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# MACHINE DESIGN 2010

THE EDITOR IN CHIEF: PROF. PHD. SINIŠA KUZMANOVIĆ

NOVI SAD, 2010

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***Abstract:*** *According FMEA method, this paper represents the results of the analysis of causes and modes of failure of the cooling fan motors as a part of the cool liquid cooling system of vehicle. Description of the FMEA method is pointed out in the introduction of the paper. Based on detailed review of the structure and operation modes of the observed object and other relevant data, FMEA discovered the weak place in the construction of the fan-motors, and then after necessaries reconstructions we repeat investigation which gave positive results. In conclusion, the paper presents possible applications of the achieved results and the effects of the cooling fan motors reconstructions.*

***Key words****: Reliability, FMEA, Cooling fan motor*

## I I

During the last decades customers changed their buying behavior. After World War II the customer demand was very high and unsatisfied. Suppliers were producing only necessary goods and in restricted uantities. During the time transaction between customer and suppliers took place. The transaction from the typical sellers market too the buyers market was the result.

Globalization and World Wide Web are keywords for the society nowadays. Due to the fact that time and distance are becoming relative, customers are placing increased demands on high uality and reliable products. Therefore manufacturers invest a lot of time and money to increase uality. But the increasing capabilities and functionality of many products are making it more difficult for manufacturers to maintain the uality and reliability.

Traditionally, reliability has been achieved through extensive testing and use of techni ues such as probabilistic reliability modeling. These are techni ues done in the late stages of development. The challenge is to design in uality and reliability early in the development cycle.

Therefore engineers introduced *Failure Modes and Effects Analysis* MEA . MEA is a methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome these issues, thereby enhancing reliability through design. MEA is used to identify potential failure modes, determine their effect on the operation of the product, and identify actions to mitigate the failures. A crucial step is anticipating what might go wrong with a product. While anticipating every failure mode is not possible, the development team should formulate as extensive a list of potential failure modes as possible.

The early and consistent use of MEA in the design process allows the engineer to design out failures and produce reliable, safe, and customer pleasing products. MEA does also capture historical information for use in future product improvement.

A subject of research are cooling fan motor type MH-KL, products of company Zastava PES Surdulica, implemented for car cooling systems and heating or air conditioning of passenger space in the bus. Production of those electro motors is done according to different technical re uests and standards of auto industry.

ormer re uest of duration period of electro motors with collectors has been hours of work. Today the most famous world producers of cars and other vehicles demand duration period of working hours and hours for buses.

In accordance with producer s regulation task of research is to increase duration time of electro motors with collector from to hours. Application of MEA in re-design process of the auto cooling fan motors MH-KL is done, potential hazards and failures are identified and premeasures are defined for problems overcoming and lifetime of systems increase.

## I I I V I
I

Security and safety have a special place in all vehicles types. Safety increase can be achieved by taking measurements of accident prevention active security or, taking measurements for minimum conse uence in case of accident passive security . Vehicle cooling system is one of most important system for internal-combustion engine security and safety. It provides that engine s working temperature is in permit limits and without breakdown.

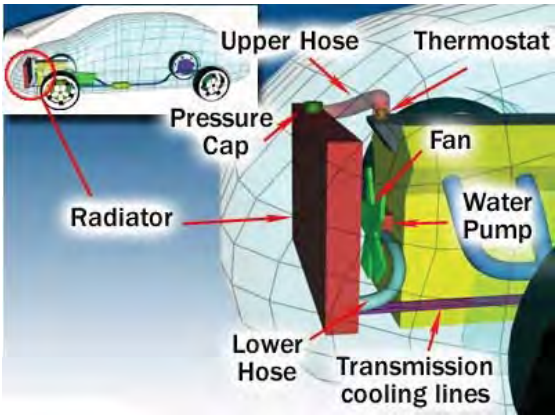


*Fig. 1. Diagram of a cooling system*

Components of car cooling system ig. li uid, radiator, water pump, thermostat, tubes, fan electro motor in further text electro motor with working circuit , it need to reduce temperature in very short time and to prevent internal-combustion engine damage.
The most important system for vehicle cooling system is electro motor, it moves rotor of working circuit, and in further course it will consider EM structure and functional way.

ailure Mode and Effects Analysis MEA is a structured, ualitative analysis of a system, subsystem, or function to identify potential system failure modes, their causes, and the effects on the system operation associated with the failure mode s occurrence. If, as is usually the case, the MEA is extended to include an evaluation of the failure criticality as assessment of the severity of the failure effect and its probability of occurrence the analysis is called a ailure Mode, Effects, and Criticality Analysis MECA and priorities are assigned to the failure mode.
The MEA task generally demands two sets of re uirements. One set, which is called general re uirements specifies the implementation re uirements, input information re uirements, and documentation or output re uirements. The implementation re uirements provide general information and ground rules such as how the MEA will be performed, and to what level of abstraction it will be performed. The input re uirements define the information needed from designers, system engineers, reliability and safety engineers. The documentation or output re uirements of the MEA task can take on many different forms depending on the applicable standards. The documentation of the information produced by the MEA must provide the needed critical information without unnecessary details. The other set of re uirements, called detailed re uirements, consists of the analytical portion of the MEA. The MEA takes a systematic approach for determining and evaluating each system, subsystem, part and component historical failure modes. This aspect of the analysis is called the failure mode portion MEA. Once the failure modes have been defined for the system, the potential effects, or impact on each part of system are evaluated according to the mission system safety.
The MEA can be extended to determine the criticality of the effects of each failure mode according to criticality criteria which involve the probability of the failure mode and the severity of the effect. The formal approach to this analysis was developed and documented in US Military Standard . It is used to assess the safety of various system components, and to identify design modifications and corrective actions re uired to reduce the effects of a failure on the system. Although MECA is often thought of as a safety analysis, its main benefit is that the system designers learn more about the system while provide the analysis. Hence MECA should be done iteratively as the design develops.
A MECA is potentially one of the most beneficial analyses done in a well reliability program. It is also one of the most tedious, time consuming, error prone and difficult in development of a product. Hence a computerized aid needs to be developed to help in performing the analysis.
The MECA methodology is based on a hierarchical, inductive approach to analysis. Before beginning, the analyst must have a good understanding of the system components and the system operation and mission. The analyst then determines how every possible failure mode of each system components, affects the system operation. When the analysis is completed the analyst should have a clearer and deeper understanding of the system components and their relationships to the system operation and mission.
As mentioned in the previous section MECA extends the MEA to include the probability of the item failure modes and prioritize them for corrective actions. Traditionally, the criticality assessment is performed be either
- developing a Risk priority Number RPN
- calculating an item criticality number.
The RPN method is used mostly in the automotive industry and the criticality number techni ues is used mostly in the nuclear and aerospace industry.
We will pay attention in this paper especially RPN techni ues. The uses linguistic terms to rank the probability of the failure-mode occurrence, the severity of its failure effect, and the probability of the failure being detected on a numeric scale from to .
These ranking are then multiplied to give the RPN. ailure modes having a high RPN are assumed to be more important and given a higher priority than those a lower RPN. The described in MIL-STD- A, first categorized the severity of the failure mode effect and then develops a criticality ranking which is, in essence, the probability of a failure with that severity occurring. The procedure consists of determining the failure effect probability $\beta$ , the failure mode ratio $\alpha$ , the part failure rate $\lambda$ and its operating time $t$ , and using these values compute a criticality number for each item failure mode severity classification.

There are several types of MEA s. Some o them are used much more often than others. MEA s should always be done whenever failures would mean potential harm or injury to the user of the end item being designed. The different types of MEA can be seen in table .

*Table 1. FMEA – types usage*

| | |
|---|---|
| System | focuses on global system functions |
| Design or Construction | focuses on components and subsystems |
| Process | focuses on manufacturing and assembly processes |
| Service | focuses on service functions |
| Software | focuses on software functions |

When do we use MEA In the past, engineers have done a good job of evaluating the functions and the form of products and processes in the design phase. But the designing in reliability and uality was a huge problem. Often the engineer uses safety factors as a way of making sure that the design will work and protected the user against product or process failure. As described in an article from the Mechanical Engineering A large safety factor does not necessarily translate into a reliable product. Instead, it often leads to an over designed product with reliability problems.

With MEA the engineer get a tool with can assist in providing reliable, safe, and customer pleasing products and processes. MEA helps the engineer to identify potential product or process failures.

MEA can be used to develop product or process re uirements that minimize the likelihood of those failures. MEA is also the basis for

- Evaluate the re uirements obtained from the customer or other participants in the design process to ensure that those re uirements do not introduce potential failures.
- Identify design characteristics that contribute to failures and design them out of the system or at least minimize the resulting effects.
- Develop methods and procedures to develop and test the product process to ensure that the failures have been successfully eliminated.
- Track and manage potential risks in the design. Tracking the risks contributes to the development of corporate memory and the success of future products as well.

MEA ensures that any failures that could occur will not injure or seriously impact the customer of the product or process. There are several different approaches to do a ailure Modes and Effects Analysis. One possible way is described in the following chapter. This way is a combination of two different internet sources. One is from Kenneth Crow and the other from Nomogen. In figure - we can see an overview about the MEA procedure.

It starts with the *FMEA Planning and Team Creation* down to *FMEA – Development* and then to the *Evaluation* of the results.

*Severity* is an assessment of the seriousness of the effect and refers directly to the potential failure mode being studied. The Customer in process MEA is both the internal and where appropriate, external Customer. The severity ranking is also an estimate of how difficult it will be for the subse uent operations to be carried out to its specification in Performance, Cost, and Time. The Ranking and suggested criteria are listed in table .

A common industry standard scale uses to represent no effect and to indicate very severe with failure affecting system operation and safety without warning. The intent of the ranking is to help the analyst determine whether a failure would be a minor nuisance or a catastrophic occurrence to the customer. This enables the engineer to prioritize the failures and address the real big issues first.

*Table 2. Severity guidelines for design FMEA (1-10 qualitative scale)*

| Effect | Rank | Criteria |
|---|---|---|
| No | | No effect. |
| Very slight | | Customer not annoyed. |
| Slight | | Customer slightly annoyed. |
| Minor | | Customer experiences minor nuisance. |
| Moderate | | Customer experiences some dissatisfaction. |
| Significant | | Customer experiences discomfort. |
| Major | | Customer dissatisfied. |
| Extreme | | Customer very dissatisfied. |
| Serious | | Potential hazardous effect. |
| Hazardous | | Hazardous effects. |

Identify the *causes for each failure mode*. A failure cause is defined as a design weakness that may result in a failure. The potential causes for each failure mode should be identified and documented. The causes should be listed in technical terms and not in terms of symptoms. Examples of potential causes include improper tor ue applied, Improper operating conditions, too much solvent, improper alignment, excessive voltage etc.

The *Occurrence* is the assessment of the probability that the specific cause of the ailure mode will occur. A numerical weight should be assigned to each cause that indicates how likely that cause is probability of the cause occurring .

or that failure history is helpful in increasing the truth of the probability.

Therefore historical data stored in databases can be used and uestions like the following are very helpful to solve this problem.

- What statistical data is available from previous or similar process designs
- Is the process a repeat of a previous design, or have there been some changes
- Is the process design completely new
- Has the environment in which the process is to operate changeable
- Have mathematical or engineering studies been used to predict failure

A common industry standard scale uses to represent unlikely and to indicate inevitable. The Ranking and suggested criteria are can seen in table Occurrence ranking and suggested criteria.

*Table 3. Occurrence guidelines for design FMEA (1-10 qualitative scale)*

| Effect | Rank | Criteria |
|---|---|---|
| Almost never | | ailure unlikely. History shows no failure. |
| Remote | | Rare number of failures likely. |
| Very slight | | Very few failures likely. |
| Slight | | ew failures likely. |
| Low | | Occasional number of failures likely. |
| Medium | | Medium number of failures likely. |
| Moderately high | | Moderately high number of failures likely. |
| High | | High number of failures likely. |
| Very high | | Very high number of failures likely. |
| Almost certain | | ailure almost certain. |

*Table 4. Detectability guidelines for design FMEA (1-10 qualitative scale)*

| Effect | Rank | Criteria |
|---|---|---|
| Almost certain | | Proven detection methods available in concept stage. |
| Very high | | Proven computer analysis available in early design stage. |
| High | | Simulation and or modeling in early stage. |
| Moderately high | | Tests on early prototype system elements. |
| Medium | | Tests on preproduction system components. |
| Low | | Tests on similar system components. |
| Slight | | Tests on product with prototypes and system components installed. |
| Very slight | | Proving durability tests on products with system components installed. |
| Remote | | Only unproven or unreliable techni ue s available. |
| Almost impossible | | No known techni ues available. |

Here we have to distinguish between two types of detection. On one hand we have to identify Current Controls design or process .

Current Controls design or process are the mechanisms that prevent the cause of the failure mode from occurring or which detect the failure before it reaches the Customer. The engineer should now identify testing, analysis, monitoring, and other techni ues that can or have been used on the same or similar products processes to detect failures. Each of these controls should be assessed to determine how well it is expected to identify or detect failure modes. After a new product or process has been in use previously undetected or unidentified failure modes may appear. The MEA should then be updated and plans made to address those failures to eliminate them from the product process.

The other thing is to asses the probability that the proposed process controls will detect a potential cause of failure or a process weakness. Assume the failure has occurred and then assess the ability of the Controls to prevent shipment of the part with that defect. Low Occurrence does not mean Low Detection - the Control should detect the Low Occurrence. Statistical sampling is an acceptable Control. Improving Product and or Process design is the best strategy for reducing the Detection ranking - Improving means of Detection still re uires improved designs with its subse uent improvement of the basic design. Higher rankings should uestion the method of the Control.

The ranking and suggested criteria are shown in table Detection ranking and suggested criteria.

The *Risk Priority Number* is a mathematical product of the numerical Severity, Probability, and Detection ratings

$$RPN = (Severity) \times (Probability) \times (Detection)$$

The RPN is used to prioritize items than re uire additional uality planning or action.

Determine *Recommended Action(s)* to address potential failures that have a high RPN. These actions could include specific inspection, testing or uality procedures selection of different components or materials de-rating limiting environmental stresses or operating range redesign of the item to avoid the failure mode monitoring mechanisms performing preventative maintenance and inclusion of back-up systems or redundancy.

After that we have to assign *Responsibility* and a *Target Completion Date* for these actions. This makes responsibility clear-cut and facilitates tracking.

Update the MEA as the design or process changes, the assessment changes or new information becomes known.

**I**

To achieve planned goal is to get lifetime of cooling fan motors from hrs to hrs, all parts from the fan motor s rotor, bearings, collectors etc, are analyzed from the aspect of importance for the motor functionality. Complete MEA analysis is done for every mentioned part and actions necessary for lifetime improvement are applied. One part MEA analysis of the applied improvements is shown in the Table .

*Table 5.*

| PES DP ZASTAVA PES SURDULICA | MEA | | | Product name Electrofan | | Drawing. No | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Responsible person | | Company | Delivery | Model System Machining | | | Technical Condition Changes | | | | | | | | | | |
| | | | | | Date | | Date | Page | | | | | | | | | | |
| | Present Condition | | | | | | | | | Corrective Actions | | | Improvements | | | | | |
| Component | unctional class | Type of malfunction | Conse uence of the failure | Cause of the failure | Controlling | Probability | Weight | ailure determination ability | Risk priority | Recommendations | Responsibilitys, planned dynamics of planning | Responsibilityes, planned dynamics of realization | Probability | Weight | ailure determination ability | Risk priority | | |
| Rotor | | ailure | ailure | Overheating of the rotor | Controlling electrode. Voltage measuring | | | | | Preassembling N wire , | Development Sector | After development of prototype series and samples as well | | | | | | |
| Rotor | | ailure | ailure | Overheating f the rotor | Power decrease | | | | | Novo design changes | Development sector | | | | | | | |
| Brushes | | ailure. Bad durability | ailure | Wearing of the collector | Durability testing | | | | | Load decrease, power decrease | Development sector, Production Sector | Documentation change I | | | | | | |

After definition of necessary actions, redesign of the electrofans is applied and experimental testings are started.

## I

In accordance to above note it can be concluded
The most important aims of the MEA, of the fan motors as a part of the car cooling system SUS, as key substructure

- through lab investigation, which bartered road investigation, receive systematic identification of all possible causes combinations which lead to unwonted event
- determinate of parts or operations which most seriously affect on certain reliability measurement and application need for measurement improvement

With MEA it can be concluded in which direction development need to go in the construction or in the production process of the fan-motors, for increasing of working time from to hours, and except invest in development and material uality control improvement, parts and subparts, new e uipment for production, this product does not charge input price increasing for raw materials material and parts .


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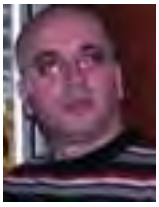

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