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Application of FMEA method in enterprise focused on quality

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ABSTRACT

Purpose: A new approach to production process monitoring in organization using Failure Mode and Effect Analysis method has been presented.
Design/methodology/approach: The possibility of use of Failure Mode and Effect Analysis methods is connected with continuous quality improvement of organization. Interdependence of the quality research methods and production process's requirements have been taken into account.
Findings: At the present time the enterprises should integrate quality management and quality control with customer's requirements, production process's requirements and also quality methods. Such kind of strategy will enable to achieve success for these companies.
Research limitations/implications: FMEA is a very important method which should be employed in companies for an engineering design, production process, new product in preproduction and production sphere in product life cycle. Aim of FMEA is establishing links between causes and effects of defects, as well as searching, solving and drawing the best decisions concerning application of proper action.
Practical implications: The example of implementing FMEA shows possibility of monitoring chosen production process according to idea of defects prevention. Usage of this method allows to keep a process production focus, reduction in the product development cycle, providing opportunities for cost reduction.
Originality/value: Application of Failure Mode and Effect Analysis in polish companies have been presented. It helps define Potential defect, Effects of defects, Defects causes in chosen production process of train hoops.
Keywords: Quality management; Failure Mode and Effect Analysis; The product life cycle

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1. Introduction

Every man tries to find the way, possibility and also tools in order to improve own surroundings, as well as oneself. The ability of being in world of changes determines his success or failure, therefore we must exactly determine the purpose and direction, in which we make its way. The way which we follow is different and often very difficult so that this way leads to the planned target, must be thought over. The man has his time given only once, so one must exploit it to achieve the effectiveness in all undertakings. If one is guided in his actions by a quality perhaps we will achieve his goal. Every manager knows that: at first the quality is necessary to search oneself, and then to require for the quality than other. The quality is fulfilling requirements and expectations of every customer, it is an idea which leads to satisfying the needs which is a very good and credible measure of quality.

Functioning of an economic units in current world come across the number of the problems on its way. In today's difficult market enterprises have to make decision, which at first are supposed to provide their survival, but after the longer time generate profits. Enterprises more and more often focus their attention on caring about the minimization of the incurred expenditure on the production of products or services. That possibility for reducing the expenditure and costs are connected with using quality tools and quality management method in all processes in company.

The quality methods structuralize the enterprise and introduce the general responsibility for all individual action of his participants: managers, employers, suppliers, customers. The organization directed to the quality focuses on distinguishing parts of its operation based on responsibility for costs and profits. This organization tries to find the answer - how to control preproduction, production, after production sphere control with using all quality methods?

Quality management gives managers controlling tools concerning current activity and more important budgeting future economic in action being aimed.

In this article quality management and quality control have been described. The chosen quality method - Failure Mode and Effect Analysis (FMEA) has been discussed and also suitable practical example has been given.

2. The quality management in the enterprise

A noticeable increase in the significance of the quality management systems and of products quality is a phenomenon of our times. The quality is regarded as the most important weapon in the market competition and the international trade [1].

Quality management is a way to get better effects. Due to the great competition on world market amongst production companies there appeared a need for effective ways of improvement of the quality level of products. For many years different methods were tried to change the quality e.g. through economical instruments, however it turned out that there had been no significant relationship between the quality and the financial result [2].

The economic policy of the organization in the sphere of the quality depends on various outside factors and internal abilities. Such activity decides on choice about the optimum strategy, which according to E. Kindlarski, takes the following form [3]:

- supremacy, imposing personal quality patterns and not-allowing for foreign standards,
- of skid, it is a concentration on achieving quality standards with using foreign standards,
- maintenances of the equal status, creating personal competing quality patterns,
- of convergence, taking the production of products on about the big coincidence with the own production program and the personal structure,
- of critical factor, it is taking what decides into account on the market about the product success.

According to ISO 9000:2005 standard - point [4]:

2.11 Quality management systems and other management system focuses - "The quality management system is that part of the organization's management system that focuses on the achievement of results, in relation to the quality objectives, to satisfy the needs, expectations and requirements of interested parties, as appropriate. The quality objectives complement other objectives of the organization such as those related to growth, funding, profitability, the environment and occupational health and safety. The various parts of an organization's management system might be integrated, together with the quality management system, into a single management system using common elements. This can facilitate planning, allocation of resources, definition of complementary objectives and evaluation of the overall effectiveness of the organization. The organization's management system can be assessed against the organization's management system requirements. The management system can also be audited against the requirements of International Standards such as ISO 9001 and ISO 14001. These management system audits can be carried out separately or in combination".

Quality management is also implementing the management function in the relationship to the quality management system and the quality of processes. It is a philosophy replacing the lost time and human effort by engaging people into the process of management [5-7].

For better understanding of Modern Quality Philosophy the Enterprises have to define a ways of quality monitoring and quality control. Such approach serve the improvement in the effectiveness and the elasticy of the production and the business as the whole. Standard ISO 9000:2005 indicate aspects of modern quality: Self-assessment and Continual improvement [5].

Self-assessment

"An organization's self-assessment is a comprehensive and systematic review of the organization's activities and results referenced against the quality management system or a model of excellence. Self-assessment can provide an overall view of the performance of the organization and the degree of maturity of the quality management system. It can also help to identify areas requiring improvement in the organization and to determine priorities" [5].

Continual improvement

"The aim of continual improvement of a quality management system is to increase the probability of enhancing the satisfaction of customers and other interested parties. Actions for improvement include the following:

- analysing and evaluating the existing situation to identify areas for improvement;
- establishing the objectives for improvement;
- searching for possible solutions to achieve the objectives;
- evaluating these solutions and making a selection; implementing the selected solution;
- measuring, verifying, analysing and evaluating results of the implementation to determine that the objectives have been met;
- formalizing changes.

Results are reviewed, as necessary, to determine further opportunities for improvement. In this way, improvement is a continual activity. Feedback from customers and other interested parties, audits and review of the quality management system can also be used to identify opportunities for improvement" [5].

Worth the attention are method applied in the process of controlling of quality: Statistical Process Control (SPC), Analysis of value, decision-making, calculation of quality costs, Seven Tools, Failure Mode and Effect Analysis (FMEA), Quality Function Deployment (QFD), Six Sigma, 5S, Kaizen, Taguchi Method, DOE, Brainstorming. W.E. Deming said that: " Isn't said that the company is supposed to be for centuries in the business". Important aspect is skill efficient connection of Deming's Cycle PDCA: Plan-Do-Check-Act with use of Quality estimation method, techniques and tools (Fig. 1) [8-10].

Suitable selection of tools and methods, orientation in which point of process we are, realization of suitable measurements will make enable analysis and understanding the reasons of errors forming in working processes, and what behind this goes in the whole firm, and this in turn will permit identifications and use of correcting activities [7].

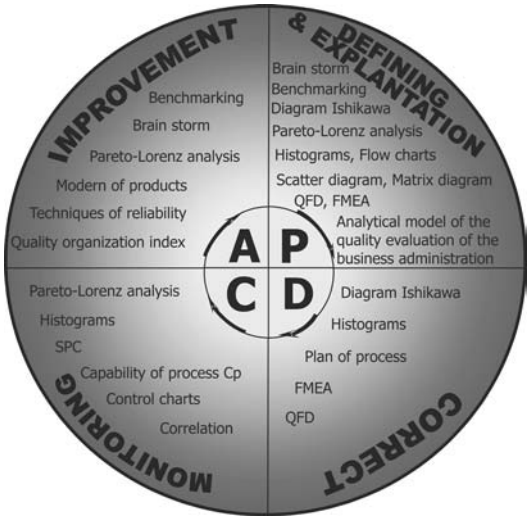

Fig. 1. Model PDCA connects with quality methods and quality tools [7]

The enterprises must take quality into account in all processes future. They are able to do it well enough, to what extent are able well to manage the present time. Creating conditions for quality development in which the organization can ensure the profitability of production and to project against the risk is necessary. Getting and keeping the confidence of the customer for the organization, in the light of requirements of the ISO 9000:2005 norm, is the most significant task.

Understanding customers needs has the key meaning for the definition of proper strategies. These proper strategies permit to hold or to raise the company's position in direct environment [11]. P. Kotler shows that each employee of organization must obey two rules [12]:

- The first: Customer is always right.
- The second: If customer is not right look the first rule.

According to ISO 9000:2000 organizations rely on customers. Therefore:

- Organizations must understand customer's needs.
- Organizations must meet customer requirements.
- Organizations must exceed customer expectations.

Point 8.2.1 ISO 9001:2000 standards described that [13]: "The organization shall monitor information relating to customer's perception as to whether the organization has met customer's requirement are as one of the measurement of the performance of the quality management system. In the next step the methods for obtaining and using this information shall be determined". The modern management focus on customer and focus on the product through:

- culture of the universal quality,
- humanization of the technological process,
- promotion of the quality awareness,
- motivation,
- programs of the improvement in the quality.

Sum up: The quality management in enterprises should include: quality policy, quality planning, quality monitoring and control, quality assurance and quality improvement.

3. The modernity of final product in organization directed by quality management

The modernity of products is analysed by diversifying the quality of the product and its cycle life, that is [14-16]:

- innovative (new generations of products),
- horizontal diversity (varieties), that is adaptation of usefulness of the product to requirements, likings and conditions of individual operating,
- vertical diversifying (classes) is based on split level of the same functional tools.

Such approach makes it possible to find the many of different definitions of the quality of product with enterprises directed by quality. However determining is expression, that: "quality is a degree of satisfying of the customer's needs". The final industrial product of good quality is a result of quality plan project, of quality production and also of quality exploitation [14-17]:

- Quality project - a degree of the excellence of the project compared with requirements.
- Quality production - a degree of compliance of the final product with adopted standards.
- Quality exploitation - a step of the agreement of the service in the after production sphere of the product with requirement of the project.

The most defects (because about 75%) arise at the stage of the concept of the construction project and preparing the production (Fig. 2). They demand that activities connected with quality management system in company and quality control in preproduction sphere are held according to system's approach. It ensures the appropriate quality of final product in enterprises which implement quality management system [14].

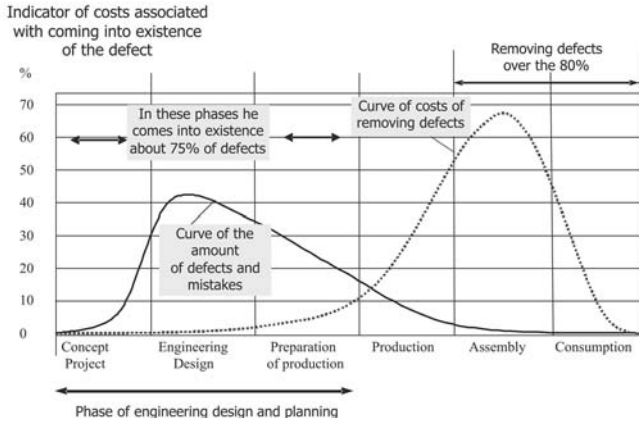

Fig. 2. Dependence between the product and its cycle life - quality control - defect costs [14]

According to ISO 9001:2008 [13]:
"The organization should establish, document, implement and maintain a quality management system. The organization can not forget about continuous improvement and also effectiveness. The enterprises should:

- determine the processes needed for the quality management system and their application throughout the organization,
- determine the sequence and interaction of these processes,
- determine criteria and methods needed to ensure that both the operation and control of these processes are effective,
- ensure the availability of resources and information necessary to support the operation and monitoring of these processes,
- monitor, measure where applicable, and analyse these processes, and implement actions necessary to achieve planned results and continual improvement of these processes.

These processes should be managed by the organization in accordance with the requirements of this International Standard. Where an organization chooses to outsource any process that affects product conformity to requirements, the organization shall ensure control over such processes. The type and extent of control to be applied to these outsourced processes shall be defined within the quality management system.

NOTE 1 Processes needed for the quality management system referred to above include processes for management activities, provision of resources, product realization, measurement, analysis and improvement [13].

NOTE 2 An "outsourced process" is a process that the organization needs for its quality management system and which the organization chooses to have performed by an external party.

NOTE 3 Ensuring control over outsourced processes does not absolve the organization of the responsibility of conformity to all customer, statutory and regulatory requirements. The type and extent of control to be applied to the outsourced process can be influenced by factors such as the potential impact of the outsourced process on the organization's capability to provide product that conforms to requirements, the degree to which the control for the process is shared, the capability of achieving the necessary control through the application of 7.4.".

The most important rank of quality management should cooperate with every subsystems of product quality management. On the top of management aims of quality and also plans and tasks of quality for all group of employers should be formulated.

Figure 3 contains the model of three-level of quality management structure in the enterprise according to K. Lisiecka. This model shows a proper place for the quality preproduction sphere [18].

A stage of the product design and production technology designing process deserve the special attention, because both these activities should be made at the same time. Such activity permit also on getting the defined quality of final product [18-21].

Quality management system as we know are implemented to the realization of the quality aims associated with the quality of product, however also for achieving the state of the high efficiency in technical sphere, economic sphere, social sphere of executive and managing processes in enterprises [16,21].

In order to achieve the maximum quality in the enterprise the following areas must be included at the same time: the quality of products, efficiency of the production system and efficiency of quality management.

The first step for reaching such ideas is understanding the life cycle of product oriented on quality and defining preproduction, production, after production quality sphere with processes in company (Fig. 4) [21].

One of the most important aspects of realization of proquality work tasks is a proper choice of quality estimation methods, used in three sphere of company: pre-production, production, after-production, and so on every stage of creating of the final product [15,16,19]

In the planning and designing phases the organization use such quality tools as the benchmarking, brains storm, Analytical Choice of Constructional Materials (ADMK), Quality Function Deployment (Customer Voice - QFD), Failure Mode and Effect Analysis (FMEA), the statistical tolerances, techniques of reliability, regression, modeling and simulation [7,9,15,19,22,23].

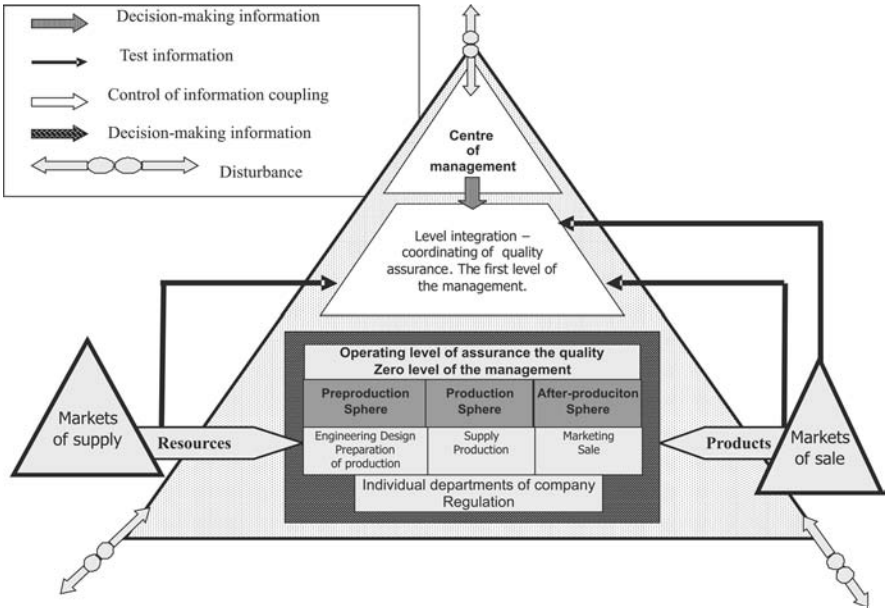

Fig. 3. The model of three-level of quality management structure in the enterprise [18]

Benchmarking is the process of identifying, understanding, and adapting outstanding practices from organizations anywhere in the world to help your organization improve its performance [15,16].

Brainstorming can be an effective way to generate lots of ideas on a specific issue and then determine which idea - or ideas - is the best solution. Brainstorming is most effective with groups of 12-15 people and should be performed in a relaxed environment. If participants feel free to relax and joke around, they'll stretch their minds further and therefore produce more creative ideas [12]. ADMK is the quality method which helps to decide which materials are possible to be used in company in economical aspects [22].

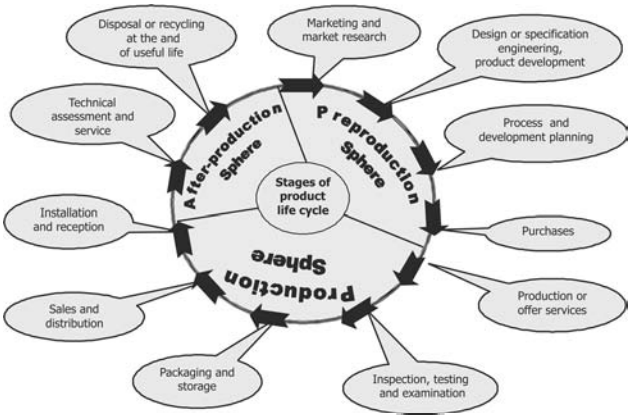

Fig. 4. The acts in product life cycle [7,9,10]

Quality Function Deployment is used to translate customer requirements into engineering specifications. It is a connection between customers, design engineers, competitors and organization. Resuming in the planning and designing stage, above mentioned methods should be used in transforming customer requirements in technical requirements and also describe preferences and also should be used for problems and lacks estimation - prevention works.

In the production phases the organization should use Statistical Process Control, and also FMEA, QFD and quality tools along with Poka-Yoke rules, Deming's rules, 5S. Statistical Process Control (SPC) is a method of monitoring, controlling and improving a process through statistical analysis. In this method company should create and maintain the flow charts, estimate capability index of production and capability index of machine. Poka-Yoke means "fail-safing" or "mistake-proofing", it is a method of preventing defects by putting limits on how an operation can be performed in order to force the correct completion of the operation [8,24].

E. Deming offered fourteen key principles for management for transforming business effectiveness.

5S is a reference to five Japanese words that describe standardized cleanup: Seiri - tidiness, organization, Seiton - orderliness, Seiso - cleanliness, Seiketsu -standards, Shitsuke - sustaining discipline. Resume this phase of life cycle product can permit on removal the defective product - prevention works. On the stage of product life cycle after sale the analysis of tendency, analysis of product modernity can permit the industrial company to identify repeated negative effects which should be corrected [9,15,19,23,24].

All this acts in company has to be connected by the people - collective activities and very useful, flexible transfer of information. Above presented considerations permitted to propose a model of quality research and estimation methods based on product life cycle. This model can be used by the organizations (Fig. 5) [8].

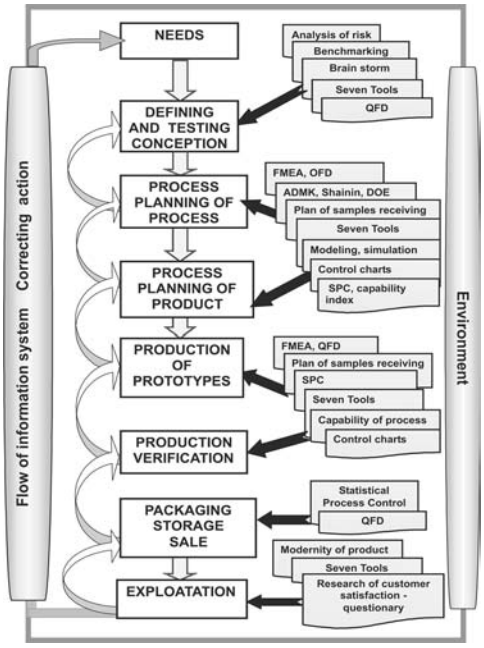

Fig. 5. Model of quality research and estimation methods based on product life cycle [8]

4. FMEA - Failure Mode and Effect Analysis

FMEA is a method which enterprises use at preventing and eliminating defects which can appear in the manufacturing process. FMEA is the best analytical technique, because allow for establishing links between causes and effects of defects, as well as searching, solving and with drawing the best decisions concerning applying proper action (Fig. 6) [20,25].

This method was applied already in the 1950ies in the United States and in Japan, FMEA ensured the reliability of products of the high risk (e.g. aviation, astronautics). However in seventies this method found application in Europe in the electronics industry but then in the mechanical engineering. The fast growth of the competition in Europe as well as in the world and civil liability behind the produced product (CEE directive of No. 85/374) forced companies into increasing efforts in area of the quality preventions. Its a result was wide spreading FMEA methods in the eighties, above all in the motorization industry [19,20,25].

We should use the FMEA method at [8,19,20,25-27]:

- creating of the product concept, for checking whether all expectations of the customer are included in this concept,
- defining the product, in order to check whether projects, service, supplies are appropriate and organised in the right time,
- process of production, in order to check whether documentation prepared by technologists is fully carried out,
- of assembly, for checking whether the process of the assembly is compatible with documentation,
- of organization of the service, in order to check whether the product or the service are harmonious with established criteria.

It is possible to divide the FMEA method depending on the category of the examined problem, to the following types [19,20,27]:

- FMEA of Product/Project according to „base to do well the first time round ”,
- FMEA of Product/Process - producing in harmony with requirements,
- FMEA of production means for guaranteeing effectiveness,
- FMEA of Organization.

FMEA analyses are conducted in order to examine [19,20,26]:

- reasons for damage to the product and also effects caused through this damage for the customer, while of the operating of product,
- reasons for coming of the disagreement (with the technical documentation) of produced elements,
- causes of damage during the technological process.

In practice, it is possible to distinguish the following kinds of this method [19,20,26]:

- FMEA of the product and the design,
- FMEA of the production process.

FMEA - of product/design is conducted during preliminary design works in order to obtain the information about strong and weak points of the product, so that at the stage of the conceptual design there still exists a possibility of introduction of amendments.

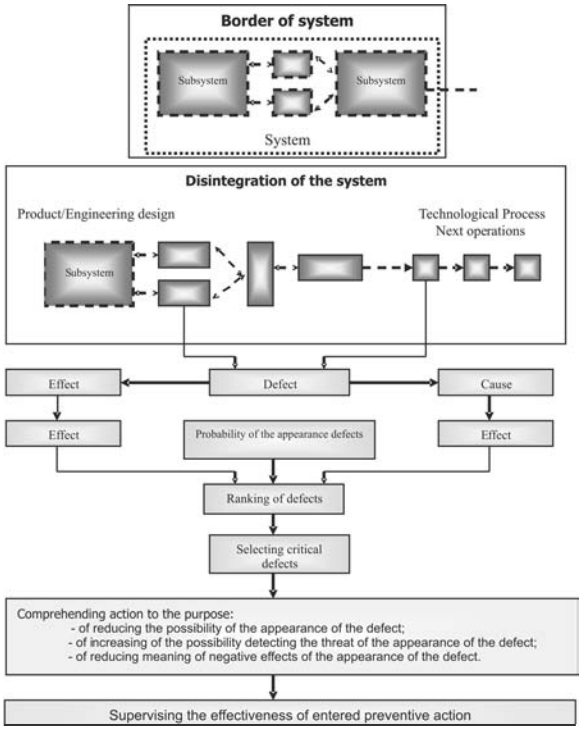

Fig. 6. Stages of FMEA method [20]

Defects of the product or the design can concern [19,20,26]:

- function which the product is supposed to carry out,
- reliabilities of the product during the exploitation,
- easinesses of the service by the user,
- easinesses of repair of the case of damage.

FMEA analysis of the product/design finds applying in cases [19,20,25]:

- of entering the new product on the market,
- of entering new materials to the production process,
- of applying new technologies in company,
- of great threat to the man,
- of use of the product in particularly difficult conditions.

FMEA of the production process is applied in order to determine factors making it difficult requirements specified in the specification of project design and disrupting normal (correct) process of producing. These factors can concern [19,20,26]: methods of processing, parameters of processing, measuring-test resources, machines and devices.

FMEA of the production process is most often used [19,20,27]:

- in the initial phase of planning technological processes,
- before starting the serial production,
- for improving unstable processes in the serial production.

FMEA analysis results from three basic stages [19,20,25]: preparations, of conducting due analysis, of entering and supervising effects of production.

The following table contains the description of three basic stages of the realization of the FMEA method (Table 1) [19,20,27].

Calculated so-called number of the priority $P = R \times W \times Z$ can be in the range from 1 to 1000. If is considerably bigger from 1, then recommendation for preventive action is given, e.g. by modernizing of structure or amendments to the technological trial [19,20,25]. In arrays 2, 3, 4 pointers were passed for estimating R rates, Z and W.

For conducting FMEA analysis drawing the special - document is required - FMEA sheet.

FMEA (Failure Mode and Effects Analysis - Analysis)

Stages of conducting FMEA analysis [19,20,25,27]:

Preparation:

defining the purpose, creating the team

Due analysis:

A. Qualitative analysis

B. Quantitative analysis

This analysis consists at estimating factors of the risk and determining the value of R numbers, Z, W and P, meaning one by one:

R number - frequency of appearing of the defect (risk of the appearance of the defect), determined in the scope from 1 to 10,

W number - level of the detectability of the defect, determined in the range from 1 to 10,

Z number - meaning of the defect (for the customer), value in the range from 1 to 10,

P number - number of the priority P = R*W*Z, taking value from 1 to 1000.

The significant importance for company has a defect with the number of the priority bigger than 100. One should also realize that the larger a number of the priority the more severe the defect is for customers. The *P* number close to value 1000 means the critical defect threatening the safety of the user or disturbing provisions of the law.

C. Drawing up the plan of preventive action

This stage consists of such designing actions that appropriately increase or reduce numbers *W*, *R*, *Z* and *P* (that is in other words to raise the level of the detectability and to lower appearing and the arduousness, severity of the defect for the customer).

D. Supervision of preventive duties

In this stage company should verify, to what planned previously action let us reduce the *W*, *R*, *Z* numbers, in and from (that is the *P* number of priority) and should draw a conclusion from conducted analysis.

Table 1.
Basic stages of the realization of the FMEA method [19,20,27]

FMEA STAGES OF THE PRODUCT/DESIGN OR OF THE PROCESS		
I STAGE PREPARATION	II STAGE DUE ANALYSIS	III STAGE PREVENTIVE AND SUPERVISION ACTION
Defining of border of analysed system. Disintegration of the system. Carrying of statement: - product, subassemblies, parts, - processes/operations.	Description of defects: - kind, effect, cause. Determining in the scale (1 - 10): - risks of the appearance of the defect (R), - meanings of the defect (W), - possibilities of detecting the defect (Z).	Issuing an order: - resources, replies, date. Supervision of the accomplishment of recommendations. Supervision of following dates.
Description of the relation: - functional (for product) - processing (for process) Choice of the frequent/operation for carrying out an analysis	Appointing the number of the priority $P = R \times W \times Z$ Choice of critical defects in the product/process	Balance: - expenditure/benefits Acting towards lowering the costs caused by the appearance of defects

Conclusions:
Results of conducted analyses serve as the ground for entering in the structure of the product, in the way of having right of usage or in processes of production amendments, being aimed at lowering the risk of appearing of defects determined as critical defects. If it is impossible to eliminate defect, one should take action increase possibility of detecting it or reduce its negative effects. Completion of recommended „action repair ” should still be supervised, and their effects subjected to the verification according to the FMEA method.

Table 2.
Pointers for setting the R number [20]

Appearance of the defect R	FMEA - Product/Design/Process
1	The appearance of the defect is almost impossible.
2-3	The defect very rarely appears.
4- 6	The defect appears occasionally, every now and then.
7-8	The defect often appears.
9- 10	Almost it isn't possible to avoid the defect.

Table 3.
Pointers for setting the W number [20]

Detectability of the defect - Z	FMEA - Product/Design/Process
1-2	Very high
3-4	High
5-6	Average
7- 8	Low
9	Very low
10	None

Benefits arising from FMEA applications

We choose FMEA analysis then, when [1-6]:

- the number of output states of the system is large and we need the technique supporting the identification of passable states of the system;
- we suspect that the system can “produce” no acceptable output states which we don't know;
- a need of the improvement in the design project exists (e.g. of increase in the level of the safety), of examining problems of the diagnostic testing or the service, preparing the specification and the plan of tests;
- we need qualitative analysis, giving the insight into behaving of providing software in case of the breakdown and certainty that for the significant scope of defects and errors associated with them the system is able to detect them and react appropriately;
- we want to verify the correctness of the process of creating the system, to plan preventive action, to establish priorities of treating defects.

Table 4.
Pointers for setting the Z number [20]

Meaning of the defect - W	FMEA - Product/Design/Process
1	There is no meaning.
2-3	Meaning of the defect is little and constructs for little worsening the jurisdiction of the product.
4-6	The defect in the product evokes the distinct dissatisfaction of the user.
7-8	The dissatisfaction of the user is great, because is triggered with impossibility of using the product.
9-10	The defect in the product threatens the safety of the user.

An improvement in the quality of the created system is a superior aim of the FMEA method. We get the following results thanks to her [1-7]: identification of the influence of damage element on other elements, subsystems and the entire system, determining means lowering the risk, the verification or supplementing the specification of requirements for the system, gain in time and costs, thanks to the identification of possible threats still before the accession of the to do system, assisting the process, making its way for better understanding the system (in particular FMEA), can constitute the ground for drawing up service and diagnostic proceedings), creating conditions for FMEA analysis of superior systems, in which the given system was applied, documentation of all ideas concerning the answer given to the reliability, documentation of acquired experience, problems and their solutions for next projects, reduction in the scope of warranty repairs.

In this place we should emphasize that from the FMEA method we should not expect ready answers how to remove causes of defects. This method gives only pointers, which place in the structure or the product critical places are in and why. Finally we can compare FMEA of product and FMEA of engineering design (Table 5) [16]. Such approach allows the company to better define a proper kind of FMEA in cycle product of life.

5. The practical application of FMEA method in Polish company

Characteristic of chosen company: Steel Mill X

Economic activity of chosen steel mill - the producer of rolled products and hammered-rolled products - is directed permanently assuring of their qualities, reducing negative influence on the environment, guaranteeing the safety in all action as well as ensuring resources for the implementation of adopted the quality politics. The above purposes should be realized thanks to follow agents:

- keeping staff competent, still increasing its qualifications formed in over 170 years of tradition of the company opinion on permanent fulfilling requirements of customers,
- applied and constantly improved methods of the industrial engineering based on new safe technical solutions, technological and organizational, including also the control and preventing the environmental pollution,
- abiding by norms being in effect and provisions of law in the quality of the production, environmental protections and the industrial safety,
- applied in the production exclusively methods tested, substantiated, guaranteeing the safe service and optimizing wearing out raw materials and energy media of the production,
- constant monitoring processes of producing, conditions of the work and the influence on the environment through: planning the quality of produced products, preventing accident at work, applying means of the collective protection, reducing emission dust-gas from burning the natural gas in technological processes, limiting the amount of stored waste, preservation of surface waters.
- cooperating and keeping the permanent contact with suppliers and customers for permanent providing for the quality products, as well as with outside individuals within the scope of introducing technologies safe and friendly to the environment; permanent promotion of achievements within the scope of the quality, environmental protectionsand the industrial safety.

Warranty of achieving the high quality of products and reducing the negative influence to the environment with guaranteeing the constant improvement in the health and safety at work of the staff is supporting integrated systems of the management.

Using the FMEA method in the preproduction sphere in chosen Steel Mill X

Decisions to apply FMEA has been undertaken by Chief Technologist. FMEA is led in the case:

- interests of the customer in the purchase of products of the mill with parameters different than standard,
- of preparing for the production of new or modernised products,
- of significant amendments to the technology,
- analyses of causes of existing defects in products and processes.

FMEA analysis is conducted team of FMEA, which consists of:

1) Chief Technologist chairing of FMEA team,
2) Production manager,
3) Main Mechanics,
4) Manager of Quality Department.

The competent specialists in given field are attached to the FMEA team in considering the analysed problem. The FMEA team should not be bigger than 8 persons. For making specific analysis a Chief Technologist reports the line-up of the FMEA team at the meeting with the Quality Manager. The Captain of the FMEA team establishes in the relation from the considered problem the method and the technique of the functioning of the FMEA team. They are available methods: brainstorming, method pro and against, chain of causation of defects, diagram of Ishikawa, Pareto - Lorentz analysis.

Table 5.
FMEA - comparing: The Product FMEA/ Engineering Design FMEA and Process FMEA method [20]

Criterion of analysis	Functional ownerships of the product while having right of usage.	Course of the process (technological, logistic).
Object of analysis	The entire product, sub-assemblies, parts.	Phases of trials of processing and of assembly (operations, treatments, activities).
Questions, to which he infects the reply	What causes can cause the complete or partial disappearance of the given function of the product? What effects can be associated with it?	What defects (problems) can turn up at a given stage in a process and what their influence on defects in the product/structure can be?
Examples of expressions of defects	Crack of the element. A contact is missing. A medium lacks the flow.	Dimension outside the field of the tolerance. Too low hardness. Cold solder. Wrong estate.
Examples of expressions of causes of defects	Mistakes of the structure. Wear and tear. Mistakes of the service. Influence of surroundings.	Mistakes of the device/machine. Human errors. Wrong methods. Wrong material.
Examples of expressions of effects	Breakdown/disappearance of the post. Reduction performance. Threat of the health/life.	Variance with requirements. Reduced productivity. Higher estimate.

FMEA analysis is conducted according to the knowledge and experience of FMEA team members based on databases. The preliminary steps covers: evaluation of the current state, establishing correct/preventive action, verification of the result.
As a result of arrangements of the preliminary stage FMEA team define potential defects. In the next steps FMEA team assignees causes of defects and determines causes coming into existence of defects. Causes of defects should consider a point of view of the customer, taking into account the predicted reaction of the customer to the defect discovered by him.

Causes of coming into existence of defects should think over comprehensively so that in the simple way it is possible to determine essential preventive action. The current result of workshop of FMEA team are presented in FMEA sheet. Arrangements of the preliminary stage are subject to an archiving in company together with the rest part of documents, which arise in the course of the FMEA team activity. Chief Technologist archives and keeps a register of FMEA analysis. The evaluation of current state including tools research and establishing the risk of the production with the help of the priority number (LPR). Priority number of the Risk (LPR) accounts according to the formula:

$$LPR = LPW \times LPZ \times LPO \quad (1)$$

where:

LPW - Priority Number of Appearing.
LPZ - Priority Number of Meaning (for customer).
LPO - Priority Number of Detectability.

Every of priority numbers means the probability of appearing of the determined defect in the scale of 1-10. Results of the work of the FMEA team are put down on the FMEA sheet. Correct/preventive action is withdrawn in the relationship to every stated or potential defects. On account of the possibility of getting notable effects FMEA team accepts the hierarchy of planned correct/preventive action oneself than LPR biggest to the LPR low figure. The leader of the FMEA team sets the date of the verification of the performance depending on established dates correct/preventive action. In case of the lack of the anticipated effects of correct/preventive action reducing LPR number to acceptable level - new action is appointed and therefore a new date of result verification should be established. Such activities should be performed in the continuous cycle for achieving the value of number LPR on the satisfying level defined by FMEA team. The finishing of the work of the FMEA team on the specific problem should be announced at the meeting with Quality Manager.

FMEA in practice: Analysis of potential defects in the production process of train hoops

FMEA analysis for determining defects in the productionprocess of train hoops running in 12 operations: inspection and control of charge, cutting the charge, heating in the rotating furnace, pressing, rolling, mark, cooling, heat treatment, measuring of hardness, flaw detection, trim and sending to the final acceptance.

All operations with FMEA analysis has been presented in FMEA Sheet (Table 6).

6. Summary

The market economy in the fundamental way changed nature of enterprises and conditions of their functioning. The existing market changes into the real market for the customers.

Wanting to deal better with the management of organization, one should implement new concepts, tools and techniques of managing which will help to increase profitability and a financial potential of company.

In the enterprise of the future, besides the quality and the innovation, undoubtedly an important role efficiency of activity of the company action is played by towards with customers, because it is they will be the greatest good for the company.

It means that it is necessary to implement the systematic planning, the effective control and managing of individual processes in the enterprise.

Thanks to that it will be possible to make right decisions, and the area of the uncertainty will shrink.

That is not the point only about quality management and quality management system, but also for appropriate choice of developmental decisions of the enterprise.

Functioning of enterprises in current time is exposed to a lot of adversities resulting from the market. In the moment, when the level of the income from the sale is established on the certain, or fixed level, but marketing action doesn't influence the turnover, enterprises resort to amendments inside the organization.

Implementing the system of the quality management, and consequently integrating it with the environmental system and safety system constitutes a factor of the success, surviving and the development of the enterprise.

Paying attention to the aspect of continuous improvement by the enterprise with using of quality techniques and quality evaluation methods of every sphere of company's action, particularly the preproduction sphere, will do good for increasing the competing position on the market.

The next as reducing costs, minimizing the potential defects in the process and bigger fulfilling expectations of customers.

Applying the FMEA method allows for enhancing the possibilities of the enterprise. Significant integration of employees takes place. And it causes that is started "Machine of ideas" what give in the end final „ plan perfect almost ".

Thanks to the efficient system of quality management a company develops. This process is supported by efficient quality method as FMEA. Based on this method the company gains good results in the production process.

This method combines the possibility of supervising many activities of branch with the simultaneous delegation of entitlements and the decentralization of the power which are necessary for effective functioning of individual divisions of company.

FMEA method is an important method of preventive quality and reliability assurance. It involves the investigation and assessment of all causes and effects of all possible failure modes on a system, in the earliest development phases.

Usage of quality research methods -specially FMEA method - in preproduction sphere in Polish companies permits an avoidance of occurrences of productive defects already in the first stages of product cycle, which helps in elimination of source of their formation.

Professor R. Kolman opinion is right [22]:
"It seems not correct to call preproduction sphere "background area", because this is a place when we start to create whole of productive activities ".

This kind of thinking is particularly clearly in quality monitoring and control process, where preproduction sphere became a beginning of quality programming processes and of entire company development.

Table 6.
FMEA sheet for the production process of train hoops in chosen company

Operations	Potential defect	Effects of defects	Causes of defects	Current state: Research and test resources	LPW	LPZ	LPO	LPR	Commissioned preventive actions	Improved state: LPW	LPZ	LPO	LPR
INSPECTION AND CONTROL OF CHARGE	Chemical analysis incompatible with requirements.	Premature wearing the hoop. Destroying tracks.	Charge incompatible with requirement.	Inspection of charge materials.	3	8	1	24	To tighten the inspection of the charge. To increase the requirement, as for the quality of the charge offered by the supplier.	2	5	1	10
	Surface defects: - crack; - rolling; - burning; - pitting	Premature wearing the hoop. Impossibility to make the hoop.	Charge incompatible with requirements.	Inspection of batch materials.	4	8	1	32	To tighten the inspection of the venture capital. To increase the requirement, as for the quality of the charge offered by the supplier. Applying the magnetic method.	3	5	1	15
	Internal defects: - inclusions - skin hole - discontinuity	Premature wearing the hoop. Increasing the failure frequency of the hoop.	Charge incompatible with requirements.	Flow detection	4	6	1	24	To increase the frequency of taking attempts for the research on the macrostructure in the laboratory.	3	5	1	15
	Shape defects: - oval - warp	Impossibility to conduct the technological process of rolling the hoop. Receiving the hoop after rerolling incompatible with customer's requirements.	Charge at variance with requirements.	Inspection of charge materials.	3	8	1	24	Inspection of charge materials. Customer complaint of the charge.	3	7	1	21
	Lack of identification: - incomplete numbering - lacks indicating the grade; - incomplete marking of the grade; - lacks the marking.	Impossibility to allow the production.	Charge at variance with requirements.	Preparing the charge for rolling the hoop and rings. Acceptance and the inspection of charge materials for the department.	3	4	1	12	Applied of bar codes, magnetic payslips which would contain the full numbering and indicating the kind. Containing agreements guaranteeing applying by the supplier durable markings of the charge.	2	3	1	6

Operations	Potential defect	Effects of defects	Causes of defects	Current state: Research and test resources	LPW	LPZ	LPO	LPR	Commissioned preventive actions	Improved state: LPW	LPZ	LPO	LPR
CUTTING CHARGE	Wrong dimension.	Impossibility to allow the production.	Mistake of the regulation in the specification of the cut.	Plans of the quality control of the department.	3	4	1	12	Correct placing the ingot for the cut.	2	3	1	6
	A marking is missing.	Impossibility to allow the production.	Not moving the marking by "worker of ingots notching"	Plans of the quality control of the department.	3	4	1	12	Training "worker of ingots notching" Automatic bringing a lot of markings. Applying bar codes and magnetic payslips. Printing markings with laser.	2	3	1	6
	Estate of the block incompatible with requirements: - too big; - too small.	Impossibility to allow the production.	Bad cutting. Length of the charge incompatible with requirements. Thickness of the charge incompatible with requirements.	Preparing the charge for rolling the hoop and rings, Acceptance and the inspection of charge materials for the department.	3	4	1	12	Training "worker of ingots notching" Increasing of the frequency measurements of parameters of the charge as well as weighing the block and his dimension.	2	3	1	6
HEATING IN THE ROTATING FURNACE	Inappropriate chemical composition. Wrong arranging blocks.	Production incompatible with requirements.	Wrong identification of block from metal sawing machine.	Program of pressing and rolling; Preparing the charge for rolling the hoop and rings.	3	8	1	24	To tighten the inspection of the charge and to comply closely with the program of pressing and rolling.	2	6	1	12
THE ROTATING FURNACE	Failure to adhere to the temperature. Failure to adhere to the time of heating. Speed of heating incompatible with requirements.	Failure to adhere to parameters required for rolling.	Mistake furnace heater in leading the furnace. Unpredictable failure of the furnace.	Pressing and rolling rings and the hoop.	3	4	1	12	Staff trainings. Frequent making of services the furnace.	2	3	1	6
PRESSING	Surface defects: - cracks - hot tear	Impossibility to conduct rolling. Receiving production incompatible with requirements.	Parameters incompatible with requirements on the press. Allowing for charge at variance with requirements.	Pressing and rolling rings and the hoop.	3	6	1	18	Correct placing the machine. Staff training.	2	5	1	10

Operations	Potential defect	Effects of defects	Causes of defects	Current state: Research and test resources	Current state: LPW	Current state: LPZ	Current state: LPO	Current state: LPR	Commissioned preventive actions	Improved state: LPW	Improved state: LPZ	Improved state: LPO	Improved state: LPR
	Dent the scale	Product incompatible with requirements.	Wrong work crusher of scales.	Pressing and rolling rings and the hoop.	4	6	1	24	Correct placing the machine. Staff training	3	3	1	9
ROLLING	Rolling	Production incompatible with requirements.	Badly conducted process of rolling.	Pressing and rolling rings and the hoop.	4	9	1	36	Heating material in the course of rolling according to the accepted technology. Applying thermal imaging cameras letting determine the temperature of rolled products. Frequent making services of the mill.	3	6	1	18
	Cracks	Production incompatible with requirements.	Low temperature, bad quality of the charge.										
	Casings	Production incompatible with requirements.	Badly conducted process of rolling.										
	Delaminating	Production incompatible with requirements.	Wrong parameters of the mill.										
	Non-performance	Production incompatible with requirements.	Badly conducted process of rolling.										
	Lack of the correct dimension	Production incompatible with requirements.	Disturbance of the process of rolling.										
	Ovality	Production incompatible with requirements.	Wrong parameters of rolling.										
MARK	Wrong numbering: - tile; - too high; - too low; - too deep.	Production incompatible with requirements (wrong identification of product).	Disturbance the work. Device for marking. Incorrect of placing device for marking.	Pressing and rolling rings and the hoop.	5	6	1	30	Service of mark machine.	3	4	1	12
COOLING	Hydrogen cracks.	100% of examinations flaw defector.	Low temperature.	Pressing and rolling rings and the hoop.	2	9	1	18	Inspection of the charge. Correction of the technology of cooling.	1	5	1	5
HEAT TREATMENT	Inappropriate mechanical properties: - hardness; - resistance to stretching;	Production incompatible with requirements.	Failure of parameters of the heat treatment. Badly selected heat treatment parameters.	Heat treatment of rings and the hoop.	3	9	1	27	To train the staff from the heat treatment scope, more often to control achieved heat treatment parameters, to change the heat treatment technology.	2	4	1	8
	Inappropriate technological properties.	Production incompatible with requirements.	Failure of parameters of the heat treatment. Badly selected heat treatment parameters.										

Operati-ons	Potential defect	Effects of defects	Causes of defects	Current state					Commissioned preventive actions	Improved state			
				Research and test resources	LPW	LPZ	LPO	LPR		LPW	LPZ	LPO	LPR
MEASURING OF HARD-NESS	Inaccuracy of indication. Deficiency of the legaliza-tion.	The low or high hardness and the scattering of the measured hard-ness.	Bad preparing the surface, inaccurate reading, wrong technology of the measure-ment.	Preparing for the receipt the hoop and rings.	3	7	1	21	Checking qualifications of the staff and if necessary to train. To carry: milling, grind-ing, polishing. Correction of the technology.	2	3	1	6
FLAW DETECTION	Incorrect indication of flaw detection.	Production in-compatible with requirements.	Incorrect re-search findings due to the bad preparation (cleaning) of surface worked from the scale. Breakdown flaw dete-ction, wrong preparing the surface. Mistake of the operator in interpretation of the results.	Ultrasound examining the hoop.	3	8	1	24	Training the staff. Services of devices. Correct pre-paring the surface of studied mate-rial. Servicing.	2	4	1	8
TRIM AND SENDING TO THE FINAL ACEPTANCE	Defects of revision.	Production in-compatible with requirements.	Bad quality of the charge.	Final inspec-tion of prod-ucts.	2	7	1	14	The quality check of the charge and his structures. Checking qualifications of the staff.	1	3	1	3

References

[1] E. Skrzypek, Quality and efficiency, UMCS, Lublin, 2000 (in Polish).

[2] J. Michalska, Quality costs in the production process, Special Issue of the Worldwide Journal of Achievements in Materials and Manufacturing Engineering 17 (2006) 425-428.

[3] E. Kindlarski, Product quality, PWN, Warszawa 1998 (in Polish).

[4] Standard EN ISO 9000:2005, Quality management system - Fundamentals and vocabulary, ISO 2005.

[5] J. Ketola, K. Roberts, Demystifying ISO 9001:2000 - part 1, Quality Progress 34/9 (2001) 65-70.

[6] J. Ketola, K. Roberts, Demystifying ISO 9001:2000 - part 2, Quality Progress 34/10 (2001) 44-47.

[7] M. Dudek-Burlikowska, Aspects of improving the organization directed to the quality, Archives of Materials Science and Engineering 43/2 (2010) 101-108.

[8] M. Dudek-Burlikowska, D. Szewieczek, Quality estimation methods used in product life cycle, Journal of Achievements in Materials and Manufacturing Engineering 24/2 (2007) 203-206.

[9] M. Dudek, Quality methods as a factor of functionality and improvement preproduction of organization sphere, Proceedings of the Materials of Nationwide Scientific Conference: „Management of organization of project oriented" UMCS'2004, Lublin, 2004, 89-93 (in Polish).

[10] E.W. Deming, Quality, Productivity and Competitive Postion, University of Cambridge, 1982.

[11] T. Karkoszka, Improvement of chosen process based on the occupational health and safety criterion, Journal of Achievements in Materials and Manufacturing 37/2 (2009) 735-742.

[12] H. Bieniok, Basic rule of company management, AE, Katowce, 2003 (in Polish).

[13] Standard EN ISO 9001:2008, Quality management systems - Requirements, ISO 2008.

[14] A. Hamrol, Quality assurance in production processes, Publishing House of Poznań University of Technology, Poznań, 1995 (in Polish).
[15] R. Nowosielski, A. Kania, M. Spilka, Integrated recycling technology as a candidate for best available techniques, Archives of Materials Science and Engineering 32/1 (2008) 49-52.
[16] M. Dudek-Burlikowska, Quality research methods as a factor of improvement of preproduction sphere , Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 435-438.
[17] D.E. Hardt, Modeling and Control of Manufacturing Processes: Getting More Involved, ASME Journal of Dynamic Systems Measurement and Control 115(1993) 291-300.
[18] A. Chodyński, Proquality management of production develop in company, Bielsko-Biała, 2000 (in Polish).
[19] A. Tabor, A. Zając, M. Rączka, Quality Management, Volume II, Cracow, 2000 (in Polish).
[20] A. Hamrol, W. Mantura, Quality Management. Theory and Practice, PWN, Warsaw, 2005 (in Polish).
[21] M. Dudek-Burlikowska, D. Szewieczek, The modern quality control of preproduction sphere in a company, Journal of Achievements in Materials and Manufacturing Engineering 28/1 (2008) 79-86.
[22] R. Kolman, Quality Engineering, PWE, Warsaw, 1992 (in Polish).
[23] M. Dudek-Burlikowska, D. Szewieczek, The Poka-Yoke method as an improving quality tool of operations in the process, Journal of Achievements in Materials and Manufacturing Engineering 36/1 (2009) 95-102.
[24] S. Tkaczyk, M. Dudek, Methodology research of quality in industry, Proceedings of the 7th Scientific International Conference "Achievements in Mechanical and Materials Engineering" AMME'1998, Gliwice-Zakopane 1998, 513-516 (in Polish).
[25] M. Dudek, D. Szewieczek, Usage of quality methods: Failure Mode and Effect Analysis (FMEA) and Statistical Process Control (SPC) as a element of continuous improvement of production process, Proceedings of the 12th International Scientific Conference "Achievements in Mechanical and Materials Engineering" AMME'2003, Gliwice-Zakopane, 2003, 317-321.
[26] A. Hamrol, Quality management. Science and practice, PWN, Warsaw-Poznań, 1998 (in Polish).
[27] D. H. Stamatis, Failure mode and effect analysis: FMEA from theory to execution, ASQ 2003.