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# PREDETERMINATION AND IDENTIFICATION OF FAILURE MODES RELATED TO A WELDED CAR CHASSIS COMPONENT

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***Abstract***

Failure Mode and Effects Analysis (FMEA) is a method commonly used in activities with the main objective of finding measures to improve manufacturing processes or products, by identifying actual and potential ways in which components fail or processes malfunction. The paper presents the practical application of the FMEA method for the process of obtaining an important component of the resistance system of a motor vehicle, namely a chassis. Some general information is presented on the importance of the FMEA method, the product analyzed, followed by the practical application of the method, starting from the determination of the probable causes of failure and their effects on: the organization, the customer and the end user. The processes carried out to obtain the chassis are identified and for a category of processes the Severity (S), Occurrence (O), Detection (D) and Risk Priority Number (RPN) indicators are calculated. Also, the preventive control methods and the control methods to be applied to reduce the occurrence of the defect are identified and indicated.

**Keywords: Car chassis, Occurrence, RPN, Severity, FMEA Process**

## 1. INTRODUCTION

In a free market with many manufacturers, users' desire for continuous improvement of components in both passenger and goods vehicles has become a moral obligation for manufacturers In addition, manufacturers also face problems related to legislative requirements, service recalls, legal obligations deriving from legal liability for the delivery of defective products, etc., which is why performing risk analyses that will identify and minimize component/system failures throughout the product lifecycle is a competitive plus.

In a statistic [1] on recall campaigns for cars with various faults, it is reported that in 2024, 249 recall campaigns were carried out covering 256 models from 41 different manufacturers. In addition, also in 2024, the Safety Gate system reported on the most common risks associated with vehicles, which included risks of injury (193 cases), fire hazards (69) and environmental risks (11). However, a more detailed analysis of the database shows that the most common defects were: Airbags - 89 cases, Engines - 74 cases, Brakes - 56 cases, Electronics and software - 52 cases, Steering - 30 cases, Suspension - 20 cases and Body components - 15 cases.

According to the Global Recalls portal (OECD) the total number of automobile recall campaigns in the period 2010- 2025 was 6042, as depicted in Figure 1. A large part of car failures are caused by driving conditions but also by the quality of the asphalt on the roads. [2,3].

In accordance with the rules in force and the internal rules applicable to vehicle manufacturers, when carrying out risk analyses, they must highlight at least the following:

- potential failures and their effects;
- actions that could reduce/eliminate potential failures/ effects associated;
- documents that will provide the identification, evaluation and correction activities so that the quality of the product will improve.

One of the most common methods used by manufacturers in automotive field, that will lead to the results mentioned above, is the Failure Mode and Effects Analysis (FMEA) [7 -11].

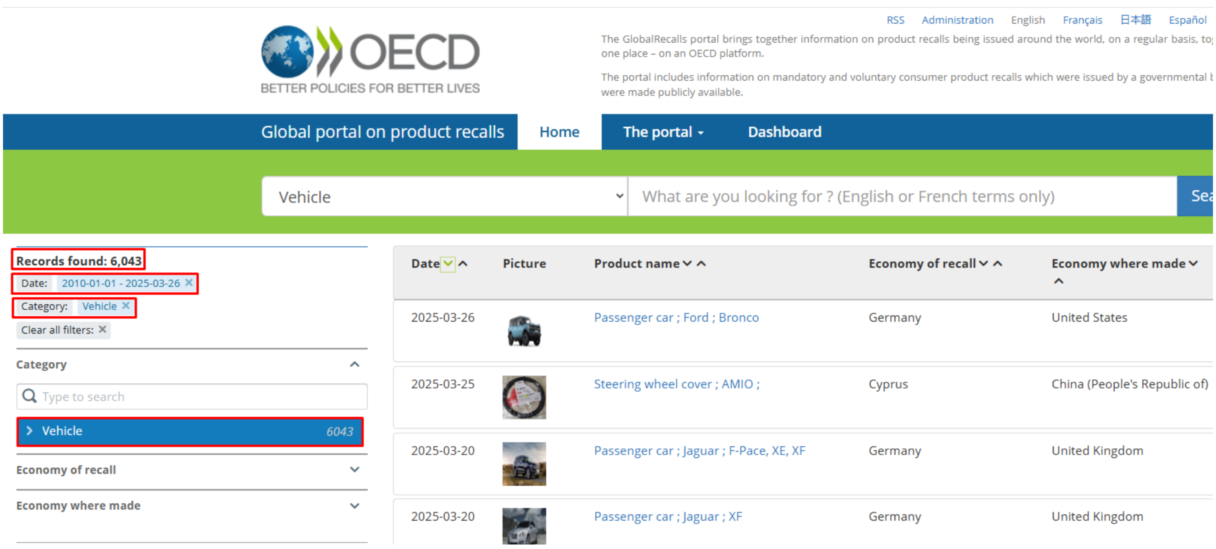
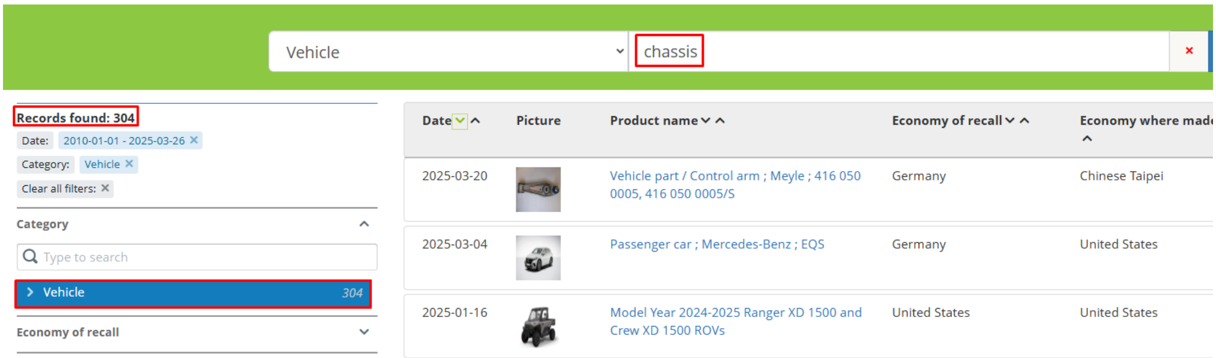
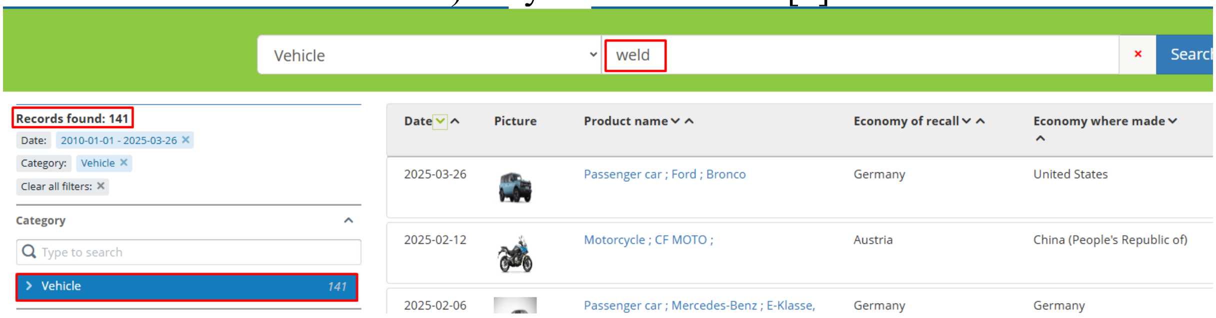


**Figure 1.** Number of recall campaigns [4]




a) Key word "chassis" [5]




b) Key word "weld" [6]

**Figure 2.** Number of recall campaigns resulting from keyword searches, according to the Global Recalls portal

The main standards that can underpin the application of FMEA are [12]:

- MIL-STD-1629A, Military Standard: Procedures For Performing A Failure Mode, Effects, And Criticality Analysis.
- IEC 60812:2018 Failure modes and effects analysis (FMEA and FMECA).
- SAE JA1012 "A Guide to the Reliability-Centered Maintenance (RCM) Standard" amplifies and clarifies each of the key criteria listed in SAE JA1011 ("Evaluation Criteria for RCM Processes") and summarizes additional issues that must be addressed to apply RCM successfully.
- AS13004 Process Failure Mode and Effects Analysis (PFMEA) and Control Plans.

Types of FMEA's based on nature of application are [13]:

- ✓ Concept FMEA (CFMEA).
- ✓ Design FMEA (DFMEA).
- ✓ Process FMEA (PFMEA) – applied in this paper.

The FMEA process is used to identify the causes of possible malfunctions that may occur during the devices manufacture or component assembling and to identify the fault elimination measures [12].

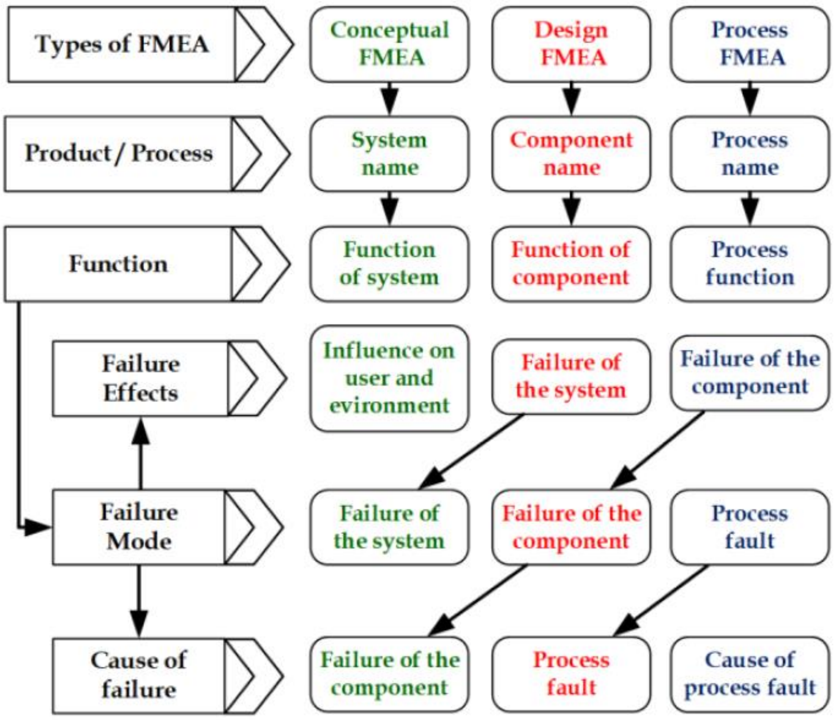



**Figure 3.** Different connections between the above-mentioned types of FMEAs [14]

During an FMEA study, the product/process/service/system being reviewed is broken down into smaller items/subsystems [15].

For each item/subsystem identified, the steps in Figure 4 are followed.

The definition of severity, occurrence and detection are [16, 17]:

- Severity (S) is a rating corresponding to the seriousness of an effect of a potential failure mode.
- Occurrence (O) is a rating corresponding to the rate at which a first level cause and its resultant failure mode will occur over the design life of the system, over the design life of the product, or before any additional process controls are applied.
- Detection (D) is a rating corresponding to the likelihood that the detection methods or current controls will detect the potential failure mode before the product is released for production for design, or for process before it leaves the production facility.

The Risk Priority Number (RPN) identifies the greatest areas of concern.

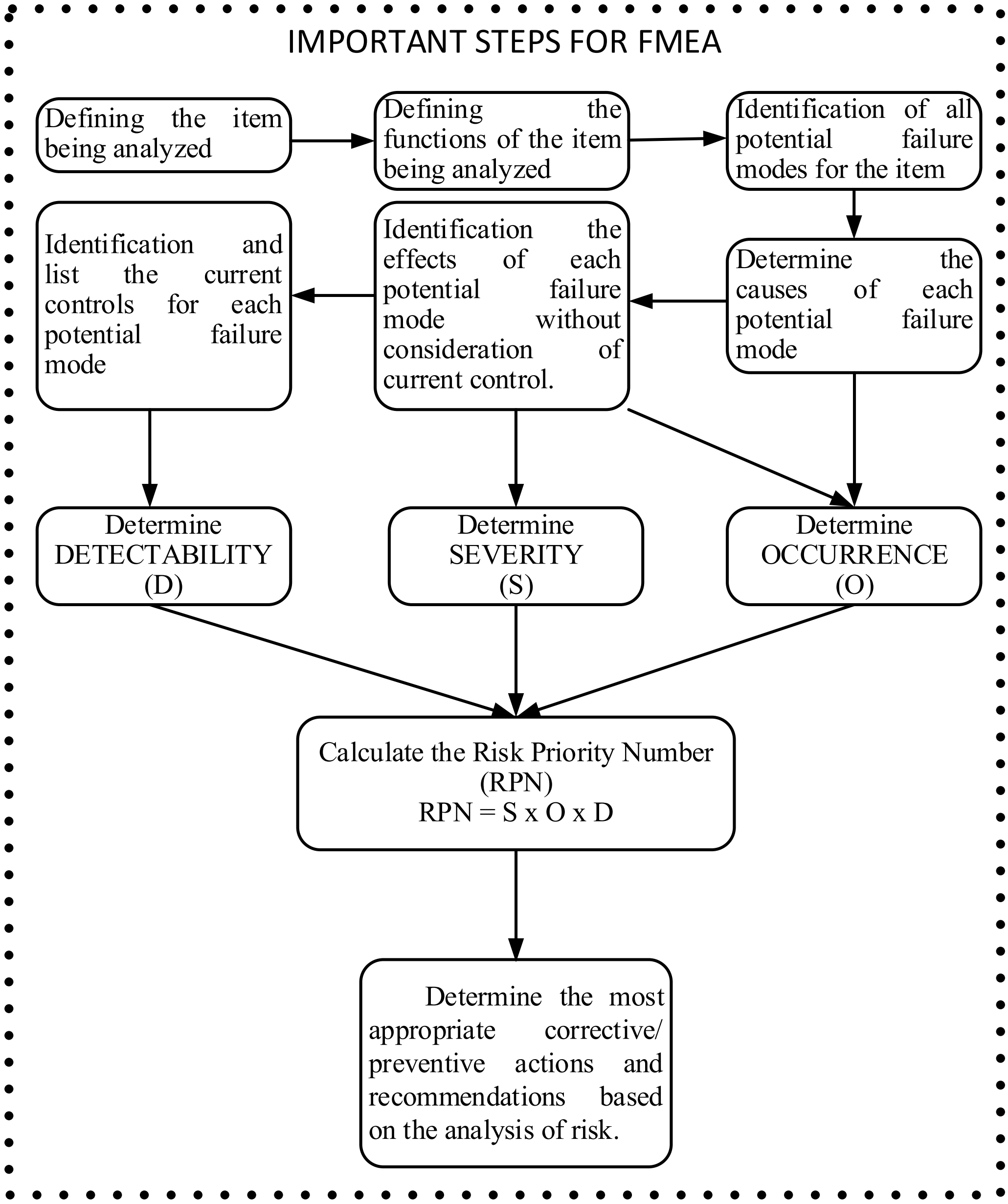



**Figure 4.** Important steps in FMEAs

The calculation of RPN values for each smaller items/subsystems is done using relation 1.

RPN = Severity Rating (S) x Occurrence Rating (O) x Detection Rating(D) (1)

Depending on the assigned risk indices (S, O, and D), the priority actions (AP) of the implementation of corrective actions are established. The prioritization process consists of classifying the risks according to three levels: high (H), medium (M), and low (L) [18].

The obtained results can be indicated, for easier visualization and interpretation, in a table of the form presented in Figure 5.

| Item | Item Function | Failure Modes | Causes | Critical/Control / Significant item | Failure Effects | Initial Conditions | | | | Current Control | Recommended Corective Actions | Corective Actions Taken | Action Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | S | O | D | RPN | | | | S | O | D | RPN |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

**Figure 5.** FMEA worksheet sample [19]

Several methods can be used to identify the failure modes [20]:
- Traditional method.
- Theoretical modelling.
- Intelligent clustering.
- Knowledge processing.

Since a widely used technological process in the automotive industry is welding [11, 21, 22], the FMEA method should be applied to this process (it generates consequent defects, or other defectuous processes) to identify possible activities that may lead to non-conformities and to identify improvement solutions, .

## 2. PRODUCT AND MANUFACTURING PROCESS ANALYSIS

The chassis is the main part of the car, together with the engine and the body, which is responsible for supporting the car, transmitting motion from the engine to the driving wheels, steering and propelling the car.
The chassis is a complex assembly made up of several groups of components:
– Support/resistance system.
– Transmission system.
– Propulsion system.
– Driving system.
– Auxiliary installations.

The support/resistance system of the car supports the weight of the whole car, passengers and cargo as well as all the forces that are generated by stopping, starting, accelerating, inertia, braking and changing direction. To fulfil this role, the support system has a high load-bearing capacity and is composed of rigid and moving and flexible parts. The engine, bodywork, and the rest of the chassis components are attached to the supporting structures to form a joined assembly.

One of the important components of the support/strengthening system is the longeron, which is an integral part of the vehicle structure. Essentially, the longeron is a longitudinal bar that ensures the strength and structural stability of a vehicle. This component plays an important role in absorbing the impact and distributing the forces generated during transportation or in the event of an accident. It is also responsible for maintaining the car's structural rigidity and is crucial in protecting passengers.

In this case, the longeron is a welded construction consisting of several rectangular pipe-type elements (e.g. 60x40x3, 40x40x2), which are joined by welding using a robotic cell presented in Figure 1, consisting of a two-axis positioner, Lorch welding power sources S8 RoboMIG XT (Lorch Schweißtechnik GmbH, Auenwald, Germany) and the welding robot Fanuc Arc Mate 120iC (Fanuc Corporation, Oshino, Yamanashi, Japan).

**Figure 6.** Longeron robot cell welding workstation. [23]

The parts to be welded are cut and machined in such a way as to comply with the dimensional tolerances imposed by the designer. The gauge dimensions of the longeron assembly are shown in Figure 7. Lonjeronul este realizat prin sudarea prin topire componentelor [23] Considering that the assembly is realized by fusion welding and that during the process the components are subjected to the effects of a thermal cycle, there is the possibility of deformation [23]. To avoid possible deformations, the components are welded in orientation and fixing devices. The materials used to realize the welded construction of the longeron (Figure 7) were: S355J2H base material (structural steel for hollow section - acc. EN ISO EN 10210). The filler material was solid wire type G3Si1 according to EN ISO 14341: 2020 and the shielding gas used was the mixture type M2.0 according to EN ISO 14175: 2008.

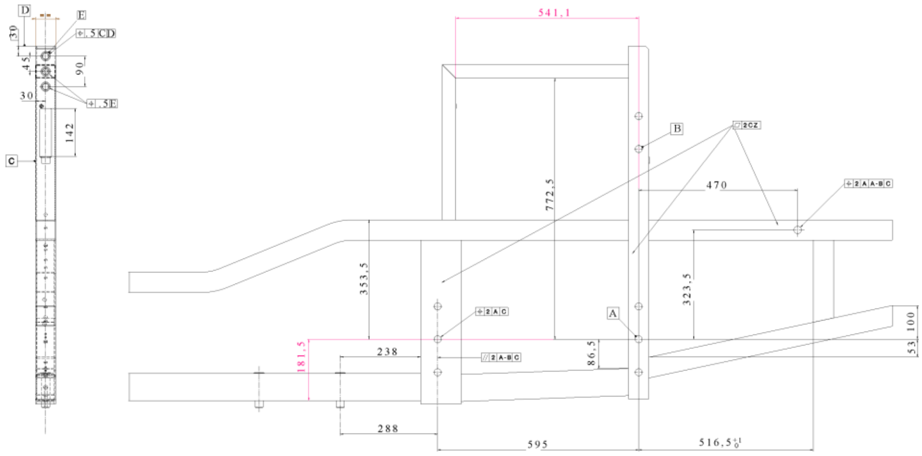


**Figure 7.** Nominal dimensions of the longeron. [23]

## 3. APPLICATION OF FMEA FOR CHASSIS

The first step in applying the FMEA to the chassis longeron is to define and score each S, O and D element [11].

Thus, for the parameter:

- S will be considered the effect that the failure can generate in/to: organization (EOTO), customer (EOTC) and end user (EOTEU).

- O will be considered: Prediction of Failure Cause Occurring (POFCO), Type of Control (TOC) and Prevention Control (PC).

- D will be considered: Ability to Detect (ATD), Detection Method Maturity (DMM) and Opportunity for Detection (OFD).

În concordanță cu [11] parametrii S, O și D pot lua valori întregi din intervalul 1-10, dar fiecare organizație în care se aplică FMEA, pornind de la recomandările teoretice, va defini elementele incluse în fiecare categorie.

Pentru situația analizată în cadrul lucrării, realizarea în construcție sudată a lonjeronului, the parameters S and D, can take one of the values:

✓ For Severity (S):

**10 – HIGH**, Failure may result in an acute health and/or safety risk for the manufacturing or assembly worker (EOTO), Failure may result in an acute health and/or safety risk for the manufacturing or assembly worker (EOTC), Affects safe operation of the vehicle and/or other vehicles, the health of driver or passenger(s) or road users or pedestrian (EOTEU).

**9 - HIGH**, Failure may result in in-plant regulatory noncompliance (EOTO), Failure may result in in-plant regulatory noncompliance (EOTC), Noncompliance with regulation (EOTEU).

**8 - MODERATELY HIGH**, 100% of production run affected may have to be scrapped. Failure may result in in-plant regulatory noncompliance or may have a chronic health and/or safety risk for the manufacturing or assembly worker (EOTO), Line shutdown greater than full production shift; stop shipment possible; field repair or replacement required (Assembly to End User) other than for regulatory noncompliance. Failure may result in in-plant regulatory noncompliance or may have a chronic health and/or safety risk for the manufacturing or assembly worker (EOTC), LOSS of primary vehicle function necessary for normal driving during expected service life (EOTEU).

**7 - MODERATELY HIGH**, Product may have to be sorted, and a portion (less than 100%) scrapped; deviation from primary process; decreased line speed or added manpower (EOTO), Line shutdown from 1 hour up to full production shift; stop shipment possible; field repair or replacement required (Assembly to End User) other than for regulatory noncompliance (EOTC), DEGRADATION of primary vehicle function necessary for normal driving during expected service life (EOTEU).

**6 - MODERATELY LOW,** 100% of production run may have to be reworked offline and accepted (EOTO) Line shut down up to one hour (EOTC) LOSS of secondary vehicle function (EOTEU).

**5 - MODERATELY LOW,** a portion of the production run may have to be reworked offline and accepted (EOTO), Less than 100% of products affected; strong possibility for additional defective product; sort required; no line shutdown (EOTC), DEGRADATION of secondary vehicle function (EOTEU).

**4 - MODERATELY LOW,** 100% of production run may have to be reworked in station before it is processed (EOTO), Defective products trigger significant reaction plan; additional defective products not likely; sort not required (EOTC), Very objectionable appearance, sound, harshness, or haptics (EOTEU).

**3 - LOW,** A portion of the production run may have to be reworked in-station before it is processed (EOTO), Defective products trigger minor reaction plan; additional defective products not likely; sort not required (EOTC), Moderately objectionable appearance, sound, vibration, harshness, or haptics (EOTEU).

**2 - LOW,** Slight inconvenience to process, operation, or operator (EOTO), Defective product triggers no reaction plan; additional defective products not likely; sort not required; require feedback to supplier (EOTC), Slightly objectionable appearance, sound, vibration, harshness or haptics (EOTEU).

**1 - LOW,** No discernible effect (EOTO), No discernible effect or no effect (EOTC), No discernible effect (EOTEU).

- ✓ For **Detection (D) we use the next system:**

**10 - VERY LOW,** No testing or Inspection method has been established or is known (DMM), The failure mode will not or cannot be detected (OFD).

**9 - VERY LOW ,** It is unlikely that the testing or inspection method will detect the failure mode (DMM), the failure mode is not easily detected through random or sporadic audits (OFD).

**8 - LOW,** Test or inspection method HAS NOT BEEN proven to be effective and reliable (e.g. plant has little or no experience with method, gauge R&R, results marginal on comparable process or this application, etc) (DMM), Human inspection (visual, tactile, audible), or use of manual gauging ( attribute or variable) that should detect the failure mode or failure cause (OFD).

**7 - LOW,** Test or inspection method HAS NOT BEEN proven to be effective and reliable (e.g. plant has little or no experience with method, gauge R&R, results marginal on comparable process or this application, etc) (DMM), Machine based detection (automated or semi-automated with notification by light, buzzer, etc.) or use of inspection equipment such as a coordinate measuring machine that should detect failure mode or failure cause (OFD).

**6 - MODERATE,** Test or inspection method HAS BEEN proven to be effective and reliable (e.g. plant has experience with method, gauge R&R results are acceptable on comparable process or this application, etc.) (DMM), Human inspection (visual, tactile, audible), or use of manual gauging (attribute or variable) that will detect the failure mode or failure cause (including product sample checks) (OFD).

**5 - MODERATE,** Test or inspection method HAS BEEN proven to be effective and reliable (e.g. plant has experience with method, gauge R&R results are acceptable on comparable process or this application, etc.) (DMM), Machine based detection (semi-automated with notification by light, buzzer, etc.), or use of inspection equipment such as a coordinate measuring machine that will detect failure mode or failure cause (including product sample checks) (OFD).

**4 - HIGH,** System has been proven to be effective and reliable (e.g. plant has experience with method on identical process or this application), gauge R&R results are acceptable, etc. (DMM), Machined-based automated detection method that will detect the failure mode DOWNSTREAM, prevent further processing or system will identify the product as discrepant and allow it to automatically move forward in the process until the designated reject unload area. Discrepant product will be controlled by a robust system that will prevent outflow of the product from the facility. (OFD).

**3 - HIGH,** System has been proven to be effective and reliable (e.g. plant has experience with method on identical process or this application), gauge R&R results are acceptable, etc. (DMM), Machine-based automated detection method that will detect the failure mode IN-STATION, prevent further processing or system will identify the product as discrepant and allow it to automatically move forward in the process until the designated reject unload area. Discrepant product will be controlled by a robust system that will prevent outflow of the product from the facility (OFD).

**2 - HIGH,** Detection method has been proved to be effective and reliable (e.g. plant has experience with method, error-proofing verification, etc.) (DMM), Machine based detection that will detect the cause and prevent the failure mode (discrepant part) from being produced (OFD).

**1 - HIGH,** Failure Mode cannot physically produce as-designed or processed, or detection methods proven to ALWAYS detect the failure mode or failure cause (DMM and OFD).

The value for occurrence is shown in table 1 where the following abbreviations have been used: prediction of failure cause occurring (POFCO), value (V), type of control (TOC) and prevention control (PC).

**Table 1. Occurrence values (O)**

| POFCO | V | TOC | PC |
|---|---|---|---|
| **EXTREMELY HIGH** | 10 | None | No prevention Controls |
| **VERY HIGH** | 9 | Behavioral | Prevention controls will have little effect in preventing failure cause |
| | 8 | | |
| **HIGH** | 7 | Behavioral or Technical | Prevention control somewhat effective in preventing failure cause |
| | 6 | | |
| **MODERATE** | 5 | | Prevention controls are effective in preventing failure cause |
| | 4 | | Prevention controls are effective in preventing failure cause |
| **LOW** | 3 | Best Practices: Behavioral or Technical | Prevention controls are highly effective in preventing failure cause |
| **VERY LOW** | 2 | | |
| **EXTREMELY LOW** | 1 | Technical | Prevention controls are extremely effective in preventing failure cause from occurring due to design (e.g. part geometry) or process (e.g. fixture or tooling design). Intent of prevention controls- Failure Mode cannot be physically produced due to the Failure Cause |

For the prioritization of the actions to be taken (H - High, M - Medium, L

- Low), an Action Priority plan has been drawn up, which is based on combination of Severity, Occurrence and Detection ratings to prioritize actions for risk reduction:

- Action plan for effect Product or Plant Effect Very High (S = 9-10),
- Action plan for effect Product or Plant Effect High (S = 7-8)
- Action plan for effect Product or Plant Effect Moderate (S= 4-6)
- Action plan for effect Product or Plant Effect Low (S = 2-3)
- For S= 1, grade for action plan is L.

The application of the method was carried out on 4 distinct directions of analysis:

- Structure Analysis Direction (SAD) containing information on: Process Step (PS) and Process work element (PWE)
- Function Analysis Direction (FuAD) containing information on: Function of the process item/ Process Name (FPI/PN), Function of the process Step/ Product Characteristics (FPS/Prod.C) and Function of the process work element/ Process Characteristics (FPWE/Proc.C)
- Failure Analysis Direction (FaAD) containing information on: Faillure Effect (FE), Severity (S), Failure Mode of Process Step (FM) and Failure Cause of Work Element (FC)
- Risk Analysis Direction (RAD) containing information on: Current Prevention Control of FC (CPC-FC), Occurrence (O), Current Detection Control of FC & FM (CDC - FC & FM ), Detection (D).

The processes required to obtain the chassis are:

- Preparation of welding kit.
- Welded chassis building.
- Sheet welding.
- Welding pose piece, specific welding jigs.
- Operation after welding.
- Chassis Final Control.

The results of the FMEA application for the first process are presented below, with the observation that the research team applied the method for all the 6 processes identified and indicated above.

| Parameter | | | Detection (D) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RATING | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | EFFECT | VERRY HIGH | HIGH | | | MODERATE | | LOW | | VERY LOW | |
| Occurency (O) | 10 | EXTREMELY HIGH | H | H | | | H | | H | | | |
| | 9 | VERY HIGH | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 7 | HIGH | H | H | | | H | | H | | | |
| | 6 | | | | | | | | | | | |
| | 5 | MODERATE | M | H | | | H | | H | | | |
| | 4 | | | | | | | | | | | |
| | 3 | LOW | L | | | | M | | H | | | |
| | 2 | VERY LOW | | | | | | | | | | |
| | 1 | EXTREMELY LOW | L | | | | | | | | | |

**Figure 8.** Action plan for effect Product or Plant Effect Very High (S = 9-10)

| Parameter | | | Detection (D) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RATING | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | EFFECT | VERRY HIGH | HIGH | | | MODERATE | | LOW | | VERY LOW | |
| Occurency (O) | 10 | EXTREMELY HIGH | H | H | | | H | | H | | | |
| | 9 | VERY HIGH | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 7 | HIGH | M | H | | | H | | H | | | |
| | 6 | | | | | | | | | | | |
| | 5 | MODERATE | M | M | | | M | | H | | | |
| | 4 | | | | | | | | | | | |
| | 3 | LOW | L | | | | M | | M | | | |
| | 2 | VERY LOW | | | | | | | | | | |
| | 1 | EXTREMELY LOW | L | | | | | | | | | |

**Figure 9.** Action plan for effect Product or Plant Effect High (S = 7-8)

| Parameter | | | Detection (D) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RATING | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | EFFECT | VERRY HIGH | HIGH | | | MODERATE | | LOW | | VERY LOW | |
| Occurency (O) | 10 | EXTREMELY HIGH | M | M | | | H | | H | | | |
| | 9 | VERY HIGH | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 7 | HIGH | L | M | | | M | | M | | | |
| | 6 | | | | | | | | | | | |
| | 5 | MODERATE | L | L | | | L | | M | | | |
| | 4 | | | | | | | | | | | |
| | 3 | LOW | L | | | | L | | L | | | |
| | 2 | VERY LOW | | | | | | | | | | |
| | 1 | EXTREMELY LOW | L | | | | | | | | | |

**Figure 10.** Action plan for effect Product or Plant Effect Moderate (S= 4-6)

| Parameter | | | Detection (D) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RATING | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | EFFECT | VERRY HIGH | HIGH | | | MODERATE | | LOW | | VERY LOW | |
| Occurency (O) | 10 | EXTREMELY HIGH | L | L | | | M | | M | | | |
| | 9 | VERY HIGH | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 7 | HIGH | L | L | | | L | | L | | | |
| | 6 | | | | | | | | | | | |
| | 5 | MODERATE | L | L | | | L | | L | | | |
| | 4 | | | | | | | | | | | |
| | 3 | LOW | L | | | | L | | L | | | |
| | 2 | VERY LOW | | | | | | | | | | |
| | 1 | EXTREMELY LOW | L | | | | | | | | | |

**Figure 11.** Action plan for effect Product or Plant Effect Low (S = 2-3)

The results obtained following the application of the FMEA method are centralized in a table as in the Figure 12.

| Structure Analysis | | Function Analysis | | | Failure Analysis | | | | Risk Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Process Step/Stn no | Process work element | Function of the process item/ Process Name | Function of the process Step/ Product Characteristics | Function of the process work element Process Characteristics | Faillure Effect- FE | Severity | Failure Mode- FM of Process Step | Failure Cause- FC of Work Element | Current Prevention Control of FC | Occurrence | Current Detection Control of FC & FM | Detection(D) of FM & FC | RPN | PFMEA AP |

**Figure 12.** FMEA centralized results table

**Table 2. Structure Function (SAD) and Analysis Direction (FuAD) for Preparation of welding kit processes**

<table>
<tr><th>SAD</th><th colspan="3">FuAD</th></tr>
<tr><th>PWE</th><th>FPI/PN)</th><th>FPS/Prod.C</th><th>FPWE/Proc.C</th></tr>
<tr><td rowspan="3">Kitting operator<br>Kitting method<br>Chariot</td><td rowspan="3">Intern (phosphatation and welding line) the existence of compliant parts on the production line<br>Next customer: mounting bus elements<br>Final customer: proper operation of the vehicle</td><td>Presence of all the components for process, see table 3</td><td rowspan="3">Presence off all the components on the welding line</td></tr>
<tr><td>Compliant parts, see table 4</td></tr>
<tr><td>Presence of all the components on the final product, see table 5</td></tr>
</table>

**Table 3. Failure Analysis Direction (FAD) and Risk Analysis Direction (RAD) for Presence of all the components**

| FaAD | | | | RAD | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| FE | S | FM | FC | CPC-FC | O | CDC -FC & FM | D | RPN | AP |
| Stopping of production internally. intern: 5; next customer:5; final customer:5 | 5 | Missing components from kits | Forgot of operator | Drawings of the parts Specific trolleys with special conditioning shapes for each parts of the kits with specifing labeling. Instruction Sheet to manage the missing parts from the specific Iveco trollyes with specific visual aids | 4 | Visual check based on the list of the components and the trolley with the specific conditioning shapes for the parts of the kits. | 6 | 120 | L |
| | 5 | | The trolleys is not at the last index | Validation audit for the new index. Checking the condition of the trolleys during the validation audit. Audit workstation. | 4 | Visual check based on the Check list of the last index. | 6 | 120 | L |
| | 5 | | Documentation at the workstation is not at the last index or false | Update documentation with new index at the workstation. Validation audit for the new index. Checking the condition of the trolleys during the validation audit. Training of the people | 4 | Visual check based on the Check list of the last index. | 6 | 120 | L |

**Table 4. Failure Analysis Direction (FAD) and Risk Analysis Direction (RAD) for Compliant parts**

| FaAD | | | | RAD | | | | RPN | AP |
|---|---|---|---|---|---|---|---|---|---|
| FE | S | FM | FC | CPC-FC | O | CDC - FC & FM | D | | |
| Reworking on the internal production line intern: 5; next customer:5; final customer:3 | 5 | Strikes and deformation on the parts | Bad manipulation of the parts (bad handling by the operator) | Realization of a specific transportation trolley. | 4 | Visual check based on the list of the components of the kit. | 6 | 120 | L |
| Reworking on the internal production line intern: 5; next customer:5; final customer:3 | 5 | Strikes and deformation on the parts | Unsuitable handling method | Work instruction for handling parts in the internal flow | 3 | Visual check | 6 | 90 | L |

**Table 5. Failure Analysis Direction (FAD) and Risk Analysis Direction (RAD) for presence of all the components on the final product**

| FaAD | | | | RAD | | | | RPN | AP |
|---|---|---|---|---|---|---|---|---|---|
| FE | S | FM | FC | CPC-FC | O | CDC -FC & FM | D | | |
| Impossibility of mounting on the customer intern: 2; customer: 2; final customer:1 | 2 | Bad identification of kit concerning the | The information is not clear on the workshop | Apply label supports on the trolley for identification: with the checklist and with status of kit. | 4 | Visual check based on the list of the components and the labels of each component on the | 6 | 48 | L |
| Impossibility of mounting on the customer intern: 3; customer: 5; final customer: 2 | 5 | Bad part index | Documentation at the workstation is not at the last index or false | Update documentation with new index at the workstation. Validation audit for the new index. Checking the condition of the trolleys during the validation audit. Training of the people based of the documentation of the last index | 4 | Visual check based on the Check list of the last index. Validation audit. | 6 | 120 | L |
| Impossibility of mounting on the customer intern: 2; customer: 5; final customer: 5 | 5 | Missing of components in the kitting from working station | The racks is not at the last index | Validation audit for the new index. | 4 | Visual check | 6 | 120 | L |

From the analysis performed, only in two processes, welded chassis building and chassis final control, a sub-process (Problem of mounting at customer's line) was identified and categorized in M category according to the action plan. The results are presented below.

**Table 6. Structure Function (SAD) and Analysis Direction (FuAD) for Welded chassis building**

| SAD | FuAD | | |
|---|---|---|---|
| PWE | FPI/PN) | FPS/Prod.C | FPWE/Proc.C |
| Welder Welding device Welding method | Intern (welding line) the existence of compliant parts on the production line Next customer: mounting bus elements Final customer: proper operation of the vehicle | Compliant chassis, table 7 | Proper positioning of all chassis components / dimensionally compliant chassis |

**Table 7. Failure Analysis Direction (FAD) and Risk Analysis Direction (RAD) for Compliant chassis – processes Welded chassis building**

| FaAD | | | | RAD | | | | RPN | AP |
|---|---|---|---|---|---|---|---|---|---|
| FE | S | FM | FC | CPC-FC | O | CDC - FC & FM | D | | |
| Problem of mounting at customer's line intern:4; customer: 5; final customer: 5 | 5 | Distance 1530 mm Between T6-T7 NC | Deformations occurred during the welding process | Making the spacer for adjusting the dimension. | 6 | Periodical validation of the device and control 3D. | 5 | 150 | M |
| Problem of mounting at customer's line intern:4; customer: 5; final customer: 5 | 5 | Distance 3070 mm Between T6-T9 NC | Deformations occurred during the welding process | Making the spacer for adjusting the dimension. | 6 | Periodical validation of the device and control 3D. | 5 | 150 | M |

**Table 8. Structure Function (SAD) and Analysis Direction (FuAD) for final control**

| SAD | FuAD | | |
|---|---|---|---|
| **PWE** | **FPI/PN)** | **FPS/Prod.C** | **FPWE/Proc.C** |
| Quality controller light<br>Control method<br>Gadgets of control | Intern (control workstation) the existence of non-compliant parts after the control operation<br>Next customer: mounting bus elements<br>Final customer : proper operation of the vehicle | Compliant chassis, as depicted in table 9 | Proper positioning of all chassis components and dimensions |

**Table 9. Failure Analysis Direction (FAD) and Risk Analysis Direction (RAD) for Compliant chassis - processes Final control**

| FaAD | | | | RAD | | | | RPN | AP |
|---|---|---|---|---|---|---|---|---|---|
| **FE** | **S** | **FM** | **FC** | **CPC-FC** | **O** | **CDC -FC & FM** | **D** | | |
| Problem of mounting at customer's line - intern: 7; customer: 7; final customer:1 | 7 | Chassis NC (delivery at an old index) | Bad management of modification (documentation is not updated) | Management of product/process modifications<br>Set up a meeting on new chassis / modified chassis, with participants manufacturing, methods, quality and logistics | 4 | Control 100% based on checklists. Check list problems reported by the client | 6 | 168 | M |

## 5. CONCLUSIONS

Based on the theoretical and experimental research, the results obtained and their interpretation, the following conclusions can be drawn:

- ✓ the process of implementing, maintaining and improving a quality requires the use of analysis methods to continuously improve the products/components supplied.
- ✓ One of the methods used in the automotive industry is the FMEA method.
- ✓ By applying the FMEA method, the research team was able to identify the

potential problems that can occur in chassis construction so that preventive measures can reduce or even eliminate them.

- ✓ From the analysis performed, only in two processes, welded chassis building and chassis final control, a sub-process was identified (Problem of mounting at customer's line) which was categorized as M according to the action plan. For this subprocess were indicated both preventive action (Realization of work instruction with the order of the welds), and Detection Action (Check list control. Check list problems reported by the customer).

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