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TRACEABILITY AND RELATIONS OF THE PROCESS DOCUMENTS IN AUTOMOTIVE INDUSTRY

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Abstract: *This paper presents the interconnection between the main documents for process side, how we can maintain the traceability of them and what is the trend of working with them. In most of the audits we can see a mismatch between the process documents and this is generating failures at manufacturing level. One of the root causes is the lack of communication between the departments of the companies or by lack of the multidisciplinary team when the process documents are created. To secure this problem, we started to use a software that manage the level of information in all documents. The result of the research is that we have eliminate mismatches between documents and the time for documents creation was decrease.*

Key words: *FMEA software, FMEA, PFMEA, DFMEA, Control Plan.*

1. INTRODUCTION

All the companies active in the Automotive industry are required to be certified IATF 16949, which was developed by the International Automotive Task Force (IATF). This kind of certification involve having a strong Quality Management System (QMS), which is a formalized system documenting processes, procedures, and responsibilities for ensuring consistent delivery of high-quality products and services to the consumer. The QMS should be designed in such a way as to provide the necessary information to manage the business.

An effective QMS will help the Company to:

- Manage quality risks
- Reduce product defects
- Improve customer satisfaction
- Increase productivity
- Identify areas where improvement is needed
- Control costs
- Ensure compliance with regulations
- Communicate effectively with customers and suppliers
- Make informed decisions
- Meet regulatory requirements.

The QMS pillars are:

- Quality Policy;
- Quality Manual;
- Procedures;
- Work Instructions;
- Records.

Control Plan describes the methods for controlling product and process variation in order to produce conform parts, which meet customer requirements. Control plans are a critical part of the overall quality process. FMEA (Failure Mode and Effects Analysis) is a key development tool for ensuring that errors and weaknesses are avoided. This paper focuses more on how a company can manage the relations between process documents (PFMEA-Process Failure Mode and Effects Analysis and Control Plan) starting from DFMEA (Design Failure Mode and Effects Analysis) and how the documents traceability is kept.

2. THE ACTUAL RELATIONS BETWEEN DOCUMENTS

PFMEA and Control Plan should not be standalone documents. They are leaving documents that are changing anytime when

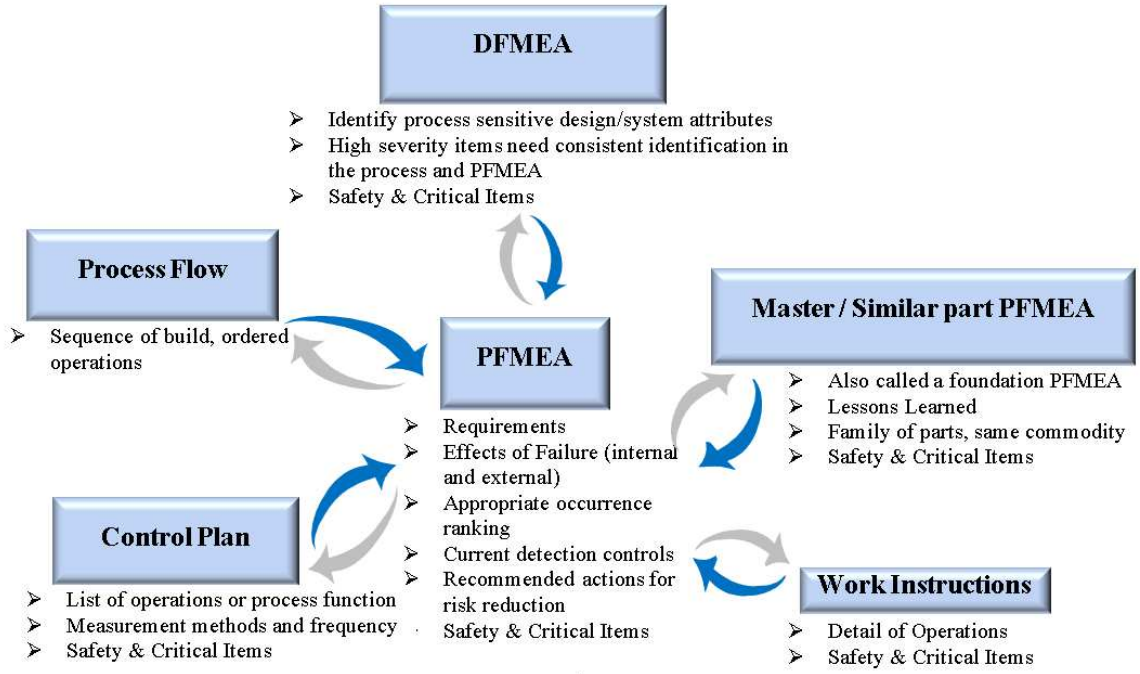

Fig. 1. Relations of the documents (after [1,2]).

changes in the process. The link between documents it is presented in figure 1.

Anytime when something occurred in one of the documents, immediately the related document must be updated accordingly. Unfortunately, this is an escape point – documents are managed by different employees, different departments and the bigger is the Company the coherence of information between documents is less accurate.

3. NEWS AND FACTS

In 2019 it was released the new AIAG & VDA FMEA Handbook with an innovative approach [3] in how the failures are quoted during the analyse and many recommendations regarding the way of working with this powerful tool.

Most of the OEM's (Original Equipment Manufacturer – "manufacturer of the original equipment, that is, the parts assembled and installed during the construction of a new vehicle") have embraced this approach and started to put pressure on their suppliers to work in this way.

In December 2021, Ford was the first company that imposed to his suppliers to implement a software for documentation management.

In the page 22 from FORD IATF CSR (Customer Specific Requirements) we can find "*FMEA Information Flow and Linkage*
The Part and Foundation FMEAs shall be living documents that are always aligned. An update to the Foundation FMEA shall result in a review of the applicable information for the Part FMEA.
This process also shall work backwards from the part FMEAs to the Foundation FMEA in that any updates to the part FMEAs result in updates of the applicable information in the Foundation FMEAs. In addition, FMEAs shall be aligned to the control plans and work instructions/visual aids."[4]

Moreover, Ford is requesting that FMEA shall be linked with other documents, without limitation: "Suppliers shall use FMEA software which ensures the alignment of the Foundation FMEA, Part FMEA, control plan and other applicable documents." [4]

This request has created a revolution upon the Automotive Industry who has put an instant pressure on the IT market for software suppliers and on their process people to pass from Excel or other integrated systems to a software that respect the Ford demand.

4. PROPOSALS FOR THE IMPROVEMENT

Design FMEA it is built together with the part design and it is release to the Manufacturing Plant after the part design is frozen. All the other documents presented in the chapter 2 start to be realized during the industrialization phase of the project and become mature (ready to be audited) at SOP (Start of Production).

In the FMEA software demanded by Automotive Industry, the flow is similar – first Product Engineers must build the DFMEA, then Industrialisation Engineers together with Quality, Production and other Departments (multidisciplinary team) must build the PFMEA, Control Plan and the last step is RFMEA (Reverse Failure Mode and Effects Analysis, which is done after SOP).

For building the DFMEA and PFMEA, the software requires Foundation Steps. The Foundation Steps are standard requirements for part or manufacturing process based on type of parts (part family – tires, bumpers, seats, etc.), type of function (front/rear lightening, break lines, fuel lines, etc.) or type of process (drilling, grinding, etc). In the Foundation Steps are included all the Lessons Learned and expertise of the company.

In the Foundation Steps, all failures that may occur are analysed, including the prevention, the detection of them and how to react if the failure appear – reaction loop (immediate action and corrective action). All the information introduced here must be applicable to one or more type of parts, functions or processes upon the Company that implement the software. It means a huge upgrade on the standardisation of the Automotive Industry Companies, especially on the multinational Companies because, until now, same failure it was treated differently, from Plant to Plant or from Country to Country, but now it must be prevented, detected and have the same reaction loop in all Plants. That impose similar technologies in all Plants (same way to detect the failures - poka-yoke), same culture (reaction loop) and same prevention (operator trainings, standard documentation, preventive maintenance, first part OK, start-up of production, etc).

In the following sentences I will explain how the software is working in details.

As all software systems, first it must be configured. Administrator will define users and rights, company profile, measurement units, approval routings etc. Then the key users will define clients, projects, products, special characteristics, etc.

Software has three main databases that need to be loaded before/during the Foundation Steps are created:

- Failures Pool,
- Preventive Control Pool,
- Detection Control Pool.

Based on these databases the users are constructing the Foundation Steps. After the Foundation Steps are approved, they are available for constructing the FMEA. FMEA starts from the Process Flow (in case of PFMEA) and with BOM (Bill of Materials – for DFMEA). In DFMEA, for each component, it will be attached one or more Foundation Steps that contain the function requirements of that component/subassembly/finished good.

In PFMEA, on each step from the Process Flow, it will be attached one or more Foundation Steps that contain the type of part or process failures that can appear during manufacturing process (from Raw Materials reception until Finished Good delivery). Because PFMEA is linked with DFMEA and Control Plan, all the special characteristics from DFMEA will be conducted also in PFMEA and in Control Plan (including the class of the part – S(safety), R(Reglementary), CC(Critical Characteristic, etc). This will prevent to avoid any mismatch of information between the documents. After the FMEA and Control Plan can be released for approval (all documents must be checked and validated by one or more users).

If the AP (Action Priority) will be Medium or High, the system does not let you save/close the risk analyse without an action release to improve the AP result (to status Low). Any action that needs to be implemented it is introduced in the software. Issuer of the action will establish a responsible, eventually a team and a deadline for the action to be implemented. If the action is not finalized in time, the system starts to send

automatically notices (on email and in the software home menu for each user) to all involved people. The notifications can repeat with a periodicity established by the administrator of the software. The actions can be closed only when the approval person/team is validating the results in the software. When the actions are closed, the system will let the user to introduce the new quotation for Occurrence and Detection and a new RPN (product between Severity x Occurrence x Detection) or AP (Action Priority) will be release for the analysed failure risk. If any change is done on the Foundation Steps, all the FMEA's and Control Plans that contain that Foundation Step will be notified for update. Any revision of the Foundation Steps, FMEA and Control Plan is held as traceability in the software (number of the revision, what was changed, by who, who approved and when).

5.1 Case study

On the market we can find many FMEA software's with prices between 6 000 euros and 80 000 euros, in function of number of licences, number of modules and complexity. This paper study the simplest software on the market and it will be improved during implementation.

For exemplification it will be considered the tightening of a car wheel. First it will be declared in the system the components of the assembly: wheel assembly, Stud Bolts and Wheel Hub. Based on the customer requirements it will be declared the special characteristics (rules and symbols) – in this case, parts are SR (Safety and Regulatory) and impose a Severity Class 10.

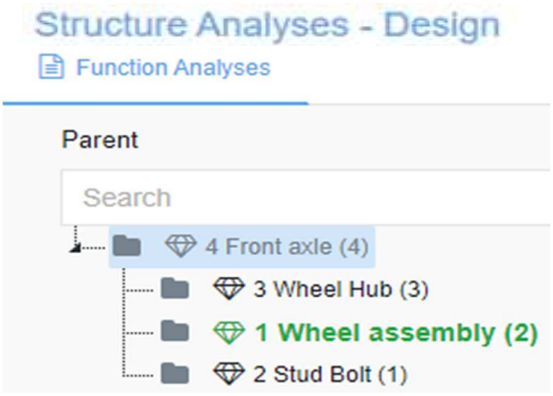

Fig. 2. BOM used in DFMEA.

DFMEA for the wheel assembly contain the analyse of all the failures that can appear on the product (each component and the full assembly functions): diameters, roughness, etc.

From all design failures it will be exemplified the wheel vibration due to wrong fixation on the wheel hub [5]. Based on the BOM bellow, a draft of DFMEA is presented in the Fig. 3

PFMEA and Control Plan are created in the industrialization phase. These documents starts based on a frozen design and an approved DFMEA. In this study case it will be considered the assembly of the components and analyse of the effects (Fig. 4).

As we can see the Class and Severity have been reconducted by the system from DFMEA to PFMEA. This link has been realized when it was introduced in the Process Flow the components to be assembled. During the trials with this software, it was realized that the system works well and some improvements have been realized during implementation phase:

- it was added product and process responsible to prevent another unauthorised user to modify the documents;
- for Control Plan there were added more information (instructions/procedures used for controlling the parts, dimensions and tolerances to be checked);
- if the AP (Action Priority) is Medium or High, it was added a condition to make an action to decrease the Occurrence and/or Detection, otherwise the user can't validate the risk analyse;
- for each line of failure risk analyse it was added the possibility to upload relevant files (pictures, Lessons learned, or other documents) that can support a better understanding of the analyse;
- routings for approval with time and approval groups have been setup in the software; - for all the actions launched in the software has been implemented the notification system by mail with links directly in the software on the related action (approval, escalations, etc.);
- each Preventive and Detection Control from the database show now the lines that use them, from the Risk Analyses. With this improvement, the users can check if the updated control is valid for all the concerned lines from the Risk Analyses.

Next Higher Element	Focus Element	Focus Element Function	Next Lower Element Function	Failure Effect (FE)	S.C	S	Failure Mode (FM)	Failure Cause (FC)	Current Preventive Control	O	D	AP	RPN	Output To PFMEA
Front axle	3 Wheel Hub	Car mobility	Proper fixation of the wheel on the axle	System failure (End User)	SR	10	000 - Petals failed in shear	Inaccurate calculation of forces	Validation tests	6	2	H	120	
	1 Wheel assembly	Car mobility		Decreased stability at high speeds (End User)	-	6	0001 - Wobbling at high speeds	Insufficient toe base	Increased toe base	8	6	H	288	
	2 Stud Bolt	Assembly of the Wheel on the Car		System failure - wheel loose/unstable car (Plant)	SR	10	0002 - Crack	Inaccurate calculation of forces	Research on forces and materials	2	7	H	140	Yes

Fig. 3. Partial DFMEA in software.

Process Step	Step Function	Element Function	Failure Effect (FE)	S	S.C	Failure Mode (FM)	Failure Cause (FC)	Preventive Control	O	Detection Control	D	AP	RPN
Assembly of the Wheel on the Car	Assembly of the Wheel on the Car	Properly fixing of the Wheel	System failure - wheel loose/unstable car (Plant)	10	SR	0005 - Stud bolt untighten	Bad dimension of the components	Preventive maintenance. Tooling & machinery specifications and validation. Use electric machines with turns/angle count for each tightening. Periodic calibration of the machine.	1	According to internal procedures	2	L	20
	Assembly of the Wheel on the Car		System failure - wheel loose/unstable car (Plant)	10	SR	0004 - Torque too low	Tightening machine not calibrated	Preventive maintenance. Tooling & machinery specifications and validation. Periodic calibration of the machine.	2	According to internal procedures	2	L	40
	Assembly of the Wheel on the Car		Stud Bolts broken (Plant)	10	SR	0003 - Over torque	Tightening machine not calibrated	Preventive maintenance. Tooling & machinery specifications and validation. Periodic calibration of the machine.	2	According to internal procedures	2	L	40

Fig. 4. Partial PFMEA in software.

6. CONCLUSIONS

We have successfully applied and update the software. The number of errors between DFMEA, PFMEA and Control Plan dropped from 182 to zero (documents from 100 part no. where analysed). Time for realization of PFMEA and Control Plan for one part no. was reduced from 2.5 hours to 1 hour (60% decrease of time). Traceability of any modification in the system is much better than before and subjectivity of the users for choosing the right quotation and special characteristics has decrease due to rules created in the software.

Next step in our research is to find a tool capable to link CAD data software with FMEA software. In other words, to manage automatically all data needed in a manufacturing project starting from drawings (collecting BOM, attributes of the components like dimensions, applicable standards, special characteristics, etc.) and create Product Feasibility, DFMEA, Process Feasibility, PFMEA, Control Plan, work instructions and RFMEA.

With this kind of tool, we can manage easier the changings from the product side – each change will be instantly transposed to all documents and with full traceability of who, when and what was modified. First purpose of this new research is to eliminate the errors between the drawings and all the other documents and second one is to decrease the time of the Project from Design to Manufacturing.

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TRASABILITATEA SI CONEXIUNILE DOCUMENTELOR DE PROCES IN INDUSTRIA AUTO

Această lucrare prezintă interconectarea dintre principalele documente utilizate în proces, cum putem menține trasabilitatea acestora și care este tendința de lucru cu acestea. În majoritatea auditurilor putem observa o neconcordanță între documentele de proces și acest lucru generează probleme la nivel de fabricație. Una dintre cauzele principale este lipsa de comunicare între departamentele companiilor sau lipsa unei echipe multidisciplinare în momentul creării documentelor de proces. Pentru a rezolva această problemă, s-a folosit un software care gestionează nivelul de informații din toate documentele. Rezultatul cercetării este eliminarea neconcordanțelor dintre documente și reducerea timpului de creare a acestora.

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