, which are impregnated with electrical insulating varnish immersion process. The installation of the protective layer elements takes place on an automatic line with dedicated devices.

Figure 2. The finished product

In accordance with the procedures of the company that is under research, specific data (numerical values) will not be visible in this paper because they are secret, but they can always be available and presented to a potential customer.

— PPAP – customer requirements

This paper presents a part of the PPAP analysis that is performed in the observed company, as a process of approving the first parts for a specific project of production and assembly of the final product.

In order to make the first parts and send them for approval, all the requirements stated in the technical documentation must first be realized. The first step in accepting and developing the first PPAP samples is to form a team, which will follow and support the whole process of making the first parts and develop an APQP plan, based on their knowledge and skills. This plan facilitates communication between all participants in the process and ensures that all required steps are implemented on time. The benefits expected from the application of the APQP are:

≡ directing resources to achieve customer satisfaction,
≡ enabling early identification of necessary changes,
≡ avoiding delayed changes,
≡ providing a quality product, on time, with minimal costs [3].

As shown in Figure 3, the customer submits a request stating all the necessary analysis, or specific requirements, for the first product samples to be approved, which are:

≡ three reference samples,
≡ the dimensions of the samples must be within the tolerances shown in the drawing,
≡ performing analysis of materials that are part of the stator,
≡ FMEA process analysis,
≡ a process flow diagram, and
≡ a control plan.

Also, the request provides key measures:

≡ inner diameter (during further installation, this dimension is one of the key functional characteristics),
≡ breakdown (100% control, value ›2s/ 750V),
≡ water resistance (air release test), etc.

Figure 4. shows the measurement report. The analysis and production of the first samples is given on the example of stator assembly.

PPAP – REQUIREMENTS PSW	Številka naročila: 22/20 Datum naročila:			
DOBAVITELJ				
Naziv:	Kontaktna			
Naslov:	Tel.: e-mail: borisa.radovic@ba.mahle.com			
PROIZVOD 16.286.995.599				
Naziv proizv. **stator z nosilcem krtačk**		Mahle	Dobavitelj	
Vzrok vzorčenja:	Ident.št. proizvoda			
☐ Nov dobavitelj	Št.obvestila/datum			
☐ Nov proizvod	Standard			
☐ Sprememba konstrukcije	Kataloška št.			
☐ Sprememba materiala	Ostale zahteve Mahle:			
☐ Sprememba tehnologije				
☑ Sprememba lokacije proizvodnje				
☐ Daljša prekinitev proizvodnje				
☐ Zamenjava nabavnega vira ali poddobavitelja				
☑ Ostalo: Projekt Scania	Odgovorni SQE: Andrej Jerkič			

PPAP ZAHTEVE	Pojasnila	Zahtevek	Prejeto	Opombe
1. Vzorci	Zahtevana količina: 3	☑	☐	
2. Risba	☑ Mahle ☐ Dobaviteljeva	☑	☐	
3. Meritve dimenzij		☑	☐	
4. Analize materialov	☑ Kem. ☑ Meh. ☐ Metal. ☐ Elek.	☑	☐	
5. Rezultati preizkusov		☐	☐	
6. FMEA konstrukcije		☐	☐	
7. FMEA procesa		☑	☐	
8. Diagram poteka proiz.procesa		☑	☐	
9. Analize sposobnosti procesa	Ppk ≥ 1,67 Cpk ≥ 1,67	☐	☐	
10. Analize sposobnosti merilnega sistema MSA		☐	☐	
11. Načrt nadzora kakovosti	Control plan	☑	☐	
12. Podatki o laboratorijih		☐	☐	
13. Poročilo o zunanjem izgledu		☑	☐	
14. Zapisi o skladnosti s posebnimi kupčevimi zahtevami		☐	☐	
15. Izjava o skladnosti materialov z okoljskimi zahtevami		☑	☐	
16. IMDS		☑	☐	
17. Drugo:		☐	☐	

POTRDITEV PREDLOŽITVE			Teža (kg):
Odgovorna oseba (tiskano): Njegoslav Đokić, Aleksandra Jokić	Podpis	Naziv: e-mail: njegoslav.dokic@ba.mahle.com Tel.: 00387 51 535 480	Datum predložitve vzorcev: 10/7/2020
Opombe: Prvi uzorci			

ODLOČITEV MAHLE:		Opombe:
☐ **ODOBRENO** ☐ **ZAČASNO ODOBRENO** ☐ **ZAVRNJENO**		
Odgovorna oseba: Podpis:	Datum:	

Figure 3. PPAP requirements

PPAP - MEASUREMENT RESULTS		Številka naročila: 22/20 Datum naročila:			
Dobavitelj:		Naziv proizvoda: **stator z nosilcem krtačk** Ident.št. Mahle:		List 1 od 1	
REZULTATI MERITEV					
Poz.	Predpisana vrednost	Izmerjena vrednost		Nesprejemljivo	Sprejemljivo
		DOBAVITELJ	MAHLE EDS		
1.	MIN Ø				
2.	MIN 2 x MIN				
3.	MIN				
4.	MIN				
6.	MIN				
7.	PRIVIJALNI MOMENT ZA POZ 4. JE	-			

Figure 4. A measurement report

— MSA/SPC analysis

Since most customers have certain dimensions on their products that are defined as key process characteristics (KPC), for such dimensions / measures during the production process, continuous statistical monitoring is performed.

Figure 5 shows the samples on which the measurement was performed. Measurement results can be presented in two forms, a process under statistical control and a process not under statistical control. A total of fifty samples were tested, of which forty-nine are within the prescribed limits, while sample number twelve goes beyond the set limits, which means that the samples meet the set tolerance limits. It is crucial that the process is under statistical control, if 2/3 of the values of the controlled parameters are within the central third of the control chart, in a width ± σ around the central line. The values of Cg and Cgk are indicators of the process ability, and as Cg = 2.01 and is in the range (1.62 ‹2.01 ‹2.41), the results show that the possibility of scrap is reduced.

Figure 5. MSA analysis for the product (winding)

This ensures that the most important measures are under constant control and that potential errors are detected as soon as possible, which allows us to stabilize the process and reduce production costs.

Figure 6 shows the SPC analysis of the windings and based on a hundred values tested, they were all in the prescribed tolerance field. Process capability index Cp = 3.45 as well as long-term study of a stable process Cpk = 1.56.

Figure 6 shows us that the process is stable, as shown in the diagram, both parameters are green and are within the allowable limits (Cp → 2.95 ‹3.42 ‹3.90); (Cpk → 1.33 ‹1.56 ‹1.79).

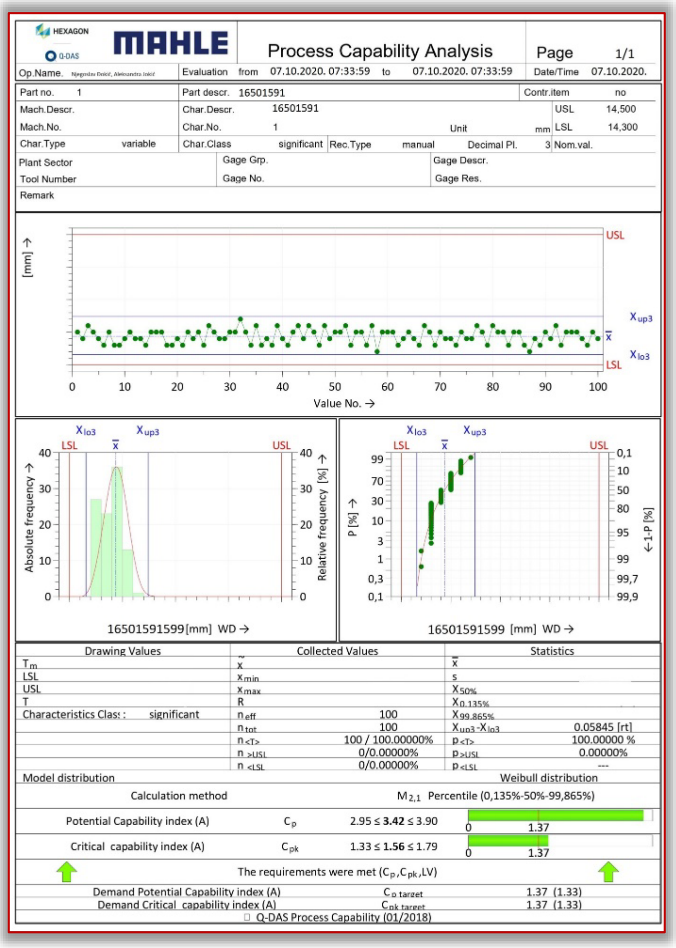

Figure 6. Statistical monitoring of critical measures (winding)

— **The control plan**

To ensure good traceability, the most important thing is to create a good control plan. At the workplace, there are forms called "Process takeover", which define the measurements to be performed, and which are prescribed by control plans. The control plan clearly follows the technological process of product development and provides support in ensuring the control of measures to comply with the prescribed tolerances, Figure 7.

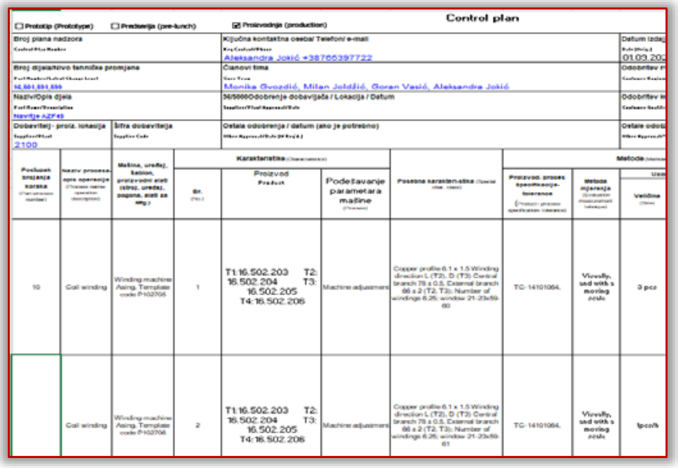

Figure 7. The control plan – extract

In case of deviations, it is prescribed how to act in order to avoid poor product quality. It is very important to distinguish and abide by the methods of control that are also prescribed, and relate to:

- **PP (taking over the process)** - performed by the person responsible for adjusting the machine, which confirms that the first three pieces are good, both as visually and in terms of metrology, and meet the requirements prescribed by the control plan, after which production can begin.
- **NP (process control)** – performed by a line or process controller, at the beginning of the process and during the production process.
- **AK (auto-control)** – performed by a worker at his workplace, who has a defined procedure when he should perform the measurement, while confirming that the production is going according to plan, i.e. there are no deviations.

— **FMEA analysis**

As shown in the form in Figure 8, the parts supplier should perform a failure risk analysis based on the flowchart and control plan. It is necessary to have a systematic approach to operations and to perform an analysis of the entire production process, in order to reduce the risk of failures and minimize them.

Figure 8 shows part of the conducted FMEA analysis. Based on the defined functional requirement of the process, the team determines the potential forms of failure and the potential consequences of the fault failure. Evaluation performed on the basis of a defined procedure for performing FMEA analysis (RPN = SxOxD).

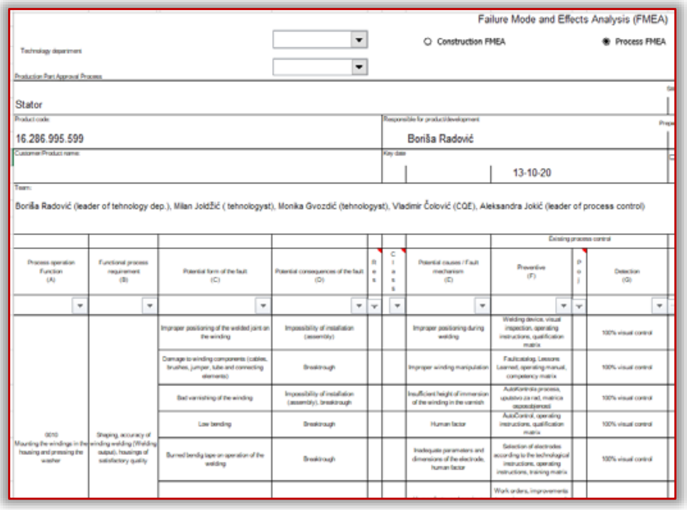

Figure 8. FMEA analysis – extract

CONCLUSION

In today's turbulent business environment, organizations can successfully achieve and direct defined goals only by establishing the right strategies and policies, finding the right methods and their implementation, and constantly monitoring the effects achieved.

In the automotive industry, in addition to multiple requirements for meeting standards, both basic quality standards such as ISO standards and required standards specific to the automotive industry IATF 16949, VDA 6.3, AIAG quality tools, CQI standards still need to meet customer specific requirements. Very often, IATF 16949 is called the customer standard, since the specific requirements of the customer have priority over the requirements of the standard itself. The links between the requirements of the standard and the customer specific requirements must also be harmonized with the existing technologies of manufacturing individual components, whereby new technologies are often approached and applied in order to achieve competitiveness in the market. New technologies, new suppliers, and projects represent a huge set of risks for the successful placement of products on the market while achieving appropriate competitiveness.

The revision of the standard, ISO / TS 16949: 2009 and the transition to IATF 16949: 2016 aims to develop a quality management system that provides continuous improvement highlighting the lack of prevention and reduction of waste and variation in the supply chain. The incorporation of ISO 9001: 2015 and IATF 16949 requirements includes specific requirements: employee competence (awareness and training), design, development, production and provision of services, control and monitoring of measuring devices and measurements, analysis, and improvement. All of this aims to get products and services that satisfy customers.

Quality control is performed by process controllers at all stages of production. In order to make a product of satisfactory quality, it is important that the production process is stable.

Constant investment in new technologies, modernization of production, education, and training of employees at all levels improve the quality system in the company

Continuous improvement of the quality of the production process, based on increasing the productivity and knowledge of each employee in the organization, is crucial for the realization of the mentioned preconditions. Competition and the globalization of all flows are forcing companies to find increasingly successful management approaches using quality management tools in all business processes. The main goal of every company is to strive to always deliver improved value to the customer and user, as a result of improving the overall performance of the business system as well as capabilities and success in the market.

Note:
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