Product Quality Improvement Using FMEA for Electric Parking Brake (EPB)

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Abstract. One of the most frequently used methods to improve product quality is complex FMEA. (Failure Modes and Effects Analyses). In the literature various FMEA is known, depending on the mode and depending on the targets; we mention here some of these names: Failure Modes and Effects Analysis Process, or analysis Failure Mode and Effects Reported (FMECA). Whatever option is supported by the work team, the goal of the method is the same: optimize product design activities in research, design processes, implementation of manufacturing processes, optimization of mining product to beneficiaries. According to a market survey conducted on parts suppliers to vehicle manufacturers FMEA method is used in 75%. One purpose of the application is that after the research and product development is considered resolved, any errors which may be detected; another purpose of applying the method is initiating appropriate measures to avoid mistakes. Achieving these two goals leads to a high level distribution in applying, to avoid errors already in the design phase of the product, thereby avoiding the emergence and development of additional costs in later stages of product manufacturing. During application of FMEA method using standardized forms; with their help will establish the initial assemblies of product structure, in which all components will be viewed without error. The work is an application of the method FMEA quality components to optimize the structure of the electrical parking brake (Electric Parching Brake - E.P.B). This is a component attached to the roller system which ensures automotive replacement of conventional mechanical parking brake while ensuring its comfort, functionality, durability and saves space in the passenger compartment. The paper describes the levels at which they appealed in applying FMEA, working arrangements in the 4 distinct levels of analysis, and how to determine the number of risk (Risk Priority Number); the analysis of risk factors and established authors who have imposed measures to reduce / eliminate risk completely exploiting this complex product.

1. Introduction
Currently in automobile construction envisages, among other things, the satisfaction of customer needs, implementing the concept of Taguchi: Robust Quality. An argument for implementing this concept is to apply the FMEA both in the design and manufacturing processes and assembly components finished products in the automotive industry; envisages products are designed and manufactured to meet customer needs, despite the adverse conditions which appear and develop manufacturing processes. Taguchi suggests that it is more cost effective eliminating negative qualities of a nonconforming than it generates cause analysis [1, 4]. Developing this idea, Taguchi argues that
small changes in the quality of materials used in the manufacture of a product, and / or small changes in manufacturing processes, product quality not destroy, if it is conceived in the spirit of robust quality. In this idea can be defined as loss of function (Quality Loss Function - QLF); is a feature that identifies all costs related to poor quality (not correspond with documentation) of the product. QLF shows that these costs once determined, they have a trend which increasingly depends on the wishes of customers. General relationship calculation of this function is:

\[ P = D^2 C \left( \frac{RON}{product} \right) \]

In which: \( P \) - loss to society; \( D \) - Distance to the objective (target) chosen; \( C \) - total cost of deviations (deviations) than originally specified limits.

All losses due to poor performance of a product, which the company entered in a period are included in QLF. The products have lower losses, so they are more socially desirable. The losses are more severe, the products are spaced targets initially proposed. It was noted that the approach of a direct relationship between the quality of compliance and provisions documentation relating to the quality of a product (expressed as tolerances), is a simplistic approach, underperforming, if we take into account effects of inadequate quality, relative to some market, or more precisely a certain level of society. Following the continuous improvement process, from research and design-manufacturing-control planning -logistics- outlets will be continuously to the attention of the producers; they will use methods to improve these processes; one of the most commonly used is FMEA.

2. FMEA method

It is known FMEA is really a predictive process that determines where can malfunction and develop actions to eliminate or reduce their effect. As shown in the literature, using FMEA is primarily intended for new developments in safety related components or changes in products and processes [2].

![Diagram of FMEA method]

**Figure 1.** A detailed analysis of the flaws.

FMEA method is interpreted by the authors as a potentially significant new developments complete error analysis of products and processes [3].

Description of a analysis process FMEA covers two distinct areas: system analysis and risk analysis may occur due to system error occurred. (Figure 1); stages of analysis are:
The results of analyzes performed will be entered in a standard form, which has in its structure information about the product itself (components of product structure, failure mode potential, the potential effects of failure, level of severity), and information on how to conduct processes (potential causes of the failure of processes, preventive manner, mode of occurrence, failure mode of manifestation of the process, way of detecting processes. After analysis takes place prioritization of individual errors taking into account three aspects:

1. Capability multiplication of significant errors to the user. (Class B -type severity errors).
2. The probability of error in relation to its importance to the client (Class errors appearance -Type A).
3. The probability of error detection (error detection -Type D) Determine the Risk Priority Number (RPN) the product of three types of factors that generate the defect (RPN = BxAxD).

The objective of each company should be in the early stages of product development phases of research / product design, market studies and parallel preliminary, highly stable processes in terms of the performance guarantee. This implies that the design process to be effective and efficient. After Göbbert quality of a product will be in the future a criterion for differentiation in the global market.

Due to significant economic potential for preventing mistakes in recent decades have been developed to improve the quality of preventive techniques, both in the manufacturing steps and in matters involving executive management. Only producers can react at short notice to changes in customer product life cycle, and can also show the same level of quality required product supplied, can invest long-term in crucial resources for new product development. To prevent and reduce scrap in production in recent years’ specific preventive techniques are used management quality; Six Sigma method as part of scientific research is one of them.

On a scale from 1 to 1000, can make a detailed analysis of the flaws identified in the analysis system, as shown in Figure 1. During the interval, in the range from 1 to 1000, there are some significant features specific, of which the most important are:

- Distribution of RPN values is not uniform throughout the range.
- Because among the three factors there is a relationship product, the effect factors on RPN is disproportionately to reality; Such change with a unit of one of factors lead to changes RPN with a value equal to the product of the other two factors.
- RPN value chain there are blank areas called holes in RPN scale are becoming increasingly rare as it approaches the maximum extreme values.
- The measures are not necessary for all of the time; for the case presented only 88% of the values in the range 1-1000 are used.

![Figure 2. RPN values.](image-url)
From Figure 2 it is noted that the values of RPN are available in a range of 1-1000 differentiated. So:

- Range 1000 - 800 encompasses 3% of values
- Range 799 - 600 includes 6% of values
- Range 599 - 400 includes 14% of values
- Range 399 - 200 includes 22% of values
- Range 199 - 1 encompasses 55% of values.

Evaluation of importance failures, when applying FMEA / process or FMEA product can be done, taking into account certain general criteria for assessing the significance of defects. On the other hand, by using PRS can be sorted according to their relevance to various possible errors. RPN number at higher values determine what ultimately reduce the number RPN; These measures have the end result:

- be diminishing probability of error,
- be increasing the probability to detect this error in both cases
- elimination of error in each case lead to a reduction RPN.

The procedures for individual types of FMEA are essentially the same. They are based on cause-effect relationship; is charged in advance the effect of the error; it can be seen in the vicinity of the case that it generates, somewhere in the system due to which it belongs, or even outside the system. Making it possible to effect the error occurred, the type of error. Deepening analysis can determine the cause of the error; FMEA applying at different levels (system, process design, manufacturing processes), at any time, the cause of the error can be a result of the error, distinct to that level.

Applicability and use of FMEA is possible differently. On the one hand FMEA can be applied in a given system, which is structured parts overlapping and interrelated; FMEA application in this case is done sequentially at the system level and at the level of parts, to catch the error that prevented objective.

During the planning phase of FMEA are established scope of the FMEA methodology. Thus, the applicable system-level FMEA can be described as a development, an evolution, design FMEA and process FMEA; the last, in turn, can be subdivided into FMEA "montage" and FMEA "landmark". Each of these basic procedures are accompanied by a process of risk analysis, indicating that the critical points of the concept, using experience, the calculation, the testing and inspection will eliminate the hazard, or at least be reduced.

From the structural point of view, however, an overlap is possible / applicable parallelization between different types of FMEA: FMEA system, FMEA level design and process FMEA level. FMEA each procedure in this case is based on a different type of error; may appear overlapping areas of analysis, both types of error, and the causes that generate the error; that an error can generate other effects communicable ranks and be seen by them; by providing this overlap / duplication in applying FMEA, ensure describing interfaces at different levels, to highlight the domino effect caused by a fault.

Quality, cost and time are known as "magic triangle". Especially in the automotive industry and horizontal industry suppliers, these elements are crucial to overall efficiency, which is why they are in the spotlight. At first glance, it seems that the achievement of a high quality with lower costs at a time is a conflictual relationship goals. However, it can be shown that an improvement of the defects leading to an improvement in the net production. A strategy of "zero defects in production", increase a company's competitiveness by increasing production capacity, productivity of labor and delivery.

3. USE FMEA for E.P.B.
FMEA is really a predictive process that determines where can malfunction and develop actions to eliminate or reduce their effect. As shown in the literature, using FMEA is primarily intended for new developments in safety related components or changes in products and processes.

FMEA method is interpreted by the authors Dietzsch, Althaus and Brandner as a potentially "significant new developments complete error analysis of products and processes". One of the current systems integrated into the manufacture of automobiles is EPB 1 - Electrical Parking Brake.
system is supplied by the company producing packed with information specifically required to ensure quick installation, simple safe provided documentation related, and required by the automotive manufacturer. This ensures customer interface; these, in turn, by the specific conditions they impose the product, the manufacturer commits to a review /modification continuous product parameters.

Although FMEA method aims to prevent error and the relationship between cause and effect, it does not focus on the possible combination of errors. These combinations are investigated using the method FTA (Fault Tree Analysis) [5].

Avoiding errors in the early stages of the process, it is preferred rather than further improvement of product characteristics during the process; the idea is based on the fact that the detection and prevention of errors in the early stages causes lower costs than solving them in the later stages of the process.

This idea can be viewed using the rule "Factor Ten". It is assumed that the removal of an error in the phase in which it was discovered requires some expense; dismissed later in relation to timing, generates higher costs, amplified by a factor of ten [6].

Following are recommended in earlier phases FMEA process of developing a product or process and should be completed before the start of series production.

In the planning phase, the team has established components / technological operations that will be the subject of analysis and improve product performance designated team has considered applying FMEA four distinct levels:

- **Level 1** - EPB specific issues in relation to product features that are installed. (the gearbox)
- **Level 2** - Specific aspects of the motor drive unit
- **Level 3** - Specific aspects of installation processes of components in the structure of the motor drive unit.
- **Level 4** - Causes generating errors when installing the drive unit components.

Each level was drawn up by a sheet analysis, it analyzed the top level functions, are shown in green. Possible defects that can be reported, including during tests performed before and after installation, are shown in red.

For each possible error is attached Reting index of 1 to 10. Values on the scale of Reting are determined by each company, given the rules and quality indicators imposed by its technical level. But also with their customers' requirements are then determined the amount of Risk Priority Number (RPN).

It follows from this analysis that the main defect that could occur in EPB, is related to the clamping force / closing EPB, which is electrically controlled, and a number of issues related to the dynamics in time [7].

Once complete analysis of the 4 levels was passed in preparing possible network failures in manufacturing EPB. In same times was determined RPN for each situation individually. RPN for EPB's distribution is presented graphically in figure 3.

### 4. Conclusions

Six-Sigma method is suitable for scientific purpose, where the constant is introduced and implemented, both in the final manufacturing processes -montaj and horizontal processes of manufacturing the component. As a result, car manufacturers require their suppliers a supply of quality products at zero-defect, or somewhere near this level. Companies that supports and integrates a high level from the beginning of Six Sigma and can achieve cost reductions while ensuring certain quality levels available; while they also generate competitive advantages in terms.

The objective of this work took into account the need for a control program very detailed process of EPB assembly to maintain control of the assembly process; for which it was used the use, as an application carried out on four levels of the FMEA method. Based on information gathered in the technical documentation, and after studying the functions of the family EPB top products, divided into four levels top functions. Making each function is conditional on interconnection components belonging. For each level was drawn up a set of sheets of FMEA analysis, which were scored
separately so top functions and possible failures that may be raised during the conduct of inter operational tests or final testing; for each possible type of error was attached Reting by an index, with values of from 1 to 10; with these values determined by the Risk Priority Number value (RPN).

Risk assessment were conducted 53 tests of risk, which were developed and constructive solutions so that, when the prototype product is assimilated RPN to be at minimal risk levels appropriate range of values for RPN: 18-54.

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Figure 3. RPN Distribution for EPB 1.
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