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ENVIRONMENTAL FAILURE MODE AND EFFECTS ANALYSIS (FMEA) – A NEW APPROACH TO METHODOLOGY

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The purpose of this paper is to present a concept of FMEA analysis for environmental aspects, together with a discussion of the importance, implementation and application of the proposed concept. The analyses and the developed E-FMEA methodology have resulted in a proposal of management tools for manufacturing processes.

Key words: Industrial Management and Organization, Environmental Management, FMEA, Environmental FMEA, E-FMEA Methodology.

INTRODUCTION

Failure Mode and Effects Analysis (FMEA) is one of the most popular methods for the systematic prevention of errors. The problem of early defect detection has become so important to result in developing a method for identifying errors in the design phase of the product.

The analysis can be carried out for the whole product, a single component or a structural component of the product and for the whole technological process or any operation [1 - 5].

ENVIRONMENTAL FMEA

E-FMEA is one of ecodesign tools used in the product design process [6 - 9].

The environmental application of FMEA takes into account the environmental impacts caused by technical problems, deficiencies or irregularity errors or processes. This analysis can be used to make constructional, process and system improvements.

E-FMEA method allows for a systematic summary of potential environmental problems associated with a product or process, before their consequences appear [9].

The notion of 'environmental impact' is "evaluation free", while the notion 'environmental load' describes the negative consequences of influences and it can be used to evaluate the importance or the importance of environmental impact (S).

The second criterion involves potential technical causes used to estimate the probability of impact risk occurrence (O). Finally, one can estimate the possibility of influence of the causes and the related risk. For the criteria used to evaluate the importance of environmental impact (S), the probability of cause occurrence (O) and for the causes of influence (D), like in the quality area, values in the range of 1 (small risk) to 10 (high risk) are assigned. This is the way the product of these three values RPN (Risk Priority Number) is obtained [9].

METHODOLOGY OF E-FMEA

The authors assume that the essence of environmental management in an enterprise should be maintained within the range of environmental management of the manufacturing processes, including technology and infrastructure management, allowing to reduce the level of risk of process environmental impact.

Considering the above given assumption the methodologies for risk analysis of the environmental impact of the manufacturing process were developed.

The values of occurrence probability indexes, as well as significance and detection for environmental risk in E-FMEA analysis were defined.

The developed E-FMEA analysis uses the assessment of the three most important criteria to be met by production processes:

- meeting the legal requirements in the field of environmental impact,
- meeting the requirements for the impact of the technological process implementation on the environment,
- meeting the requirements for the effects of the infrastructure used in the manufacturing process - machinery and equipment.

The analysis assumed that the existing defects were also a burden for the environment - it is associated with the second treatment or disposal of the defect, which affects the assessment of the process eco-efficiency.

Table 1 sets out general criteria of the E-FMEA analysis developed.

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The result of the E-FMEA analysis is the risk assessment of the process impacts on the environment. The result in the form of numerical values constituting the product of three adopted values based on the description provided in Tables 2 - 4 is E-LPR. The critical value of the E-LPR above, used to define preventive/corrective actions to be taken, is established by the company.

Table 1 General criteria used in the particular parts of the E-FMEA analysis

Occurrence, O	Significance, S	Detection, D
Standards and environmental ranges	Standards and environmental ranges	The use of systems and supervising measures with regard to machinery and equipment
Stability and failure of machines and equipment	Stability and failure of machines and equipment	The use of systems and supervising measures with regard to the standards and scope of environmental processes

Table 2 Directions to adopt the O indicator

Possible risks for the risks of the process impact on the environment, including the exceeding of standards and scopes, the law established for the process and machine failures and technological equipment used in the process - that affect the environment.			
O	Occurrence		Characteristics
1	Improbale	Does not occur.	The violation of established standards and environmental ranges in a process is excluded. Stable, without the emergency operation of machinery and technological equipment.
2	Almost unbelievable	Providing an incompatible product (lack of) is almost impossible. Very high quality of the process and the ability of the machine.	Almost impossible violation of established environmental standards and ranges for the implemented process. Very high assurance that no failure of machinery and technological equipment will occur.
3	Rarely	There are shortcomings, but rarely. The high quality of the process and the capacity of the machine.	There are short duration violations of established environmental standards and scopes for implemented processes. High assurance of the absence of machinery and technological equipment failure.
4 5 6	Average	The appearance is very likely. The process has good qualitative ability, but is unstable.	The implementation of processes with established standards and environmental ranges, but there are temporary violations. A failure of machinery and technological equipment is probable or very probable.
7 8	Frequently	Frequent gaps are expected. The process is characterized by a low quality and is unstable.	The process is characterized by frequent violations of standards and environmental ranges. Frequently occurring failures of machinery and technological equipment with impact on the environment.
9 10	Very common	Error is almost unavoidable. The process is characterized by a very low capacity and the quality is unstable.	The process is often carried out at a level violating established standards and environmental ranges. Very frequently occurring breakdowns of machinery and technological equipment with impact on the environment.

Table 3 Directions to adopt the S indicator

The importance of the impact of machinery and equipment failure on the environment, the continuity of the process, exceeded environmental standards and ranges of the process			
S	Significance		Characteristics
1	Extremely small	The defect of the product will not affect the conditions of use. The disadvantage of the process will not affect in any way the quality of the product / service.	Failures of machinery and equipment in the process have no impact on the environment. No violation of environmental standards occurs.
2-3	Small	The importance of defects is small and leads only to a slight deterioration of the product. The disadvantage of the process slightly affects the quality of the product / service.	Failures of machinery and equipment are rare and have little impact on the environment, they require taking the standard methods for stabilizing the process. Shut down process is short, and does not significantly affect the continuity of production. Violations of the environmental standards do not occur often.
4-6	Average	The defect of the product provides a clear dissatisfaction. The disadvantage of the process significantly affects the quality of the product.	The increasing number of machinery and equipment breakdowns have a clear impact on the environment, and require adopting standard methods to improve stabilization. The shut down process is short, slightly affecting the continuity of production. Violations of the environmental standards are rare, and their impact on the environment is local (for the area of machinery, equipment).
7-8	Large	It is impossible to use the product as intended. The disadvantage of the process results in a product incompatibility.	The occurring breakdowns of machinery and equipment have a significant impact on the environment, and require the use of more than just the standard methods of stabilization processes. The interrupted process seriously affects the continuity of production. Exceeding the environmental standards affects the environment around the production hall - workplace.
9-10	Very large - critical	The defect of the product endangers the safety of the user or violates the law. The disadvantage of the process can lead to the need of product repair.	The breakdowns of machinery and equipment have a large impact on the environment and people, and require the use of specialized methods to stabilize the process, including the intervention of specialized services unavailable to the company. The interruption process has a strategic level impact on the production continuity. Exceeding environmental standards affects the environment with an area larger than just the production hall / workplace.

Table 4 Directions to adopt the D indicator

The detection of machinery and equipment failure having an impact on the environment, as well as exceeding standards and environmental ranges in the process			
D	Detection		Characteristics
1-2	Very high	Control measures used and supervision provided make us almost certain that the product defect or disturbance of the process that the defect may cause will be detected.	The system and surveillance measures used provide almost full assurance and: • Predict the failure of machinery and equipment and its protection against the occurrence of environmental risk; • The stability of the process remains within the limits of accepted standards and environmental ranges.
3-4	High	The control measures used and supervision provide a good opportunity to detect defects in the product or a process interference .	The system and surveillance measures used provide a good opportunity to: • Predict the failure of machinery and equipment and its protection against the occurrence of environmental risk; • Detect the absence of process stability within accepted standards and environmental ranges.
5-6	Average	The control measures used and supervision provide a good opportunity to detect a fault or process interference, but they have limited ability to control it in 100% .	The system and surveillance measures used provide an opportunity to predict the failure of machinery and equipment and its protection against the occurrence of environmental risk.
7-8	Low	It is very likely that the measures of control and supervision do not detect a fault or process interference.	The system and surveillance measures used are not capable of predicting machinery and equipment failure and its protection against the occurrence of environmental risk.
9	Very low	It can be assumed with great certainty that the control measures adopted do not detect defects in the product or process interference.	The system and surveillance measures used allow for predicting the failure of machinery and equipment and its protection against the occurrence of environmental risk to a very small extent.
10	Impossible	There are no known means of control and supervision of detecting the product defect or process interference.	There are no system and surveillance measures available to predict the failures of machines and equipment and its protection against the occurrence of environmental risk.

CONCLUSIONS

The methodology of E-FMEA suggested in the paper is part of the scope of eco-management methods dedicated to manufacturing processes.

The purpose of the suggested method of E-FMEA is to improve both projects and the implemented manufacturing processes. It allows us to assess the environmental risk of productive processes in terms of individual operations, both involving manufacturing and transportation processes.

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Note: The responsible translator for English language is Jarosław Nasiek, Gliwice, Poland