Applying FMEA methodology to evaluate different shapes of car struts

A Maftei, A I Dontu and D P Barsanescu

Mechanical Engineering Department, Iasi Technical University, Iasi, Romania
E-mail: alexandru.maftei90@yahoo.com

Abstract. The automotive industry is forever growing and leading the world of research and development on a large number of fields; thus, quality assurance and functional safety are two of the main interest in today’s automotive world. The Failure Mode and Effect Analysis method is used according to ISO 26262 to enhance the product quality. Applying methodology learned from the FMEA standard one can compare different variants of the prototype from an early stage of concept and decide which design features will best suit the intended requirements of the system. The method used is comparing a few types of car struts design, but it’s not limited only to design, manufacturing and material being also brought in discussion and compared. All in the end the method has applicability for the early stage of the product, if it’s conducted with responsibility and documented accordingly.

1. Introduction

The evolutions of integrated systems o more complex designs, if forcing the automotive industry to do a better documentation of recurring problems. Functional safety analysis started in military applications, after that in the aviation industry and in the end in the automotive industry. Functional safety analysis is defined in ISO standard 26262, first draft of the standard was published in June 2009, since then more automotive constructors have start to align to the ISO rules.

The pursue of autonomous driving has led different countries to look for rules that will be applicable to assure the vehicles are road legal, ISO 26262 is the basis for such laws in countries like the United States and Germany. For example, in German legislation automotive constructors are responsible for the bodily injury of their clients if it can be proven that their systems failure lead to the incident. The responsibility may shift if the failure mode is not detected through conventional testing methods.

FMEA comes from the English acronym Failure mode and Effect Analysis, and it’s driven by the customers who ask for safer and quality products.

Applying the FMEA methodology from the start of the design process and in a correct way, can lead to the discovery from an early stage of the problems that may occur in the chosen design, and, in this way, prevent future failures through design changes or appropriate testing.

The FMEA can be described as an ordered group of activities which will:

- Identify and evaluate the potential failure mode and the effect of it for a given product or process;
- Identify actions which will eliminate or mitigate the change that the potential effect will manifest;
• Document the process; complete the process of defining the role of a design or process.

2. Method of conducting an FMEA

A very important factor in the success of an FMEA is the moment in the project lifecycle when it’s started. Normally an FMEA started in the concept phase of the project will help prevent a failure before happening and not just documenting that it happened. It is recommended that all the failure modes and effects to be implemented in the FMEA from an early stage and all of them should be addressed.

Studies conducted by the automotive Ford Company, has revealed that a great amount of money can be saved if time is invested in creating a FMEA best practice for development.

Generating a robustness and prevention of mistakes are 2 distinct methods, but they both complete each other. Both of them have their own point of interest and own power of influence to the system.

![Figure 1. Flow of information when doing FMEA. [1]](image1)

In Figure 1 we can see all the stages of how information from FMEA is flowing through the design process. The blue lines are the information flow in the project, and the black dotted lines are the experience gained and the feedback from the different stages of design. The lines with arrows on both edges are the interfaces between the FMEA and the REDPEPR (Robust Engineering Design and Product Enhancement Process) [1].

![Figure 2. Inputs and interaction of information in the DFMEA](image2)
3. Applying FMEA know how to set up a car strut analysis

Normally FMEA is not used to compare products between them, but there are opportunities to do some in the same interface on similar products, in this way differences, strengths and weaknesses can be compared directly before taking a firm design solution to the prototype phase.

We used APIS IQ-RM 6.5 software. The software has a special “variant” function, in which components, functions, failures and actions can be evaluated separately for every variant of the design and then compared between them in the same interface. In this way the other discussed solutions will not just be documented lessons learn in another format, but will be on hand in the same software when a question regarding design solution decision is asked.

For the car strut analyse the following criteria were brought in discussion:
- Complexity of structure and form;
- Functions and requirements;
- Failures and failure chain;
- Preventive actions;
- Detection actions.

The end result has given us the following structure tree “Figure 3” which respects the FMEA rule, we have Effect – Mode – Cause strategy applied.

![Car strut functions](image)

**Figure 3.** Structure tree of car strut analysis

**Figure 4.** Functionalities and requirements defined on Effect level.
Main functionalities and requirements of the vehicle strut were considered similar to all the considered types Figure 4, at this effect level also severity was defined according to VDA standard [2] for functional safety. A severity with value of 10 was considered for the failures that can lead to bodily injury or death of the user, and severity with value of 6 was considered for high costs or functional inconveniences. All of these functions and failures on the effect level were linked to failure modes for every type of strut.

We need to point out that there are very little differences between the analysed struts, the main differences will be made by the design itself and how well it can sustain the impact forces.

To have a correct evaluation a Risk Probability Number (RPN) has been calculated individual and analysed. The RPN is a simple calculation regarding Severity, Occurrence and Detection, in which we multiply all the factors, the formula will look like the one presented below.

\[
RPN = S \times O \times D
\]  

Figure 5. Construction types considered for the strut model.

The Occurrence and Detection values are different for every strut type analysed Figure 5, the VDA catalogue was used, and corresponding to what actions were implemented the values were defined. Because some designs are more complex and need more testing and proof of functionality, they will have a high RPN value than others.

![Figure 6. Functions and Failures defined on mode level.](image)

On the failure mode level, the functions and failures were defined Figure 6 in such a way in which to describe the manifestation of a failure mode directly linked to the causes.

![Figure 7. Functions and Failures defined on cause level.](image)
Figure 8. Preventive and Detection actions defined on cause level.

For the failure cause level, material characteristics were considered, together with geometrical dimensions and level of contamination, in this way the design can be improved by looking directly in these 3 areas Figure 7. Main difference between the struts in this analysis will be found at this level, for example the hollow strut will miss the geometrical dimensions which the cross-type strut has implemented. Preventive and detection actions are also slightly different and they are defined here Figure 8.

Figure 9. Pareto compact chart with top 10 RPN values for hollow design strut.
Generating a Pareto chart for the hollow strut design we can observe how the software, using the inputs given by us, is prioritizing the main functions in a graphic view Figure 9.

| No. | System element | RPN | S | O | D | Function | Failure | Effect | Cause | Preventive action | Detection action |
|-----|----------------|-----|---|---|---|----------|---------|--------|-------|------------------|------------------|
| 1   | Hollow car strut | 80  | 10| 2 | 4 | Car strut geometry absorbs impact forces in a controlled way | Car strut absorbs insufficient forces | [Car strut functions] Insufficient absorption of impact forces, too little | Material robustness | Testing: robust testing methods including customer requirements | Verification: FEA analysis regarding impact Test: impact test |
| 2   | Hollow car strut | 80  | 10| 2 | 4 | Car strut geometry absorbs impact forces in a controlled way | Car strut absorbs too much forces (collaps) | [Car strut functions] Insufficient absorption of impact forces, too much | Material robustness | Testing: robust testing methods including customer requirements | Verification: FEA analysis regarding impact Test: impact test |

**Figure 10.** Top 2 RPN for hollow strut.

If we put the main findings for hollow strut in a form sheet table, standard format for FMEA, we can observe for example all the actions that are coming tighter for the evaluation of the strut design, top 2 failure causes are highlighted in “Figure 10”.

If we look further in the analyse, to the other designs of struts, we can observe that the RPN values are different, according to the occurrence and detection ratings that were given, this does not mean necessarily that the design is worst, but its worst at this case when we don’t have sufficient information to prove the design of the concept better.

RPN values can be lowered by implementing additional actions to lower the chance of the failure from occurring (occurrence), or by adding additional verification methods to lower the detection value.

**Figure 11.** Pareto compact chart with top 10 RPN values for horse tail design strut.

We can see in Figure 11 and example from the horse tail design strut, this has a higher RPN, up to 160, instead of 80 as in the case of the hollow one. This is due to the differences in the occurrence and detection ratings, combined with links that are leading to the corresponding severity value from the system, tailoring these values with corresponding actions can change the shape of the chart.
If we want to understand what is happening different we need to look at the top RPN “Figure 12”, if we compare the top RPN for hollow design and the top RPN for horse tail design we can see that the RPN for the horse tail design is worst because of the risk of collapse, the design as we considered and analysed it was not appropriate for the application. For example, maybe changing the design will improve the outcome, but for now it can be shown in the Pareto chart.

4. Conclusions

- From the collected analysed data, we observed that longitudinal displaced design of struts is not good for the reduction of impact forces;
- The FMEA analyse is a good way to document the lessons learned in a structured manner;
- The results of the analyse can be maintained easily and with no effort in the used tool;
- The Pareto charts can be compared side by side but with extra effort, the software does not have this feature, but the values are easy to export as PDF for comparison.
- Decision on what design to go further with can be drawn by looking at a good documented FMEA of the product.

5. References

[1] Ford FMEA Handbook V4.2.
[2] VDA 6.1 German quality management system standard.
[3] Soumava Boral and others - A novel hybrid multi-criteria group decision making approach for failure mode and effect analysis: An essential requirement for sustainable manufacturing
[4] Sardar Muhammad; Sulaman Armin Beer; Michael Felderer; Martin H’ost - Comparison of the FMEA and STPA safety analysis methods--a case study