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# FAILURE MODE AND EFFECT ANALYSIS AND ITS EXTENSION POSSIBILITIES

*In the 21th century, mass production is the main method of manufacturing. The occurring failures during mass production cause significant damages and lack of income. There the quality-centered mindset gains more and more importance. Nowadays, the focus is set on prevention instead of problem handling. The (Process) Failure Mode and Effects Analysis is one of the most widely used quality methods. Its aim is to map production failure modes, to prevent failure causes and to detect them. The utilization is specified by standards, but it is advisable as well for companies working in the production sector. In our work, we introduce the formation of Failure Mode and Effect Analysis and we point out the possible extension possibilities.*

***Keywords:*** *FMEA, prevention measures, detection measures, severity*

## INTRODUCTION

The aim of our work is to introduce Failure mode and Effect Analysis (shortly FMEA) and to point out its extension possibilities.

The development of FMEA started in the 20 century by the Military of the United States in the ’70s [1], afterwards the NASA recorded the method [2]. The American Army published its specification about the usage in 1980 (MIL-STD-1629 1980)[3].

The progress of industry branches show the necessity of FMEA usage. Nowadays, the spectacularly expanding automotive industry is aided by this systematical analyses. For example: with the development of electrical industry, the analysis of failure effects gains more importance [4]. Not only automotive companies, but mechanical manufacturers and even food industry is using it [5].

We can differentiate between four types of FMEA: System FMEA, Design (Product) FMEA, Process FMEA and Service FMEA. These types of FMEA cover the whole cycle of the product: the system, the product itself and its production process. If all analyses are made, it covers the whole product [6].

During FMEA creation, we examine potential failures, with placing them into a failure net. This way the failure is connected with its effect and cause. FMEA is an important element in quality management, because it reveals the non-conformities even on construction level; it identifies the severity, detection and prevention of the failures.

In our work, we focus on the production aspect of FMEA; in Chapter 2 we describe Process FMEA in general; in Chapter 3 we point out the evaluation of measures; in Chapter 3 we focus on the extension possibilities of FMEA and in Chapter 5 we summarize the next step of the research.

## DESCRIPTION OF PROCESS FMEA

Process FMEA is mainly used for the analysis of production [7]. It has a connection with other quality tools, such as Control Plan and 8D [8].The outcomes of P-FFMEA are the following: potential failure list ranked with RPN [9], list of special characteristics and a list of potential measures.

The advantage of P-FMEA are the corrective action plans; the development of Control Plans; the priorization of prevention measures and the documentation of process changes [6]. The FMEA process consists of four main steps: structural analysis, function analysis, failure analysis and measure evaluation.

### Structural analysis

Firstly, during the structural analysis the system elements are defined. The structural analysis can be a block diagram or even a simple flow chart. In case of P-FMEA the production processes must be divided to sub processes.

### Function analysis

In this step, functions are connected to the system elements. Function analysis defines the optimal behaviour of the process by statements [6].

### Failure analysis

At this stage the failures are derived from functions, they describe their non-fulfilment. The failure mode is in the centre of the failure net. (The result of the failure mode is the failure effect; the cause is the failure cause.) The connection between them is the following: failure effect-failure mode-failure cause.

During FMEA the failures may be repeated which causes the complexity of failure nets [6].

### Definition of measures

Measures are defined to prevent and to detect failure causes.

The rules for defining measures are the following:

- If the risk is very low, there is no need for measure definition (but in practice it is not accepted by customers);
- If the risk is moderate, measures are needed;
- If the risk is high strong actions are needed (validation and evaluation might be necessary);
- If the risk is critical, even the design, product, process or service must be changed.

Certain standards, handbooks of automotive manufacturers and suppliers contain rating catalogues (in this study we introduce the VDA P-FMEA rating catalogues) [6].

### Definition of prevention actions

Prevention describes how a failure cause can be avoided.

The rating of prevention effectiveness is evaluated with factor O (Occurrence) [10]. The rating is evaluated between 1 and 10. 1 is the rarest occurrence, 10 is the most common [11].

Ppm (Part Per million) data of production processes help to determine occurrence value [6].

### Definition of detection measures

Detection actions show the rectification of failure causes. The effectiveness of detection measures is measured with factor D (Detection) [9]. 1 is the most effective measure, 10 is least effective measure on the scale [6].

## EVALUATION OF MEASURES

The index-number of FMEA is the RPN [9]. RPN consists of the multiplication of of S (Severity) factor, O (Occurrence) factor and D (Detection) factor. The highest rating of each factor is 10, so the highest RPN rating is 1000.

### Severity evaluation

In case of failure effect rating, factor Severity (S) is used. In Table 1[12] we use the VDA definition of each severity category.

| Severity value | Severity category |
|---|---|
| Very critical 10-9 | Very critical failure, which affects safety. The failure costs are not acceptable. The produced products cannot be shipped out. |
| critical 8-7 | Strictly affected/decreased functions, where immediate intervention is needed. |
| moderate 6-4 | Decreased product/process functions. No immediate intervention is needed. High failure costs. |
| unremarkable 3-2 | Unremarkable effect loss, remote rework and failure costs. |
| very unremarkable 1 | Very unremarkable failure effect. Acceptable failure costs. |

Table 1 Process FMEA severity categories [12]

The very critical failures (rated with 9, 10) are those which result in the global non-conformity of the manufactured products. The failures effects might result in the scrapping of all products.

Critical failures (rated with 7, 8) need immediate intervention in the process, and cause very high failure costs. In certain cases, the products might be reworked.

Moderate failures (rated with 4-6) decrease the product/process functions. In this case no immediate intervention is needed. High failure costs might occur.

Unremarkable failures (rated with 2-3) have little impact and cause remote rework and failure costs.

Very unremarkable failure (rated with 1) have minimum effect with acceptable failure costs.

### Occurrence ratings

In case of occurrence rating the most likely failure cause is rated with 10, and the rarest with 1 (if it is a Poke Yoke solution) In Table 2 [12] we introduce the occurrence ratings according to VDA. We point out the correlation between occurrence ratings and process types.

| Occurrence ratings | Process categories |
|---|---|
| Very high 10-9 | New process without experience |
| High 8-7 | New process, with known but still problematic processes. |
| Moderate 6-4 | New process, with experiences of known processes. |
| Unremarkable 3-2 | Processes taken from similar practically tested practises. |
| Very unremarkable 1 | Known process with positive serial experiences and with positive process and machine capability studies. |

Table 2 Occurrence categories in P-FMEA [12]

New processes without experience are have very high ratings (rated with 9-10)

Failure causes with high occurence (rated with 8-7) occur at new processes which still have difficulties.

Failure causes of new processes with experiences from known processes have moderate occurence ratings (rated with 6-4).

Processes taken from similar practically tested practises have unremarkable failure causes (rated with 3-2)

Known process with positive serial experiences and with positive process and machine capability studies have very unremarkable failure causes (rated with 1)

## Detection ratings

In case of detection the failures causes the hardest to detect are rated with 10, and the failure causes most likely to detect are rated with 1. In Table 3 [12] we define the detection rating categories according to VDA.

Failure cause detection is very low (rated with 10-9), because there is no comparable process.

Failure cause detection is low (rated with 8-7) if the information about the comparable process are insufficient.

Failure cause detection is moderate (rated with 6-4) if there are existing comparable processes among new conditions (machine, material).

Failure cause detection is high (rated with 3-2) if there is an existing comparable process, with proven results.

Failure cause detection is very high (rated with 1) if experiences are available from proceeding comparable processes.

| Detection ratings | Detection categories |
|---|---|
| Very low 10-9 | Very low detection, because there is no comparable process. |
| Low 8-7 | Low detection, because the information about the comparable process are insufficient. |
| Moderate 6-4 | Moderate detection with existing comparable process among new conditions (machine, material). |
| High 3-2 | High detection, existing process with proven results. |
| Very High 1 | Very high detection, experiences are available from proceeding comparable process. |

Table 3 Detection ratings of P-FMEA [12]

## EXTENSION POSSIBILITIES OF FMEA

FMEA is the most known risk assessment and analysis tool. Nowadays, Process FMEA is mainly used for production processes, but the supplementary processes should also described with it to strengthen safety and effectiveness. This way FMEA can be conducted for work safety and ergonomic analyses as well.

Work safety examination studies the effect of 'human factor' on production processes. Safety relevant FMEAs can be very useful in industrial environments, where the employees are working with machines, tools and different materials [13]. Its aim is to define the effect of accident-prone situations, as well as the occurrence and detectability of failure causes. In case of a work safety oriented FMEA, the rating catalogue should be different as used at simple Process FMEAs. For example, in this case severity evaluations focus on the impact of human injuries. The worst-case scenario is death or permanent disability (the less serious effect can be minor injuries, such as scratches or bruises) [13]. The most serious effects as defined can cause a person's death, so the ratings have to be defined very carefully. One possible extension way of the traditional FMEA method to work safety analysis tool is to use further factors in the analysis. The values of possible treatment costs and duration can be also added the evaluation, this way DEA-FMEA is created. With further specification of risks (four categories: minor, tolerable, major intolerable) RDEA-FMEA is formed. DEA-FMEA and RDEA-FMEA carry more information than the 'classic FMEA'[13].

With analysing ergonomic aspect, the effects of work place conditions can be spotted on production effectiveness.  Not proper working conditions might cause serious problems to nowadays factories. Different costs may upcome, such as failure costs and costs of not-well utilized time. Ergonomic FMEA approaches might help to prevent the costs before they arise. It is very important to mention that 'back to Gemba' is very important in this situation. The work places have to visualised, which helps to solve the problems.

## SUMMARY

The most important aim of our study is to introduce the steps of P-FMEA creation. RPN is the index-number of failure causes. RPN consists of the multiplication of S, O, D factors. In our study we present rating catalogue examples of the VDA Handbook. With using these rating catalogues, each failure can be specified during the analysis. Furthermore, we present the possible extensions of the traditional FMEA into specific work safety and ergonomic FMEA. The aim of the authors is to carry out a sample P-FMEA with the focus on work safety and ergonomic aspects.

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***HIBAMÓD-ÉS HATÁSELEMZÉS ÉS KITERJESZTÉSÉNEK LEHETŐSÉGEI***

*A XXI. században a tömeggyártás vált egyértelműen a termékelőállítás fő metódusává. A tömeggyártásban előforduló hibák jelentős károkat, és bevétel kiesést jelentenek. Emiatt a minőségszempontú megközelítés egyre nagyobb teret hódít. A hangsúly a gyártási problémák kezelése helyett azoknak elkerülésére került. A Hibamód-és Hatáselemzés napjaink egyik legelterjedtebben alkalmazott minőségbiztosításai technikája. A célja a gyártási hibaképek feltérképezése, a hibaokok megelőzése, és azok detektálása. Alkalmazása szabványok által előírt, de egyben ajánlatos is a gyártó szektorban működő vállalatok számára. Tanulmányunkban a Hibamód-és hatáselemzés felépítésének bemutatása a célja, és kitérünk a módszer alkalmazásának kiterjesztésére is.*

***Kulcsszavak:*** *FMEA, megelőző intézkedések, detektálási intézkedések, súlyosság*

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