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MACHINE DESIGN 2010

THE EDITOR IN CHIEF: PROF. PHD. SINIŠA KUZMANOVIĆ

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CONTENTS:

. OPTIMUM DESIGN OF SANDWICH PANELS WITH FOAM CORE Heikki MARTIKKA, Erkki TAITOKARI	
. A BRIEF REVIEW OF STRUCTURE DESIGN AND AUTOMATION Djordje VUKELIC, Branko TADIC, Janko HODOLIC, Nenad SIMEUNOVIC	
. DESIGN FOR MODERNIZATION – A WAY FOR IMPLEMENTATION OF ECO IMPROVEMENTS OF PORTS CRANES Nenad ZRNIĆ, Srđan BOŠNJAK, Miloš ĐORĐEVIĆ	
. OPTIMALISATION OF BRITISH MACHINE PRESSING CHAMBER GEOMETRY Peter KRIŽAN, Ľubomír ŠOOŠ, Miloš MATIŠ	
. FEASIBILITY IMPLEMENTATION IN MOVING LOAD PROBLEM AT BRIDGE CRANES Vlada GAŠIĆ, Milorad MILOVANČEVIĆ, Zoran PETKOVIĆ	
. REDESIGN OF THE CONNECTING EYE-PLATE OF THE BUCKET WHEEL BOOM HOISTING SYSTEM Srđan BOŠNJAK, Nebojša GNJATOVIĆ, Nenad ZRNIĆ	
. AUTOMATION OF PRE-FABRICATED REMOVABLE STRUCTURES DESIGNING PROCEDURES Jovan VLADIĆ, Rastislav ŠOSTAKOV, Radomir ĐOKIĆ, Dragan ŽIVANIĆ	
. SIZE VERIFICATION AND DESIGN ANALYSIS OF PULLEY SHAFT AT LONEA MINING PLANT Iosif DUMITRESCU, Vilhelm ITU, Mihai Carmelo RIDZI	
. FATIGUE ENDURANCE DIMENSIONING BY STRAIN LIFE METHOD WITH A NOVEL NOTCH COEFFICIENT Ilkka PELLINEN, Heikki MARTIKKA	
. OPTIMIZATION OF CONTAINER QUAY CRANE LIFE TIME BASED ON NUMERICAL ANALYSIS Goran BOJANIC, Nebojsa RALEVIC, Milosav GEORGIJEVIC	
. MECHANISM SYNTHESIS OF MANIPULATOR OF MOBILE MACHINES Dragoslav JANOŠEVIĆ, Nikola PETROVIĆ, Vesna NIKOLIĆ	
. DESIGN, SIMULATION AND TEST OF MOBILE HEAVY-DUTY STRUCTURES Dragan MARINKOVIĆ, Zoran MARINKOVIĆ	
. IMPROVING THERMAL BALANCE IN INTERNAL COMBUSTION ENGINE USING THE TURBOGENERATOR Sławomir DZIUBAŃSKI, Jerzy JANTOS	
. FAILURE MODES AND EFFECTS ANALYSIS OF THE AUTO COOLING FAN MOTOR Branislav POPOVIĆ, Dragan MILČIĆ, Miroslav MIJAJLOVIĆ	
. A STUDY OF THE CENTRIFUGAL PUMPS DAMAGES FROM PETROCHEMICAL INDUSTRY Nicolae POPA, Cosntantin ONESCU	

. IN LUENCE O CENTRI UGAL PHENOMENON AT CVT OPERATING CONDITIONS Andrzej BIENIEK	
. COMPUTER AIDED DESIGN O THE CONNECTING ROD Vasile George CIOATĂ, Imre KISS	
. THE IN LUENCE O THE CAM PROFILE DESIGN ON THE CAM AND TAPPET HERTZ STRESSES AND WEAR Constantin ONESCU, Nicolae POPA, Ionel VIERU	
. THE MODELING AND DESIGNING O FLEXIBLE SYNCHRONOUS PRODUCTION LINE WITH REDUNDANT TECHNOLOGICAL CELL Oleg ILIPOVICH, Victor TARANENKO, Antoni SWIC, Lech MAZUREK	
. PASSIVE SAFETY OF MOBILE WORKING MACHINE LAMINATE CAB, ACCORDING ISO AND ISO STANDARDS Ján ŠEĎO, Martin TANEVSKI, Miroslav VEREŠ	
. VIRTUAL AND REAL HYDRODYNAMIC MODELS QUALITY EVALUATION BY LOW VISUALIZATION METHOD IN LOW LEVEL BATH Marketa PETŘKOVÁ, Miroslav VEREŠ	
. DESIGNING COMPUTER FROM MODEL TO FINISHED PRODUCT Goran NESTOROVIĆ, Živoslav ADAMOVIĆ	
. GENERATION OF THE APPROXIMATIVE HUMAN KNEE D MODEL BASED ON THE X-RAY Zoran MILOJEVIĆ, Slobodan NAVALUŠIĆ, Ratko OBRADOVIĆ	
. NEW METHOD FOR RADIAL STIFFNESS OF NODAL POINTS CALCULATION Lubomír ŠOOŠ, Peter KRIŽAN, Iveta ONDEROVÁ	
. DIFFERENTIAL PLANETARY TRANSMISSION OF WIND TURBINE CONTINUOUSLY VARIABLE TRANSMISSION Vojislav MILTENOVIĆ, Miodrag VELIMIROVIĆ, Jelena STEJANOVIĆ-MARINOVIĆ, Milan BANIĆ	
. HYBRID POWERTRAIN FOR LIGHT VEHICLE Andrzej LECHOWICZ, Jerzy JANTOS	
. GRIPPERS FOR INDUSTRIAL ROBOTS Peter KOŠŤAL, Jarmila ORAVCOVÁ, Miriam MATĚŠOVÁ	
. GEAR RATIOS OF PLANETARY DOUBLE STEP MULTIPLIERS FOR WIND TURBINES FROM MINIMUM VOLUME CRITERION Radu VELICU, Cristina BOZAN	
. ANALYSIS OF TYPICAL METHOD OF CONNECTION OF ELECTRIC MOTOR AND GEAR UNIT IN THE FRAME OF UNIVERSAL MOTOR GEAR REDUCER Siniša KUZMANOVIĆ, Sava IANICI, Milan RACKOV	
. THE DETERMINATION OF THE THICKNESS OF TOOTH SURFACE LAYER FROM THE ASPECT OF WEAR RESISTANCE Pavol TĽKALY, Miroslav BOŠANSKÝ, Attila VANYA	

. ON THE INFLUENCE OF GEOMETRY OVER THE CONTACT STRESS OF STRAIGHT BEVEL GEAR	
Bianca R. BUTUC, Gheorghe MOLDOVEAN, Radu VELICU	
. LOADS IN THE DISENGAGING PROCESS OF THE SAFETY CLUTCH WITH RADIALLY DISPOSED BALLS AND DOUBLE POINT FORM CONTACT	
Gheorghe MOLDOVEAN, Silviu POPA, Livia HUIDAN	
. ELASTIC AND SAFETY CLUTCH	
Ioan STROE	
. RISK OF SELECTING A TETRAHEDRON FORM STRUCTURAL MODELING	
Miomir JOVANOVIĆ, Predrag MILIĆ, Goran PETROVIĆ	
. BALL BEARINGS STATIC BEHAVIOR AND LIFE TIME	
Milan ZELJKOVIĆ, Aleksandar ŽIVKOVIĆ, Ljubomir BOROJEV	
. BEARING HOOKS MANUFACTURING PROCESS INNOVATION	
Miroslava KOŠTALOV, Svetopluk MEČIAR, Mária KAPUSTOV	
. KINEMATIC ANALYSIS AND SYNTHESIS OF COMPLEX MECHANISMS WITH HIGH CLASS KINEMATIC GROUP	
Maja ČAVIĆ, Milan KOSTIĆ, Miodrag ZLOKOLICA	
. CONSTRUCTIONS AND CALCULATIONS RELATED TO NON-CONVENTIONAL ECOLOGICAL APPROACHES FOR EARTH AND SPACE	
Milesa SREĆKOVIĆ, Mirko DINULOVIĆ, Vasko OTEV	
. INFLUENCE OF MICROCLIMATE ON THE OPERATIONS TIME STANDARD	
Miroslav CAR, Mario ŠPRLJAN	
. STRATEGIC MANAGEMENT OF TECHNOLOGICAL INNOVATIONS IN MANUFACTURING ENTERPRISES IN POLAND	
Božena GAJDZIK	
. DEVELOPMENT OF THE TOOL WEAR CONDITION CLASSIFICATION SYSTEM MODEL IN TURNING	
Aco ANTIĆ, Milan ZELJKOVIĆ, Petar B. PETROVIĆ	
. WORK TIME STRUCTURE MEASURING, THE TOOL WEAR STATE DETERMINING AND PROCESSES MANAGEMENT	
Goran LULIĆ, Miroslav CAR	
. BASIC DESIGN OF THE PROPOSED MANUFACTURING SYSTEM	
Miriam MATIŠOV, Erika HRUŠKOV	
. SENSORS APPLICATION IN THE INTELLIGENT ASSEMBLY AND MANUFACTURING SYSTEMS	
Nina DANIŠOV, Karol VELŠEK	
. ULTRASOUND SYSTEMS IN MACHINING TECHNOLOGIES	
Matjaž PEČIČEK, Marcela CHARBULOV, Angela JAVOROV	

. DESIGN OF PROFILED CUTTING TOOLS BY APPLYING PROGRAMMING SYSTEMS Bogdan SOVILJ, Snežana RADONJIĆ, Juliana G. JAVOROVA, Ivan SOVILJ-NIKIĆ	
. CUTTING PROCESS AND MACHINE TOOL INTERACTION ANALYZE Pavel KOVAČ, Marin GOSTIMIROVIĆ, Milenko SEKULIĆ	
. EXAMPLES OF GENETIC ALGORITHMS AND THEIR USE IN OPTIMIZATION OF TECHNOLOGICAL SYSTEMS Robert KOHAR, Slavomír HRČEK	
. OPTIMIZATION OF THE PROCESS OF BIMETALS LAMINATION AND THE TABLES PLATING USING THE ASYMMETRICAL ROLLING Vasile ALEA, Erika Monika POPA	
. CONTRIBUTION TO THE USE OF CAD/CAE SOFTWARE FOR SOLUTION OF CHOSEN FORMING TECHNOLOGICAL PROCESS Bohumil TARABA, Štefan HAJDU	
. STRESS ANALYSIS OF FORMING TOOLS USING CA SYSTEMS Mária KAPUSTOVÁ, Peter ZEMKO, Jana ŠUGROVÁ	
. A METHOD TO STUDY STRESSES AND DEFORMATIONS IN PIECES SUBJECTED TO HYDRAULIC PRESSURE Liviu COMAN, Draghita IANICI, Sava IANICI	
. MACHINING METHODOLOGIES WITH ULTRASONIC SUPPORT Angela JAVOROVÁ, Jantišek PECHÁČEK	
. FLEXIBLE ASSEMBLY SYSTEM GENERATION BY CAD AND PPS SYSTEMS Štefan HORVÁTH, Roman RUŽAROVSKÝ, Karol VELŠEK	
. TENSOMETRIC ANALYSIS OF THE LOAD CAPACITY OF THE MAIN BEAM OF DOUBLE - GIRDER OVERHEAD TRAVELING CRANE Krasimir KRASTANOV	
. POWER TRANSMISSION CONDITION MONITORING Miloš MILOVANČEVIĆ, Jelena STEANOVIĆ-MARINOVIĆ	
. A METHOD OF CONTACT ENDURANCE DETERMINATION OF GEARING BY ACCELERATED GEAR TESTING Nikolai ISHIN, Arkadi GOMAN, Victor STARZHINSKY	
. NON-DESTRUCTIVE EVALUATION OF YIELD STRESS OF COMPONENT IN MILD STEEL CONSTRUCTIONS Alexander POPOV	
. DESIGNING THE SYSTEM OF CONTROL OF THE STRAIGHTENING PROCESS OF LOW-RIGIDITY SHAFTS Oleg DRACHEV, Wiktor TARANENKO, Antoni SWIC, Jakub SZABELSKI	
. CONTRIBUTIONS REGARDING THE EVALUATION OF STRESSES AND DEFORMATIONS OF THE BULB TURBINES SHAFTS Mircea Octavian POPOVICIU, Ilare BORDEASU, Dragos Marian NOVAC	

. SERVICE LIFE TESTING OF LARGE SCALE BEARINGS	Slavomír HRČEK, Robert KOHŮR
. INTERLAMINAR STRENGTH-TESTS OF THE SURFACE LAYER BUILT UP WITH COLD METAL SPRAYING METHODS DURING RENEWALS	Lajos AZEKAS, Zsolt TIBA
. SIMULATION OF THE SOLIDIFICATION FRONT AT THE CONTINUOUS CAST HALF-FINISHED PRODUCT WITH ADDITION OF MICRO-COOLERS IN CRYSTALLIZER	Erika Monika POPA, Vasile ALEA
. ANALYSIS OF SURFACE ROUGHNESS FACTORS OF SOLID PRINTING AREAS ON LEAD PRINTING PLATES	Dragoljub NOVAKOVIĆ, Sandra DEDIJER, Miroslav GOJO, Sanja MAHOVIĆ POLJAČEK
. INFLUENCE OF VARIOUS CONCENTRATES ON QUALITY OF PRINTING PLATES WETTING PROCESS	Tomislav CIGULA, Miroslav GOJO, Dragoljub NOVAKOVIĆ, Živko PAVLOVIĆ
. MATERIAL LOSS IN AUTOMATED MANUFACTURING	Andrea MUDRIKOV, Peter KOŠŤAL
. ANALYSIS OF GRAY CAST IRON STRUCTURAL ELEMENTS	Georgi STOYCHEV
. COMPARISON SOME THERMO-CHEMICAL TREATMENTS FOR IMPROVEMENT WEAR RESISTANCE	Jeremija JEVTIC, Radinko GLIGORIJEVIC, Djuro BORAK
. INCREASING PRODUCTION EFFICIENCY OF HEAT TREATABLE AL-ALLOYS	Aleksandra PATARIĆ, Marija MIHAILOVIĆ, Zvonko GULIŠIJA
. AN APPROACH FOR PREDICTING FATIGUE LIFE OF NOTCHED SPECIMENS OF AZ MAGNESIUM ALLOY	Biliana DIMOVA, Veselin TSONEV
. PLASMA NITRIDING AS A METHOD FOR IMPROVEMENT SURFACE PROPERTIES OF POWDER METAL STEEL PARTS	Radinko GLIGORIJEVIC, Jeremija JEVTIC, Djuro BORAK
. SOME APPROACHES UPON THE HIGH TEMPERATURE BEHAVIOR OF ALLOYED STEELS DESTINED FOR MACHINE CONSTRUCTIONS	Imre KISS, Vasile George CIOATĂ
. BASE ELEMENTS FOR DESIGNING GALVANIZED STEEL STRUCTURES	Mihaela POPESCU, Carmen OPRIS
. CERAMICS TOOL MATERIALS WITH ALUMINA MATRIX	Katarina GERIC

. CONSIDERATIONS REGARDING THE EFFECTS OF MICROSTRUCTURE AND MECHANICAL PROPERTIES ON STEELS WITH VARIABLE NICKEL CONTENT, SUBJECTED TO CAVITATION EROSION Ilare BORDEASU, Mircea Octavian POPOVICIU	
. THE INFLUENCE OF THE PROCESSING TEMPERATURE ON MASS LOSSES FOR POLYOXYMETHYLENES (POM), POLYAMIDE (PA) AND THERMOPLASTIC POLYURETHANE (TPU) Gheorghe Radu Emil MĂRIEȘ, Ioan PANTEA, Simona Diana CHEREGI	
. CONSIDERATIONS ON THE EFFECT OF MICROSTRUCTURE AND MECHANICAL PROPERTIES OF STEELS WITH CONSTANT CHROMIUM CONTENT ON THE RESISTANCE TO CAVITATION EROSION Alin Dan JURCHELA, Adrian KARABENCIOV, Nicolae BIRAU	
. A NEW CONCEPT, THE STRUCTURE PRECONFIGURATION Dumitru DASCĂLU	
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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 necessities 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 quantities. 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 quality and reliable products. Therefore manufacturers invest a lot of time and money to increase quality. But the increasing capabilities and functionality of many products are making it more difficult for manufacturers to maintain the quality and reliability. Traditionally, reliability has been achieved through extensive testing and use of techniques such as probabilistic reliability modeling. These are techniques done in the late stages of development. The challenge is to design in quality 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 requests and standards of auto industry.

former request 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 consequence 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.

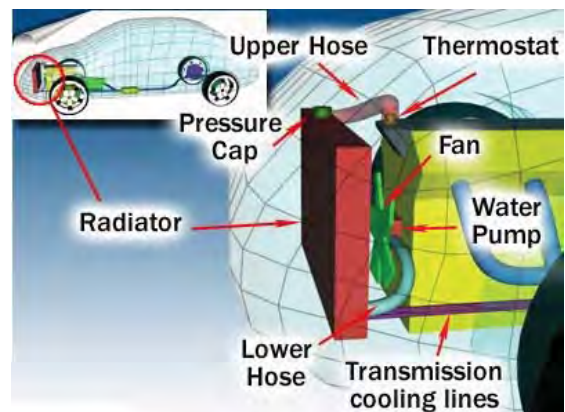


Fig. 1. Diagram of a cooling system

Components of car cooling system eg. liquid, 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.

Failure Mode and Effects Analysis (FMEA) is a structured, qualitative 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 FMEA 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 Failure Mode, Effects, and Criticality Analysis (FMECA) and priorities are assigned to the failure mode.

The FMEA task generally demands two sets of requirements. One set, which is called general requirements specifies the implementation requirements, input information requirements, and documentation or output requirements. The implementation requirements provide general information and ground rules such as how the FMEA will be performed, and to what level of abstraction it will be performed. The input requirements define the information needed from designers, system engineers, reliability and safety engineers. The documentation or output requirements of the FMEA task can take on many different forms depending on the applicable standards. The documentation of the information produced by the FMEA must provide the needed critical information without unnecessary details. The other set of requirements, called detailed requirements, consists of the analytical portion of the FMEA. The FMEA 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 FMEA. 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 FMEA 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 1633. It is used to assess the safety of various system components, and to identify design modifications and corrective actions required to reduce the effects of a failure on the system. Although FMECA 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 FMECA should be done iteratively as the design develops.

A FMECA 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 FMECA 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 FMECA extends the FMEA to include the probability of the item failure modes and prioritize them for corrective actions. Traditionally, the criticality assessment is performed by 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 techniques is used mostly in the nuclear and aerospace industry.

We will pay attention in this paper especially RPN techniques. The RPN 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 1 to 100.

These ranking are then multiplied to give the RPN. Failure modes having a high RPN are assumed to be more important and given a higher priority than those a lower RPN. The RPN was described in MIL-STD-1633A, 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 β , the failure mode ratio α , the part failure rate λ 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 FMEAs. Some of them are used much more often than others. FMEAs 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 FMEA can be seen in table 1.

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 quality 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 requirements that minimize the likelihood of those failures. MEA is also the basis for

- Evaluate the requirements obtained from the customer or other participants in the design process to ensure that those requirements 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 failure 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 subsequent 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 1 to represent no effect and 10 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 torque 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 failure 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 questions 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 1 to represent unlikely and 10 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		Failure unlikely. History shows no failure.
Remote		Rare number of failures likely.
Very slight		Very few failures likely.
Slight		Few 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		Failure almost certain.

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 techniques 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 FMEA should then be updated and plans made to address those failures to eliminate them from the product process.

The other thing is to assess 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 requires improved designs with its subsequent improvement of the basic design. Higher rankings should question the method of the Control.

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

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 techniques available.
Almost impossible		No known techniques available.

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 that require additional quality planning or action.

Determine Recommended Action(s) to address potential failures that have a high RPN. These actions could include specific inspection, testing or quality 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 FMEA as the design or process changes, the assessment changes or new information becomes known.

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

Table 5.

				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	functional class	Type of malfunction	Consequence of the failure	Cause of the failure	Controlling	Probability	Weight failure determination ability	Risk priority	Recommendations	Responsibilities, planned dynamics of planning	Responsibilities, planned dynamics of realization	Probability	Weight failure determination ability	Risk priority	
Rotor		failure	failure	Overheating of the rotor	Controlling electrode. Voltage measuring				Preassembling wire	Development Sector	After development of prototype series and samples as well documentation				
Rotor		failure	failure	Overheating of the rotor	Power decrease				Novo design changes	Development sector					
Brushes		Bad durability failure	failure	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.

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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 quality control improvement, parts and subparts, new equipment for production, this product does not charge input price increasing for raw materials material and parts .

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