sciendo

PRODUCTION ENGINEERING ARCHIVES 18 (2017) 35-41

PRODUCTION ENGINEERING ARCHIVES

ISSN 2353-5156 (print)
ISSN2353-7779 (online)

Exist since 4th quarter 2013
Available online at www.qpij.pl/production-engineering-archives

The application of the FMEA method in the selected production process of a company

Piotr Barosz[1], Marta Dudek-Burlikowska[2], Marek Roszak[2]

[1] System Barosz Gwimet Sp. z o.o., 43-267 Suszec, Poland, piotr.barosz@barosz.pl
[2] Institute of Engineering Materials and Biomaterials, Silesian University of Technology, Konarskiego 18A Street, 44-100 Gliwice, Poland

Article history
Received 25.02.2018
Accepted 16.04.2018
Available online 27.04.2018

Keywords
quality management
production process
quality life cycle
FMEA method
quality improvement

Abstract

The aim of this article is to show the use of the analysis of the failure causes and effects as a prevention tool in controlling the quality of a given production process in the company. The scope of the work covers an analysis of a selected process, definition of inconsistencies present in this process, and then the FMEA analysis. In the production company one should implement thinking and actions based on the so-called 'quality loop' – it is an interdependence model of the undertaken actions which affect the quality shaping. It is carried out from the possibility for identifying a customer's requirements through a project, production process, up to the assessment of effective capability for meeting the defined requirements.

The application of such an approach enables to take the actions improving the operation of quality management in a systemic way.

DOI: 10.30657/pea.2018.18.06 JEL: L23, M11

1. Introduction

Currently, every organisation focused on success treats the shaping of quality as an element of the strategy of production company management. Quality management as well as monitoring, control and quality assurance in today's conditions of economic change is one of the most important arguments in market competition for production companies.

Innovativeness, changeability, development of information technology, prevention of defects and errors in the processes, optimisation of processes affects the increasingly common awareness that the quality of the final product is not the result of the production process, but the result of many processes and measures related to the creation and possession of the product.

Therefore, one of the key strategic objectives of the company is to meet the requirements and expectations of customers by offering the long-lasting products and the quality defined by the company.

In order to achieve such an objective, it is necessary for companies to implement quality assessment methods, including in particular the FMEA methods. The method -Failure Mode and Effects Analysis allows to examine the quality level of manufactured products, capture weak points – failures and deficiencies, and then to introduce corrective and improvement measures. It also ensures continuous monitoring of processes, their optimisation and, thus, the reduction of costs as well as achieving a high level of quality through the prevention of failures. The article presents a general approach to the FMEA methodology with an example of the application of the method in the production process of a production company.

2. FMEA method – assumptions

Currently, there is a prevailing belief that it is necessary to constantly undertake measures aimed at preventing the causes of failures. The strategy of preventing failures completely replaced tactics based only on failure detection. At the same time, there is a belief that planning each measure gives a greater impact on shaping the quality (DUDEK-BURLIKOWSKA M. 2007, GÓRNY A. 2014).

The FMEA is a method that companies use to prevent and eliminate failures that may occur in the manufacturing process. It is the best analytical technique allowing to establish relationships between the causes and effects of failures, as well as to indicate ways to search, solve and make the best decisions regarding the application of appropriate measures (DUDEK-BURLIKOWSKA M. 2010, GÓRNY A. 2014, ROSZA M. 2013). One of the basic assumptions of the FMEA method is the statement that over 75% of all errors are the result from of irregularities that still occur during the preparation phase

of a given production. Due to the low level of work progress, the level of their detection is relatively small (GÓRNY A. 2014 IWANIEC K. 2010, ŁAŃCUCKI J. 1995). In addition, it is assumes that about 80% of all errors are still found at the stage of production and its control as well as during operation (GÓRNY A. 2014). It means that due to the FMEA method it is possible to prevent and limit the effects of failures that appear in a particular construction and in manufacturing processes (DUDEK-BURLIKOWSKA M. 2011, GÓRNY A. 2014, IWANIEC K. 2010).

In the first stage of analysis of the FMEA method, a team of people should be appointed that will monitor a defined product, process or design in detail in order to identify all the places and areas where potential errors and problems may arise, and then they will determine measures to eliminate these errors (GÓRNYA. 2014, ROSZAK M. 2013). The stages of procedure in the FMEA method include (DUDEK-BURLIKOWSKA M. 2011, ŁAŃCUCKI J. 1995, ROSZAK M. 2013): precise determination of all the elements of a product and the stages of the process; the indication of possible errors; determining the outcomes (effects) of these errors and the causes of possible errors; estimating the probability and determining on a scale of 1-10: Severity (*S*), Occurrence (*O*), Detection (*D*) and calculating The Risk Priority Number ($R = S \times O \times D$). Subsequently, comparing it with the accepted limit value, as well as the identification of measures that will eliminate the detected errors and improve the process. In the final phase, a repeated analysis is carried out to check whether the measures taken have yielded effects (HAMROL A. 2005, WIERCIAKN J. 2012, KOLMAN R. 1996, KARASZEWSKI R. 2006).

To properly carry out the FMEA analysis, a special form - FMEA worksheet. Its top part serves entering data on the analysed product/process, the name of a person in charge, the composition of the group working on the procedure and the date of its commencement and completion (HAMROL A. 2005).

Below, in the next columns there is information about the item under consideration and its function, potential failure, potential consequences of failure, hypothetical significance of failure, the anticipated causes of failure, the probability of error occurrence, design verification methods, failure delectability, the risk level factor and the recommended corrective measures (DUDEK-BURLIKOWSKA M. 2007, GÓRNY A. 2014, HAMROL A. 2005).

In a modern company, the quality plays a very important role. Every effort is made to ensure that the products manufactured there are the highest quality. Various quality tools help in improving the quality of production, among which an important role is played by the failure mode and effects analysis known as the FMEA analysis (GÓRNY A. 2014, DUDEK-BURLIKOWSKA M. 2011, IWANIEC K. 2010, ŁAŃCUCKI J. 1995, HAMROL A. 2005).

3. Product life cycle – the quality loop

The quality loop (Fig. 1) is a model of interdependence of measures that have an impact on shaping the quality. It takes place at various stages: from the ability to identify key needs to assessing the ability to effectively satisfy them (DUDEK-BURLIKOWSKA M. 2007, WIERCIAK J. 2012, KOLMAN R. 1996, KARASZEWSKI R. 2006). It allows to undertake variety of measures improving the functioning of quality management and the system being implemented. At the same time, it should be emphasised that all the actions related to quality should be comprehensive. They should include all organisational processes throughout the product life cycle (DUDEK-BURLIKOWSKA M. 2007, GÓRNY A. 2014).

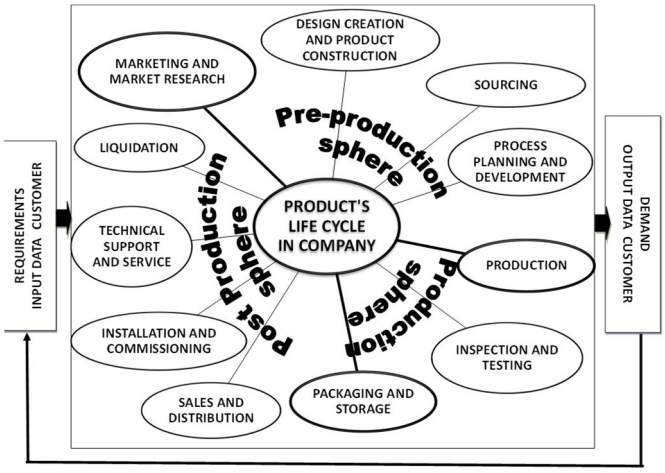

Fig. 1. Product life cycle taking into account customer requirements.
Source: Own study based on: DUDEK-BURLIKOWSKA M. 2007, ŁAŃCUCKI J. 1995, HAMROL A. 2005, WIERCIAK J. 2012, KOLMAN R. 1996, KARASZEWSKI R. 2006

The product life cycle, in technical terms, can be divided into 3 phases shown in Fig. 1 (DUDEK-BURLIKOWSKA M. 2007, GÓRNY A. 2014, HAMROLA. 2005, KOLMAN R. 1996):

- **Planning (pre-production) phase** – the initial period in which one should focus on the purpose of the item, meeting the needs of consumers, rational design, effective planning and use of materials. At this stage, it is necessary to conduct marketing research and initial interest of recipients in the product or service. The last element is such preparation of production, so that it can later work in an automatic manner and will be able to adapt to the market situation.
- **Implementation (production) phase** – covers the most extensive time range, which applies to many aspects related to the product life. In the implementation phase, the following can be distinguished: purchases (of products or services by customers), production or provision of services, inspection and verification, packaging and storage, sales and distribution, installation and commissioning. A large number of factors forming this phase makes it the most responsible

- part of the product's entire life. Even a correctly planned product or service will not bring the intended profits if distri
- bution channels, warehouses, quality control or sales forms fail. In this phase, people assigned to particular tasks must have extensive experience, knowledge of the market, as well as knowledge of sales and distribution processes. Nowadays, there is no room for errors or any stagnation that the competition may take advantage of.
- **Usability (post-production) phase** – the last part of a product's life cycle, which to the least extent depends on the manufacturer of the product or service. During this period, customer satisfaction should be supported and confidence in the future should be built by providing technical support and service as well as contacts with a customer.

In the literature, the interpretation of the product life cycle is based on the quality criterion (Fig. 2) defined as follows (DUDEK-BURLIKOWSKA M. 2007, HAMROL A. 2005; IWANIEC K. 2010, KANIA A. ET ALL 2014):

- The design quality of the product is the ability of a design, material, formula to meet the customer's expectations and all those who have contact with it during its life cycle. The design quality of processes is determined by the degree to which the implementation process allows to manufacture the goods that are consistent with the design quality of the product.
- The quality of workmanship is responsible for creating a product whose features will be perfectly compatible or similar to the product and process included in the design.
- The operational and functional quality is closely related to the level of consumer satisfaction with the product held. Customer satisfaction should result from a high degree of meeting the needs specified in the form of requirements when placing an order.
- The service quality can be defined by the simplicity of maintaining the full usability by the product. One can talk about the high service quality when maintaining the usability is not a problem for either the customer or the service technician.

The application of the method not only allows to identify significant failures, but also contributes to making the right decisions on how to eliminate the causes of failures. The correct application of the method makes it possible to improve the efficiency of measures in terms of quality, to more efficiently meet customer expectations, reduce the costs with a planned high level of quality, increase the product reliability and increase customer satisfaction (DUDEK-BURLIKOWSKA M. 2007, HAMROL A. 2005, KARASZEWSKI R. 2006). In addition to measurable aspects, the use of the FMEA analysis may improve the integration between employees and the flow of information, which results in better outcomes in team problem-solving (KARASZEWSKI R. 2006).

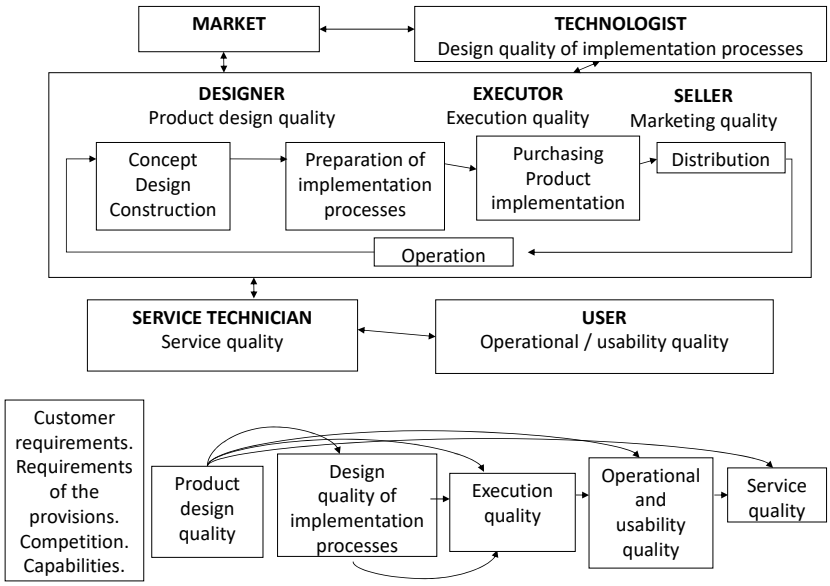

Fig. 2. Quality in the product life cycle – the quality chain.

Source: Own study based on: DUDEK-BURLIKOWSKA M. 2007, HAMROL A. 2005, KANIA A. ET AL. 2014.

4. Stages of implementation of the FMEA analysis in a selected company

In the selected company of the automotive sector, an appropriate division of responsibilities was made in the preparation of the implementation process of the entire FMEA method. It means that the whole team is responsible for the entire operation, along with other people holding key positions in the organisation, including a technical director – responsible for the continuous development and maintenance of the PFMEA; a team leader – main technologist – who defines the stages of the entire production process and prepares tasks for the analysis and implementation of the method. He/She must also define the key assumptions of the design and the objectives to be achieved. At the same time, he/she is involved in coordinating the work of the team, overseeing the work being carried out, as well as preparing and proper storage of all documents related to the FMEA analysis. The last and most important link is the FMEA team. Its task is to collect data allowing to carry out the comprehensive FMEA analysis, as well as to participate in its implementation.

He/She is also obliged to regularly (throughout the entire process) carry out scheduled inspections (at least every four months – regardless of unplanned inspections carried out, the purpose of which is to eliminate emerging failures). Figure 3 shows the course of the entire process that was implemented in the selected company. By analysing Figure 3, the process of implementing the FMEA method, even though it is complex, proceeds in an extremely orderly manner. In order for it to be effective, each of the measures should be carried out in

the right order. They cannot be implemented in a chaotic manner or according to criteria chosen by persons in charge. If the established order is not follow, it may turn out that the process does not function as expected and, thus, it will not produce concrete results.

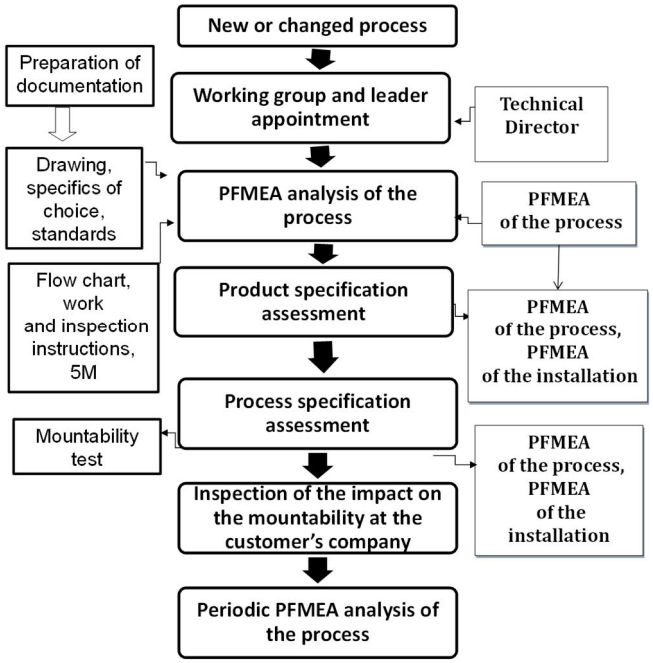

Fig. 3. Diagram of the implementation of the FMEA methodology in the company.

Source: Own study based on materials provided by the company

When implementing the FMEA method, it should also be remembered to complete the previous stage before undertaking the next one. Usually it involves the preparation of relevant documents, drawing conclusions or presenting key assumptions related to the ongoing work. At each stage of implementation of the FMEA method, it is also underlined that it cannot be expected to bring specific solutions. It should be emphasised that this method does not help in the development of corrective measures and it does not provide tools for making modifications. It allows only to locate sources of emerging failures or potential problems and raising awareness of their occurrence. Therefore, before its final introduction, it is necessary to consider what are expectations with regard to it, what results we expect and whether employees who will be responsible for its implementation will be able to find the right and most effective solutions for the problems found.

5. The application of the FMEA in the selected production process

The selected company for research is an organisation focused on quality and customer. It specialises in the design and implementation of complex and comprehensive solutions related to CNC machining, which is intended for the broadly understood automotive sector.

In accordance with the assumptions of continuous quality improvement, the FMEA method was used in the production process of a fully automated and robotised production line for machining of motor heads. The assumption of the organisation is the fact that the parts and accessories being prepared must meet certain quality standards, have specific properties and, above all, they should be free of any defects or technical problems. It may turn out that one incorrectly prepared part will affect entirely the production of other elements. In extreme cases, it may even lead to the withdrawal or destruction of the entire production, because the failure will endanger the safety of the vehicle or will make the vehicle inconsistent with the adopted legal regulations.

All this means that the company's processes must be regularly verified in terms of effective functioning and in accordance with the adopted criteria. In addition, it is necessary to take immediate corrective measures that will allow to correct problems or failures early enough. This is especially important if one considers that the organisation carries out its measures both on the domestic and foreign markets. On the one hand, it gives it the opportunity to cooperate with a wide group of customers, which also affects the quality standards used and services provided. On the other hand, however, it imposes specific working conditions. The activities undertaken by the entity must comply not only with national standards, but also with international standards. The activity conducted by the company strives to meet the highest quality standards and services provided in order to provide its customers with a high level of satisfaction with the offered products.

It is worth emphasising that most of the processes that have been implemented in the company operate on the basis of the same mechanism. Owning to this, more certainty is gained that the final product for the customer will meet all their requirements. At the same time, it will be free from any failures and problems, and hence it will not cause any problems in terms of its operation. Due to the large range of offered products, the processes are linked to each stage of their creation. They involve the preparation of appropriate projects, planning each of the measures as well as carrying out individual works leading to the creation of a specific solution.

Each of the elements of the process described above creates a coherent whole, which means that an employee responsible for the first process must ensure its correctness. If there are any errors or omissions, it may turn out that all measures and further processes will be carried out incorrectly. In turn, this can lead to a situation that, despite the control and verification of the correctness of their scope and execution, a defective product or one that does not meet all of its properties can be packed. Therefore, each time before the selected stage is completed, it should be carefully verified that all measures taken have been carried out in accordance with the applicable standards and whether any failures have been committed. Due to the fact that in the course of one process several (or a dozen or so) employees are employed, their duties include verifying the correctness of the previously completed process and identifying any possible omissions

or errors. Mutual control and verification of subsequent stages of the production process will allow to eliminate them.

The developed diagrams (Figure 4) allow to characterise the specificity of the entire company's functioning and mechanisms of its operation in detail. The presented diagram also shows the level of complexity of individual measures. In most cases, this is a consequence of the specificity of parts produced and the operation of the production mechanism itself.

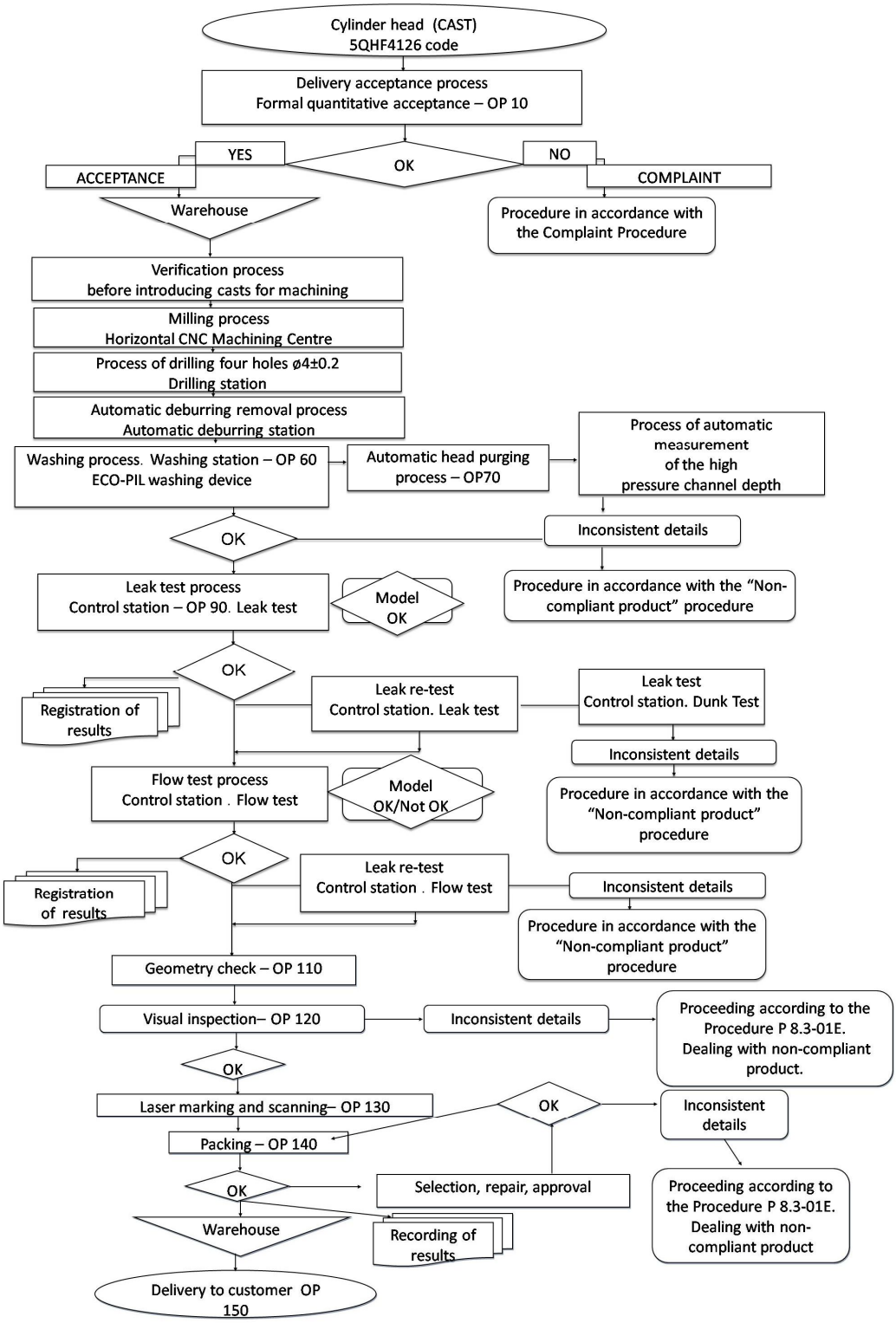

Fig. 4. Diagram of the production process of the motor head.
Source: (Own study based on materials provided by the company)

These are elements that require precise and careful execution. In this case, even the smallest error can contribute to the improper functioning of the entire device or its greater fault rate. Therefore, the entire production process is designed in such a way as to monitor, as closely as possible, every stage of its operations and to regularly control the work progress. All this makes the whole mechanism extremely complex and multi-faceted.

The FMEA analysis was based on data contained in the Pareto-Lorentz analysis, which allowed to identify the critical stages of the production process of the motor head, including 4 failures constituting 80% of omissions. They include: incompatible hole diameter (too small), dirt, contamination, chips, greasiness, exceeding the max. leak limit, the lack of detection of oxides at the visual inspection station. The process was characterised in such a way as to take into account each of its operations. Each employee is responsible for the correctness of the measures carried out. The control points in the process are used to verify whether the measures have been carried out in accordance with the applicable standards and whether any failures occurred resulting in the product being incompatible.

An analysis was carried out using the FMEA method for all identified non-compliances, potential causes for the occurrence of errors, the probability of their occurrence, the significance for the customer and the probability of detection were defined. It should be emphasised that the FMEA is a document that is constantly transformed, modified and supplemented.

This is done every time a process or product is changed or updated. This is also possible when regular and periodic inspections are carried out. In this case, particular attention is paid to the assessment of the significance of defects.

Tables 1 shows the results of the FMEA analysis and assessment carried out, including the proposed corrective measures.

It is recommended that the FMEA analysis be carried out at regular intervals. In this way, it is possible to verify its correctness and the level of validity, and at the same time, some modifications imposed by changes taking place in individual processes may be introduced. In addition, this analysis should be carried out each time after detecting problems and introducing specific remedial measures.

In this way, it will be possible to verify early enough whether the implemented solutions bring the expected effect and whether they will improve the overall quality of the product being created. In addition, they will also allow to verify whether similar problems may appear again (even if the necessary changes have been made). As a result, it is possible to verify if the changes are long-lasting enough to bring the expected benefits or if it is necessary to implement more radical and advanced measures. Each measure presented in the diagram should be verified and the scope of activities carried out should be defined. On the basis of such measures, it is possible to determine which elements may cause problems or may generate errors. It is important to specify the greatest number of potential failures or problems at any stage of the process, including defining the specific effects of their occurrence and consequences. In this way, it will be possible to determine, during the ongoing production, whether there is a specific failure or problem in a given case.

Table 1. FMEA worksheet.

FMEA of Process - Analysis of Potential Failures and their Effects														**FMEA No.:**				
Process	***Element:***						***Person responsible for the project:***							***Developed by:***				
New	***Name:***						***Made by:***							***Modification:***				
							Current process							**Result of actions**				
Process stage / / Requirements	**Potential type of failure**	**Potential effect of failure**	**Significance**	**Classification D, C, H, +, -**	**Limit**	**Potential cause of failure**	**Preventive control**	**Occurrence**	**Detecting control**	**Detectability**	**LPR**	**Recommended actions**	**Person responsible and deadline**	**Actions taken & date**	**Significance**	**Probability**	**Detectability**	**LPR**
Operation - OP. 30																		
Machining (milling, drilling, threading)	Inconsistent diameter of the opening (too small)	Improper dimensions of parts (too big allowance for finish machining)	**7**	H	100	Worn drill (Dullness of cutting tool)	Tool replacement according to the timetable established by the producer	**7**	Measurement with WMP (coordinate measuring machine)	**6**	**294**	Replacement of cutting plates every 1000 pcs.	Shift manager	Replacement of cutting plates every 1,000 pcs.	**4**	**7**	**3**	**84**
Operation - OP. 60																		
Washing (details of proper cleanness)	Dirt, contamination, chips, grease	Risk of improper engine work and operation	**8**	H	100	Improper operation of washer (damaged pouring system or clogged rinsing nozzles)	Visual inspection	**4**	Laboratory verification of the impurity significance	**4**	**128**	Increase the frequency for bath replacement from 1/per two weeks to 1/week	Junior Engineer before start-up of production	Increased frequency for bath replacement from 1/per two weeks to 1/week	**2**	**8**	**3**	**48**

Source: Own study based on materials provided by the company

The form also contains a set of measures that can be undertaken to eliminate each of the problems. It should be emphasised that in any case more than one solution should be proposed. In the event of a given failure, any changes should be introduced in order from the cheapest available solution. In this way, it will be possible to avoid generating additional costs.

However, the quantitative analysis of failures used here is of particular importance in the FMEA method. Thanks to this, it is possible to estimate risk factors of the occurrence of a specific problem. By using the appropriate integers between 1 and 10 it is possible to verify with what probability failure will occur and to what extent it will hinder the correct operation of the product or what kind of problems may occur and to what extent they will be harmful to the product in question. It seems proper to use this method at the initial stages of production – the preparatory stage involving acquiring appropriate raw materials. These are not complicated processes that involve carrying out simple operations. At the same time, errors that occur at this stage cause the most losses and problems. The use of the FMEA method in this case simplifies finding the causes and their sources. Eliminating them is much easier and involves low costs.

6. Summary

The basis for the application of quality management methods and tools is the possession of accurate and detailed information on the materials, the planned requirements of the product and the course of the manufacturing process. The lack of information about at least one stage of the process may have a significant impact on the final effect of the analyses. The failure mode and effects analysis allow for the analytical determination of cause and effect relationships of the occurrence of potential or actual failures of the product.

The company's use of the FMEA method allows it to quickly eliminate errors or oversights occurring in individual processes. This method is used every time the goods turn out to be defective and will not pass the appropriate tests. FMEA can also be implemented when, in the employee's convincing, the implemented processes deviate from the adopted standards. There is a rule in the company that whenever there are any doubts as to the correctness of the measures implemented, a process analysis should be carried out using the FMEA method. In this way, it will be possible to limit possible complaints or problems with proper functioning of the final product. In addition, early detection of an error will save a lot of expenses that would have to be incurred to withdraw defective products from the market, repair them or produce a new series.

The success of the FMEA analysis depends on numerous factors that can be divided into organisational factors (resource provision, planning, engagement, awareness of needs, effective implementation of applications) and factors related to the level of qualifications to carry out such analyses (the ability to use the FMEA worksheet, the ability to undertake group work, qualifications of the team).

Only the commitment of all employees' intellectual capital guarantees achieving the quality objective, namely the lack of complaints from the customer.

Literature

DUDEK-BURLIKOWSKA M. 2007. *Quality estimation of sale process with usage of quality methods in chosen company*, Journal of chievements in Materials and Manufacturing Engineering, 1-2.

DUDEK-BURLIKOWSKA M. 2010. *Aspects of improving the organization directed to the quality*, Archives of Materials Science and Engineering, 43.

DUDEK-BURLIKOWSKA M. 2011. *Application of FMEA method in enterprise focused on quality*. Journal of Achievements in Materials and Manufacturing Engineering, 45, 1, 89-102.

GÓRNY A. 2014. *Application of FMEA structure in ensuring technical safety*, Logistyka, 5.

HAMROL A. 2005. *Quality management with examples*, PWN, Warsaw.

IWANIEC K. 2010. *The FMEA method as an analysis of the causes and effects of defects - a selected aspect*, AGH, Kraków.

KARASZEWSKI, R. 2006. *Modern concepts of quality management*, UAM, Toruń.

KOLMAN R. 1996. *Selected issues of quality management*, WSAiB, Gdynia.

ŁAŃCUCKI J. 1995. *Quality management in the company*, OPO, Bydgoszcz.

ROSZAK M. 2013. *Technology management*, Open Access Library, 9(27), 1-140.

KANIA A., ROSZAK M., SPILKA M. 2014. *Evaluation of FMEA methods used in the environmental management*, Archives of Materials Science and Engineering, 65.1, 37-44.

WIERCIAK J. 2012. *Issues of quality and reliability in design. Quality management according to the ISO 9000: 2000 series standards. 2 - production of the product*, PW, Warsaw.

FMEA 方法在企業選擇生產過程中的應用

關鍵詞

質量管理
生產過程
優質的生命週期
FMEA 方法
質量改進

摘要

本文的目的是展示使用對故障原因和影響的分析作為控制公司給定生產過程質量的預防工具。 工作範圍包括對選定流程的分析，對流程中存在的不一致性的定義以及 FMEA 分析 在生產企業中，人們應該在所謂的“質量循環”的基礎上實施思考和行動 – 這是所採取行動的相互依賴模型，它影響質量的形成。 它可以通過項目，生產過程來確定客戶的需求，直至評估達到所定要求的有效能力。 採用這種方法可以採取系統化的方式來改進質量管理的運作