FUNCTIONAL SAFETY

FMEA – Failure Mode and Effects Analysis

Series of articles Functional Safety, Part 5

Introduction

"*Use of preventive quality instruments improves the product / process quality and reliability sustainably and counteracts potential problems early.*" This sentence can be found in most quality manuals. However, its introduction and implementation in practice is usually a lengthy process with some stumbling blocks.

In addition to FMEA, advance quality planning can include the QFD – Quality Function Deployment methodology, customer orientation, the PO – Problem Orientation methodology using PO-Matrix or a complete APQP – Advanced Product Quality Planning toolbox from the automotive environment with binding plans and guidelines.

In this part of the series of professional articles, we would like to take a closer look at an important part of advance quality planning – the FMEA. It will provide the readers with an understanding of the goals and benefits of preventive quality planning, discuss the fundamentals and the principle of FMEA, present the tools for FMEA and give tips and tricks for the implementation of an FMEA.

Advance quality planning and FMEA

"Quality costs, but the lack thereof costs much more. The troubleshooting costs for a product increase by a factor of 10 at every stage of development." This statement has been confirmed by many studies and has been accepted for a long time.

If checking a system concept costs e.g. €1,000, you can already assume a cost of €10,000 for troubleshooting in the development phase. If a potential defect is detected at the start of production, this already means a cost of €100,000. If the defect first occurs at the customer's site, its rectification can easily go to seven-digit amounts. Efforts and money should not be used for rectifying defects during production and on the field, but for avoiding defects altogether by means of preventive quality assurance during development and production preparation itself.

However, the effect of every defect is not the same, neither is the occurrence of its probability. This is where FMEA (Failure Mode and Effects Analysis) comes into play.
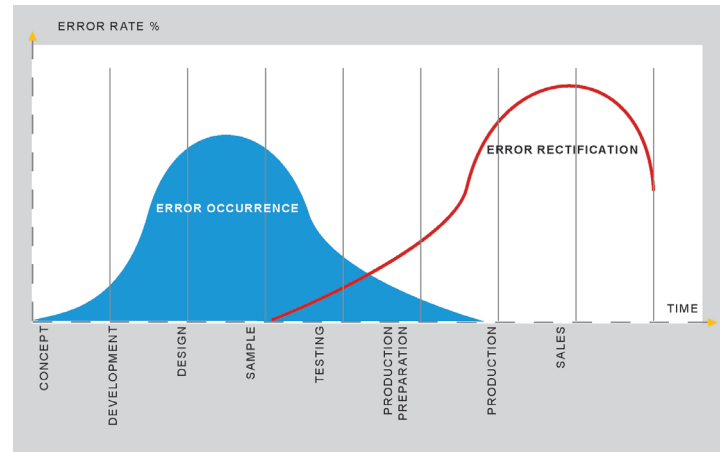

Figure 1: Block diagram of a safety-oriented drive – PDS(SR)

Fundamentals of FMEA

The FMEA is used to identify defects, their locations, effects and underlying causes. On the one hand, the objective of an FMEA is preventive identification of the correlations of potential defects, causes and consequences and the prioritisation of the cause-effect chains regarding their risk. On the other hand, it also involves preventive initiation of remedial measures for cause-effect chains with high risk.
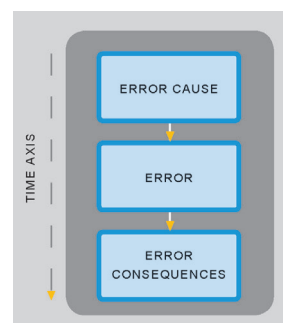
In other words, brainstorming for an existing or new product or process for possible weak points:

"What could happen?"; "What has already happened in other similar projects / processes?"; and to ensure that the weak points found are eliminated.

The fundamental principle of an FMEA is to correlate a defect to its causes and effects.

This will be illustrated by a practical example from the field of drive technology:
A rotary encoder is attached to the motor using a stator coupling. Incorrect installation of the stator coupling (*cause of defect*) can cause the stator coupling to come loose

or even break (*defect*) and lead to permanently incorrect signals (*defect consequence*).

The cause-effect chain is evaluated using the risk-priority number *RPN*. This is the multiplication of the significance of the defect consequences from the customer's point of view (*B*), the probability of occurrence of a defect with a specific cause of the defect (*A*) and the probability of detection of a defect with a specific cause (*E*), where the evaluation is carried out on the basis of an evaluation catalogue from 1 to 10.
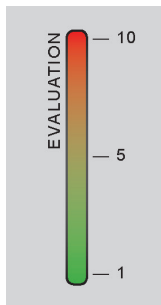
Risk-priority number $RPZ = B \times A \times E$
The higher the RPN, the greater is the risk of a potential defect.

Corrective measures
If an *RPN>100*, the risk is no longer tolerable and corrective measures should be taken, starting with the highest RPN.

Attention: The focus is on defect avoidance!
So if individual evaluations:
 B greater than *7*
 A greater than *5* and
 E greater than *6* exist,

these effects should also be checked, irrespective of the magnitude of the calculated RPN.

The above example of a cause-effect chain is shown below in a possible FMEA form.

Triggers for an FMEA

The trigger of an FMEA can be the definition and development of a new product or process, but it can also be the use of the product in a new application or the introduction of a new system.

A shortened form, the Design Review based on Failure Mode (*DRBFM*) method, is recommended for checking a product, a system or a process with a low degree of novelty when changes are made.

FMEA – variants

The Verband der Automobil Industrie (Association of the Automotive Industry, abbr. VDA) distinguishes between a system FMEA product and a system FMEA process, i.e. between the product characteristics that start from an ideal process and the production process characteristics that start from an ideally designed product.

In practice, the system FMEA product is usually divided into additional FMEAs, e.g. a safety development to determine the diagnostic functions (this specific FMEA is discussed in detail in the next article): These FMEAs build on each other and give input parameters to each subsequent FMEA.

As the name suggests, while a system FMEA allows analysis of the system correlations, a design FMEA deals with the individual design characteristics. The following illustration explains this.
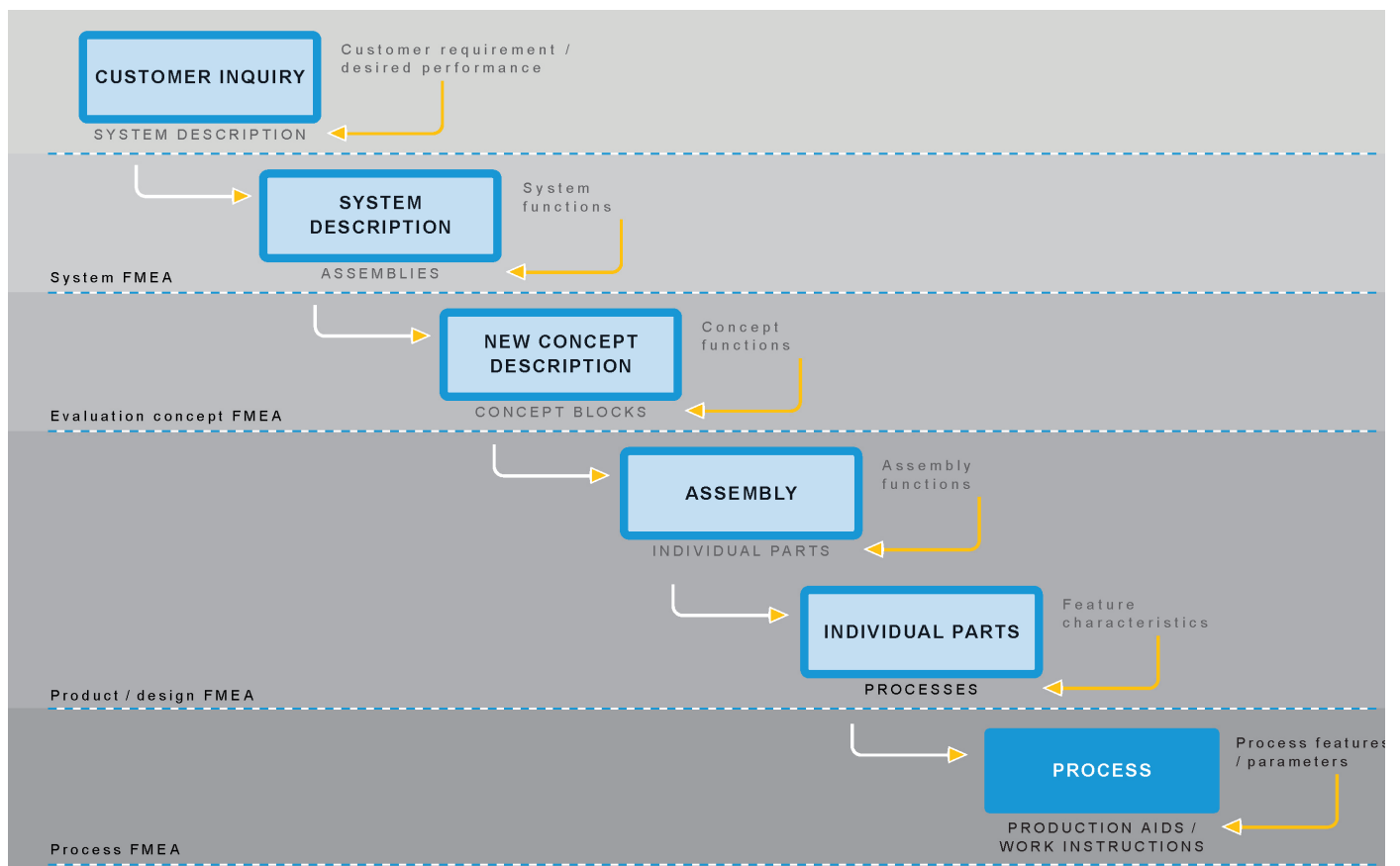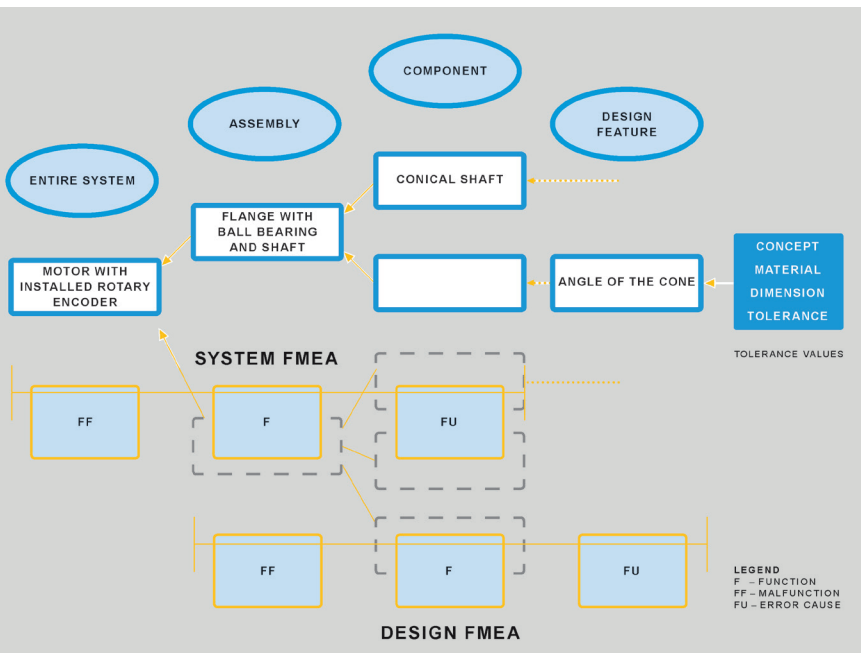
At the highest level, a process FMEA considers the overall system and/or the product to be delivered with its functions and malfunctions. Even the customer's requirements for the product in connection with the process are considered here.

The individual process or work centres are listed at the second level. As far as a function or a malfunction is concerned, the individual process or work steps for each station shown here must be carried out or might have been carried out incorrectly.

The third level has the following influencing factors according to Ishikawa – human beings, material, machine, method, milieu (environment).
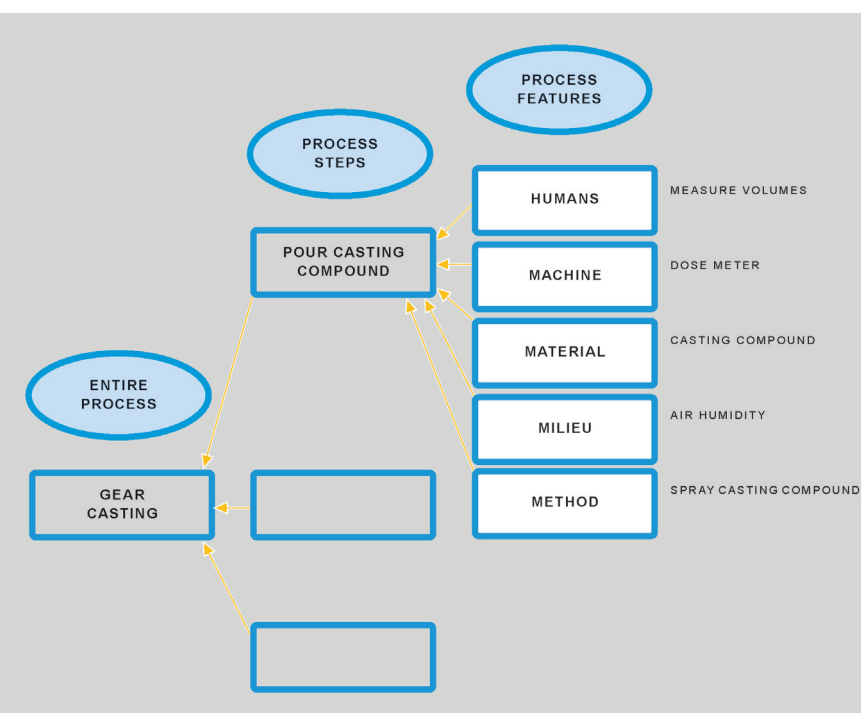

Figure 6: Clarification of the example in the text above

Tips and tricks for executing an FMEA

Generic FMEA
In order to reduce the effort for an FMEA in the medium term, it is advisable to execute a generic FMEA for recurring structural elements. Recurring structural elements have identical functions and structures. This generic FMEA can then be used for other products. The transferred scopes must be critically checked with reference to the respective use case, in particular the evaluation with the experiences from the application. It is important to ensure that changed dimensioning parameters do not lead to changed behaviour.

FMEA software tools & competence of moderators
There are a variety of proven FMEA software tools, from free products to products that are integrated into ERP systems such as SAP or Oracle Financials. These tools have advantages over standard spreadsheet forms. In addition to the graphical representation of structural elements, function and defect networks, these also simplify the partially generic use of FMEAs that have already been created and a control plan or inspection plan can be generated from the tool. However, there is no tool that allows a simple, efficient operation. The tools make sense only if FMEAs are available at least once a week, the company has trained full-time FMEA moderators and the FMEA methodology is established in the company.

It is recommended to invest first in the competence of FMEA moderators; FMEA software tools cannot replace the competence of moderators.

Who should participate in an FMEA and when should it take place?
An FMEA is basically a holistic approach, wherein the view of the customer, the view of development, the view of operating resources development, the view of production and the view of quality management are equally represented in an FMEA session.

- The system FMEA begins with the presentation of the requirements specifications
- The concept FMEA with existence of the description of the new concepts
- The design FMEA with presence of the detailed design
- The process FMEA can begin when the detailed design is available, but at the latest when the design is confirmed in the development process.
- The FMEAs are completed with the release for series production.
- The FMEAs build on each other and the points from the respective upstream FMEA, which cannot be resolved or contain references to the subsequent FMEAs, must be included in the new FMEAs.

- If an FMEA is not yet finalised at the end of a milestone, it is recommended that a limited, conditional milestone release with a short time frame for reworking is granted.

The FMEA documents are living documents during the course of the project up to the series release.

Basic information on FMEA moderation
- The moderator is not the one who creates logs.
- The developer(s) of a module, an assembly, or device are not the moderators or the ones who create logs.
- The developer(s) of a module, an assembly, or device are not the "FMEA questioners", but the ones who answer questions.
- The moderators discuss and clarify until the defect description and the answers are precise and specific.

Precise formulation of the defect and its cause
- *Incorrect:* "Diameter is not correct."
- *Correct:* "Diameter is too large."
- *Example of an "incorrect" answer*: "As is the case with standard product motors."
- *Example of a "correct" answer*: "The bearing distance is the same as for all motors that are manufactured in the standard program". The bearing load requirements for the motor do not differ from the bearing loads of standard motors. We have a 10x over-dimensioning of the parameters and these are tested by the standard product motors in the field".
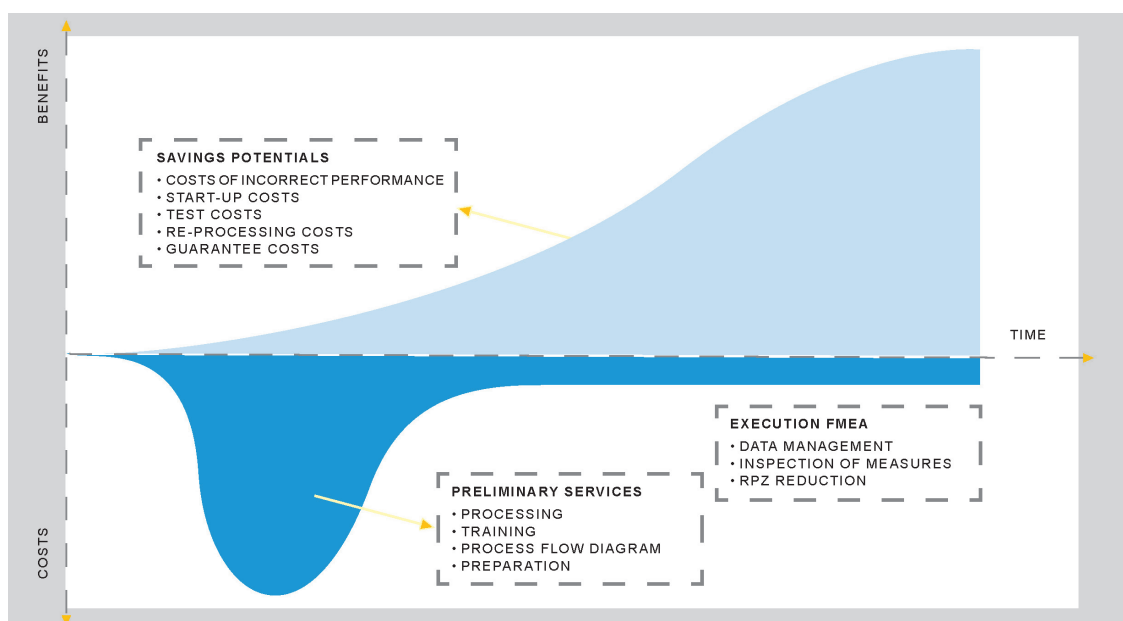
Summary and conclusion

It is not particularly difficult to learn the theoretical basics of FMEA, but there are still considerable hurdles to overcome when introducing it. The biggest hurdle here is the mentality of the individual developers, but also of the department heads and the management in some cases:
- The employees in the corresponding departments must deal intensively with the method, but often do not see any direct benefits.
- In the initial phase, there are high costs and hardly any visible improvements.
- The achieved savings and sales increases become apparent only during ongoing production or at the customer and are very difficult to measure (see figure 7).

If quality defect costs are recorded in the field, in production, in development, in quality control, the "fire brigade missions" are evaluated quantitatively, the awareness in the company for advance quality planning and thus also for an FMEA can arise quickly.

The FMEA is an established method that is widespread in the market. A company that wants to establish this method can build on the experience of others, be it through new employees with the necessary experience background or through external consulting. However, it is not advisable to establish the methodology on the basis of "textbook knowledge" and disregard the necessary practical experience.

Although the methods of preventive quality assurance cause short-term costs, they create far higher savings potentials in the long term by reducing the costs of mistakes. They help in reducing "fire brigade missions" and thus make employee deployment planning more reliable. They promote the company's reputation on the market.

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Figure 7: Achieved savings and sales increases during ongoing production

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