

Application of FMEA method for an analysis of selected production process

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ABSTRACT

Purpose: The article presents an application of FMEA method in a process of chimney system production. The analysis allowed to decrease a potential defects and their effects in the analysed process.

Design/methodology/approach: The technical analysis of the process of chimney system production indicated many defects in the product. Based on the FMEA results (value of RPN – Risk Priority Number) corrective and preventive actions were proposed. These actions decrease RPN level by half.

Findings: In this paper characteristics of the chimney system and technical analysis of its production process were presented. Failure mode and effects analysis for selected operations of the production process was performed.

Practical implications: In the analysed process are possible the nonconformities above the appointed RPN level, because they are dependent on applied technology and machinery. Increase of a quantity of control points and training employees caused a reduction of manufacturing costs, improvement of the product quality and creation of the possibility of effective quality control.

Originality/value: FMEA analysis is an effective tool for identification, determination of a risk level, planning and implementation of corrective and preventive actions to decrease a quantity of defects in the final product. Periodic application of this method enables the continuous improvement of the processes and products in enterprises.

Keywords: Risk, FMEA method, RPN level, Chimney system technological process

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INDUSTRIAL MANAGEMENT AND ORGANISATION

1. Introduction

The quality is an important aspect nowadays. The companies to get customers have to produce high quality products. Because of that processes should be realized

without disturbances. Failures can lead not only to the interruption of the processes, but also to the creation of defective products. Therefore it is important to planned and control every production process. This control requires a proper quality management.

The risk related to quality management is a problem occurring in every industry, which solve the problems and search for reason of their occurrence. Each organization should strive to decrease or reduce the risk. One of the methods used for determination of risk is Failure Mode and Effects Analysis (FMEA) method. FMEA is used to provide that potential failures and problems will be solved on time. This is a tool which is in accordance with continuous improvement rules.

The article presents the application of the failure mode and effects analysis in a selected technological process of chimney system.

2. General guidelines of FMEA method

FMEA analysis is one of the methods used in quality management. The method provides an input data to decrease a risk of the failures. FMEA method is a tool for identification of potential defects and effects. These defects usually concern [1]:

- use of a product,
- production of products in accordance with a specification,
- production of products safe for their users,
- small efficiency and effectiveness of realized processes,
- safety of implemented processes,
- material damages, loss of health or life.

In practice there are two types of FMEA analysis application: product/construction FMEA and process FMEA (Tab. 1) [2].

The scope of FMEA and way of its implementation are also selected. The following approaches are taken into account [1,3]:

- Problem – areas where any problems have been found are only analysed. The scope of activities is selected based on previous experience, current problems with a product or process, client complaints, failure analysis etc. This approach is associated with the limitations of the detecting potential threats in a product functioning or process realization.
- Systematic – in this approach products/processes are analysed comprehensively as a system consisting of many subsystems. Products/processes have their own downstream subsystems (e.g. components and parts) that fulfill certain functions and tasks. The FMEA team should first determine the boundaries of the system and identify specific subsystems in its range. This approach generalizes the analysis, makes it more transparent, simplifies the identification of potential threats in the product functioning and/or process realization, threats which have not yet been disclosed or they rarely occurred.

Identification of possible defects is a first stage of FMEA analysis. Values from 1 to 10 for three categories (occurrence – O, detection – D, severity – S) are assigned to defects. Finally Risk Priority Number (RPN) according to formula (1) is calculated [4-6].

$$RPN = O \cdot D \cdot S \quad (1)$$

RPN indicates in which area the activities have to be realized to prevent the defects. Professional literature stated that the higher RPN value, the greater severity of failure.

Table 1.
Comparison of product/construction FMEA and process FMEA [7]

	Product FMEA	Process FMEA
Criterion of analysis	fulfilment of utility functions by the product	Correct process realization, fulfilment of process requirements
Subject of analysis	Product, subassemblies, elements	Stages of process (operations, actions, procedures)
Asked questions	What causes may lead to total or partial disappearance of the product's function? What consequences may be associated with them?	What defects may occur in a given stage of the process and what may be their impact on the product/construction or service defects
Examples of defects	Element cracking, no medium flow	Wrong connection, breaking time, misadvising
Examples of defect causes	Construction defects, wear, service errors, environmental impact	Machinery/device errors, man mistakes, incorrect methods, incorrect material, incompetence, improper work organization
Examples of effects	Failure/loss of function, medical hazard/danger to life	Nonconformities, lower performance, high cost, too long waiting time

Estimation criteria and ranking system of three parameters (O, S, D) are determined by interdisciplinary team. In the case of severity "S" the value of 10 indicates that defect influences the decrease of safety without warning. The value of 1 means that there is a lack of effect/cause. In this case the defects/failures are not subject to further analysis.

Occurrence (O) analysis depends on causes of potential defects. Grading scale of "O" is similar to Severity factor. The value of 10 means a high probability of defect occurrence, the value of 1 indicates that the probability is low.

Detection (D) analysis evaluates a method of control – detection of defect/failure. It has, similar to occurrence and severity factors, 10-degree mark scale. The value of 1 means that it is not possible to produce defective elements. Value of 10 indicates lack of possibilities of defect/failure detection.

FMEA method prefers activities causing a decrease of occurrence than detection of defect/failure. It is recommended to decrease the values in following order: severity, occurrence and finally detection.

The FMEA analysis on a specially designed sheet is carried out. Numerically indicated form elements have certain functions [4,7]:

1. Identifiers – in this part of the sheet data defining the system and information regarding responsible persons with date of analysis start and finish are given.
2. Elements and functions, determine an element number and the function which it performs.
3. Potential defects, they identify all potentially possible defects and incorrect functioning.
4. Potential causes of defect occurrence, column contains all possible causes or failure mechanisms.
5. Potential causes of defects, specify possible failures perceived by a final or internal client.
6. Control methods, column defines measures used to prevent defects detection.
- 7, 8, 9, 10 – O, D, S parameters and RPN factor, numerically determine a relation of defect – cause – effect and remedial priorities.
11. Recommended remedial means, determine corrective actions for defects with the highest RPN factor.
12. The actions describe actual preventive actions taken under analysis.

The last part of the FMEA analysis are corrective and preventive actions. These activities consist of [7]:

- a) elaboration of corrective/preventive actions,
- b) determination of means, responsible persons, deadlines,
- c) supervising the preventive and corrective actions implementation,

- d) elaboration of an expenditure/benefit balance,
- e) actions aimed at reducing costs caused by defects.

The advantage of the FMEA practical application is an effective detection of failures, causes and noticeable effects for a client. Moreover, detailed analysis influences the employees' knowledge about a process or product and allows to reduce manufacturing costs or increase of the quality level in the enterprise. To the negative effects of this method for organization belong employment of a competent and trained staff as well as incurring a significant capital expenditure and time [4,7-9]. Following reasons why FMEA does not meet expectations are determined [10]:

- one person responsible for the analysis carried out,
- an attempt to create a sheet during one meeting,
- inadequate person supervising work on the FMEA sheet,
- team without qualifications,
- lack of prioritization with respect to detected defects.

Nowadays, the FMEA method is used in all branches and industries, for each type of product and process, at every stage of development, starting from design through production to the exploitation of a product [4,7,11,12].

FMEA method can be combined with other quality tools (e.g. Ishikawa diagram). The advantage of this methods is detailed problem analysis.

3. FMEA analysis of the selected technological process

Analysed enterprise produces a modern chimney systems and ventilation system elements. The company's products are based on own solutions and systems.

FMEA analysis for the selected operations (bonding and welding) of the chimney system production process was carried out (Tab. 2).

3.1. Characteristics of the final product

The final product is a system of chimney liners for the discharge of fumes, securing the existing ceramic chimneys and adapts the chimney cross-section to the requirements of modern heating devices for energy solid fuels as well as heating oil and gas. The chimney system of high-chromium steel (acid-resistant) are made. The product is characterized by high thermal conductivity and resistance to flue gas. The connectors are made of plasma welding technology and flare connection technology, which guarantee the proper tightness of the set. The product is mainly used in single-storey and multi-storey residential buildings.

Table 2.

FMEA analysis of two operations (bonding, welding) of the chimney system production process

OPERATION	POTENTIAL DEFECT	POTENTIAL EFFECTS OF DEFECTS	POTENTIAL CAUSES OF DEFECTS	S O D			RPN	RECOMMENDED CORRECTIVE ACTIONS	RESULTS OF ACTIONS			
				S	O	D			S	O	D	RPN
BONDING	the bonds prepare too close together	material separation, low durability	incorrect diameter of the bond, employee error	7	4	6	168	verification of bonding parameters, development of a pictorial instruction	7	4	3	84
	low durability	complaints	incorrect positioning of bonding elements, improperly selected places for making bonds, incorrectly selected bonding parameters	7	9	2	126	verification of bonding parameters, introduction of a training system, development of a pictorial instruction	7	8	2	112
WELDING	the discontinuity of the weld	product leak, material separation, delays in the execution of orders	extinguishing the arc, incorrectly selected welding parameters, damage of the nozzle, wear of electrode	9	4	4	144	verification of welding parameters, increasing the frequency of servicing, often electrode replacement	9	4	3	108
	shifting the edges of the element to be welded	incorrect geometry, product leak, lack of socket, complaints, delays in the execution of orders	incorrect placement of the part in the machine, incorrect calibration, incorrectly adjusted welding parameters, damage in inter-operative transport	7	9	4	252	focus on fixing the part in the machine, additional control of calibration correctness, verification of welding parameters, change of the transport means	7	9	2	126
	discoloration of the weld	corrosion, reduced durability, low aesthetics, complaints	incorrectly adjusted welding parameters, incorrect gas shield	7	3	4	84	verification of welding parameters, the gas mixture flow control	7	3	3	63
	lack of smelting	reduced connection strength		3	8	3	72	verification of welding parameters	3	8	2	48

The basic system consists of five elements: a chimney roof – it is an external element of the system, it has a protective function (mainly against rainfall), roof transition – allows to run the flue pipe from the heating device through the elements of the building walls, straight pipe – a conduit for the discharge of fumes outside the building, a tee – allowing connection of the system to the device heating and cleaning – it allows for periodic cleaning of the system with soot deposited in the system.

3.2. Characteristics of the analysed manufacturing process

The production process of the chimney system begins with receipt of the material from the supplier.

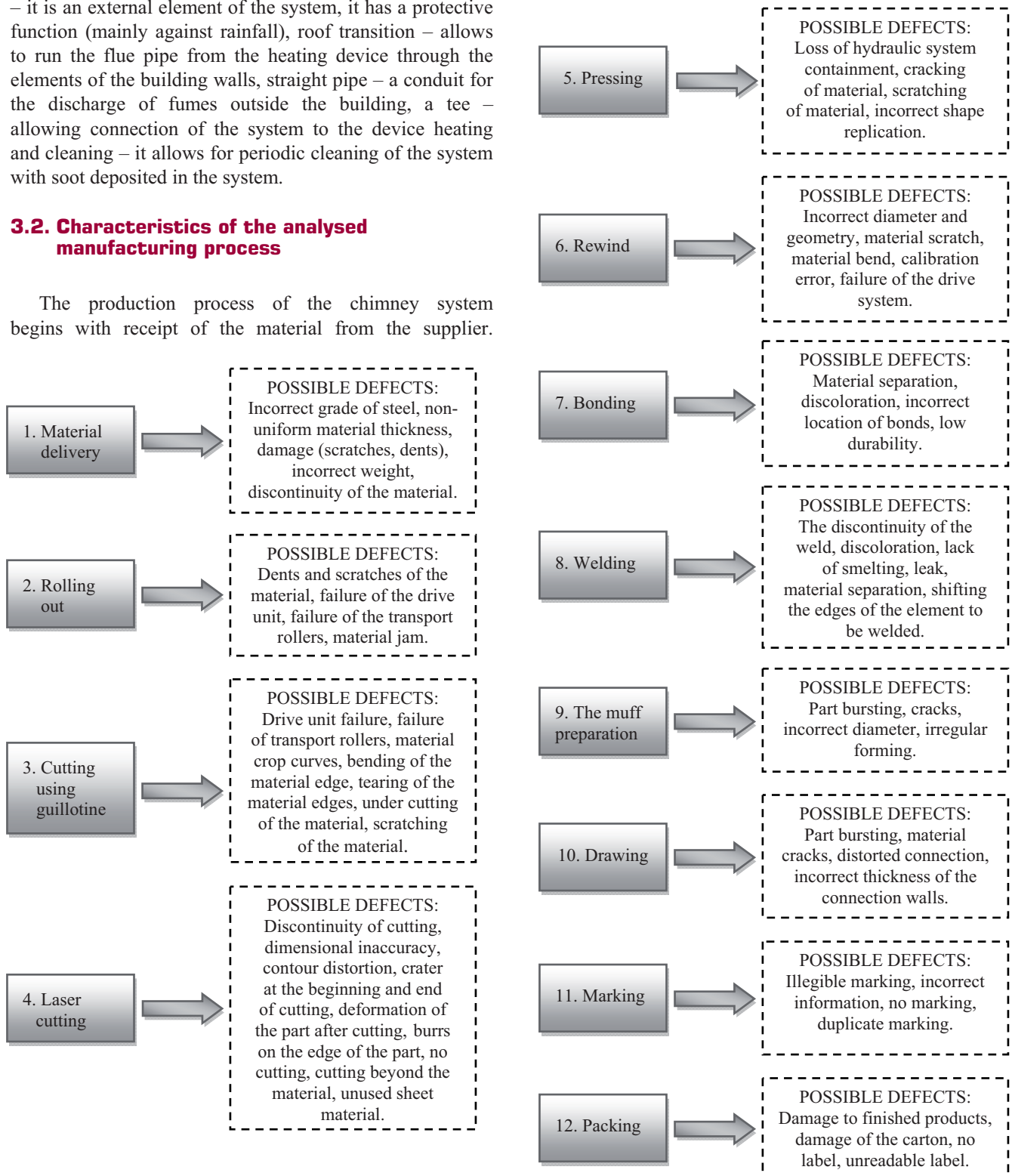


Fig. 1. Potential defects for operations of the chimney system production process

The first production stage is related to the acceptance control of the input material in the form of a steel sheet roll with a 0.5 mm thickness (in the case of the product under analysis). The control procedure is based on visual inspection of the surface roll in search of discolorations, inclusions, cracks or discontinuities of the material. The next step of the procedure is to measure the thickness at random points of the sheet using a micrometre. Randomly (or always in the case of supplier change) a steel sample intended for laboratory tests in order to determine their chemical composition is cut. The absence of any defects in the material qualifies it for use in further operations of the technological process. The sheet metal roll is transported to the developing station. The automatic decomposer coupled with the guillotine unwinds the material from the reel and cuts it into a sheet of a given length. Sheet metal is transported by a hand platform truck to the laser cutting station, where the operation of cutting the required shapes from the sheet with a beam of light takes place. The products of the operation are: tube sheets, sleeve, legs, base and flange cleaning and hat cap. The sheets of legs, the collar of the cleanout and the cap of the hat go to the position of the hydraulic press, where the sheet is bent to obtain the correct shape. The sheets of tubes and sleeves reach the station where the coiling operation is performed. The automatic coiler properly deforms the material and calibrates the diameter so that in the next operation the weld can be performed on an automatic plasma welder (own material). The other elements are joined together at the spot welding station. At this stage of the process, a complete chimney roof (legs, hat, sleeve) and a roof passage (base, sleeve) are obtained. The tubular elements are subjected to a kneading operation to obtain cup joints. As a result of this operation, the final form of a straight pipe is obtained. The next step is welding the collar to the pipe. The last operation of the last execution of the tee element is the bell's opening of the hole. The received elements of the chimney system are subjected to 100% quality control. The next stage of the technological process is marking individual elements on the ink-jet marking machine and then packing them into boxes. The marked and secured final elements are stored in the finished goods warehouse. Figure 1 presents all the potential defects identified for individual operations in the production process of the chimney system.

3.3. The results of the FMEA analysis for the technological process evaluation

In order to perform the failure mode and effects analysis, specialist information on possible discrepancies at

each stage of the technological process were collected. Then, the possible effects of their impacts were verified and specific corrective actions for defects with a risk priority number exceeding the limit of 60 points were proposed. The FMEA analysis of two operations (bonding and welding) of the analysed process was performed and showed in Table 2.

The results of the FMEA analysis showed that the corrective actions did not decrease the RPN factor below 60 points in all cases. The effectiveness of preventive actions is limited by the applied production technology and possibilities of the enterprise machinery. For the majority of identified defects, the application of proposed actions caused a decrease of RPN factor to acceptable level.

Increase of quantity of control points in the technological process was also proposed. This action allowed the identification of potential defects during the production of chimney system which cause problems in the process operations. These defects are: heterogeneous material thickness, dimensional inaccuracy of semi-finished products or their mechanical damages. The highest value of the RPN (252) was obtained for the defect in the form of detail edge displacement occurring during the welding operation. Limitation of nonconformities by application of preventive actions caused a decrease of RPN factor by half.

4. Conclusions

In order to achieve an effective quality management in a company, it is indicated to use instruments in the form of tools and methods that allow continuous improvement. Mechanisms contained in them allow the effective prevention of existing problems, detailed analysis of the causes of defects in the process or construction, and support planning processes, decision making or maintaining relations with the client.

The FMEA analysis is an effective method to identify or reduce negative effects of potential defects of a production process. In addition, a revision of FMEA document is an effective way to avoid the defects in the future. Correct determination of possible nonconformities and proposition of appropriate corrective actions are not possible without the participation of a group of specialists who have knowledge of this subject. The universality of this analysis is confirmed by numerous applications of the FMEA method in various areas of environmental management or occupational health and safety. However, the qualitative use is the most widespread in practice.

The analysis showed a multiplicity of potential threats resulting from nonconformities in the process of chimney

system production in the enterprise. Recommended remedial actions have the intended effect for the most of threats (they decrease the risk priority number below the established limit (RPN – 60 points). It was assumed that irregularities which not exceed the established limit are not qualify for taking any action due to the low profitability.

Critical nonconformities with high risk priority number occurring in operations of the analysed process (despite corrective actions) require further interventions or cost calculations. It is recommended to continue FMEA analysis of the process (in the case of a cost-effectiveness of such undertaking) or to modernize the machinery and change production technology.

Significant increase in the quantity of control points to improve the detection of defects in the analysed technological process was proposed. Increase of control points and training employees in the range of control during the realization of operations caused a reduction of manufacturing costs, improvement of the product quality and creation of the possibility of effective quality control.

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