USE OF QUALITY TOOLS TO IMPROVE THE ASSEMBLY PROCESS OF TRANSMISSION SHAFT OF A 6X4 VEHICLE

Bruno Diego de Souza Silva[1], Nilo Antonio de Sousa Sampaio[1,3], José Wilson de Jesus Silva[1,2], Rosinei Batista Ribeiro[2,4]

1 – Associação Educacional Dom Bosco, AEDB, Resende, RJ, Brazil

2 – Centro Universitário Teresa D'Ávila, UNIFATEA, Lorena, SP, Brazil

3 – Universidade do Estado do Rio de Janeiro, UERJ, Resende, RJ, Brazil

4 – Faculdade de Tecnologia de São Paulo, FATEC, Cruzeiro, SP, Brazil

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ABSTRACT. This work demonstrates how, by means of quality tools use, it is possible to obtain a better productivity in assembling process of transmission shaft of a 6x4 vehicle, in the safety of operators and customers, improvement in assembly quality, avoiding rework and gaining time in operation. By means of a study of activities carried out at assembly station of transmission tree and survey of items pointed out in the quality indicators system of the company in question, a strategy was drawn up aiming to start a plan to eliminate flaws resulting from the process as well as to implement systematic to keep the process controlled in addition to measuring results and continue in the pursuit of continuous improvement. With data collected and based on the PDCA Cycle for the use of other quality tools, it is intended to consistently apply the use of these tools to solve operational failures of this Subsystem.

Introduction. Globalization was a process that, according to many historians, began in the fifteenth and sixteenth centuries. This process has established economic and social integration among countries worldwide. Due to the saturation of their domestic markets, several multinational companies sought to find new consumer markets. Not only that, globalization has led companies to seek technological advancement to achieve cheaper production processes and the faster and more efficient interconnection between commercial and financial contacts [13].

In a globalized world with increasingly advanced technologies, the search for continuous improvement in production processes has become indispensable for companies to remain competitive in the market, adding value to products offered, with assured quality, safety for those who produce and for who purchases, in order to satisfy and exceed the customers' expectations.

The continuous improvement of productive processes is the search for reduction of costs with wastes generated by an inefficient productive process and that generates quality failures, causing rework and waste of time, besides, it is the search for client satisfaction, be it internal or external. At a critical juncture in the national economy, improved manufacturing processes may be one of the only solutions to keep consumer prices compatible with the consumer's pocket because a short-term recovery is not so visible. Eliminating failures of production, eventual reworking and problems in the field, is becoming more and more evident and companies are looking for this [10].

So that companies achieve this improvement in their production processes, there are several quality management tools that allow us to achieve surprising results and leave the process lean, identifying these wastes and eliminating them by delivering to the end customer a product that meets and exceed your expectations of both use and safety and comfort.

Materials and Methods.

This paper presents a case study approach, based on methods and data of a qualitative nature that, according to Godoy [1], "aims at detailed examination of an environment, a particular subject or situation. Dedicated to those who seek to know how and why certain phenomena happen or those who are dedicated to analyzing events about which the control possibility is reduced or when the phenomena analyzed are current and only make sense within a specific context."

From the use of tools and their practical use, which are today the best instruments used to analyze the operation, identify the problems that occur there and then be able to solve them quickly and effectively.

According to Aildefonso [2], Tools exist to, if used properly, help solve problems and/or increase effectiveness of processes. These tools help us visualize a process, detect problems, discover their causes and determine solutions, and also provide a way to evaluate proposed changes.

In addition to the field research, we will use data collection of fault control worksheet of the analyzed process, which is a material of extreme importance for the study.

Fault control worksheet.

This study first step was stratification of occurrences, from fault control worksheet that is used in final inspection of process of due assembly post that was provided by company, referring to the year 2014, so that it can be known the actual failures of this particular process.

Pareto Diagram.

It had its principle suggested by Joseph M. Juran, who named it after the great Italian economist Vilfredo Pareto.

It is a frequency chart ordered by causes and its function is to prioritize the main causes that affect the process and result in losses of production and losses to the company. Thus, the study is made on top of the most relevant occurrences, and an effective solution can be elaborated for them.

According to KUME [3], it is extremely important to clarify how losses are distributed. Most of them are due to a few types of defects, which can be attributed to a small number of causes. Thus, if the causes of these few vital defects are identified, one can eliminate almost all the losses by concentrating on these main causes, leaving aside, in a preliminary approach, the other defects that are many and trivial. One can solve this type of problem in an efficient way, by means of use of Pareto diagram.

Cause and effect diagram (Ishikawa).

The cause-and-effect diagram is a quality tool widely used for managing and controlling processes and was created by chemical engineer Kaoru Ishikawa [9].

It allows analyzing and identifying the main causes or occurrences of a problem, thus providing a global view of the subject being studied. This tool is also known as Ishikawa diagram or fishbone (Figure 1).

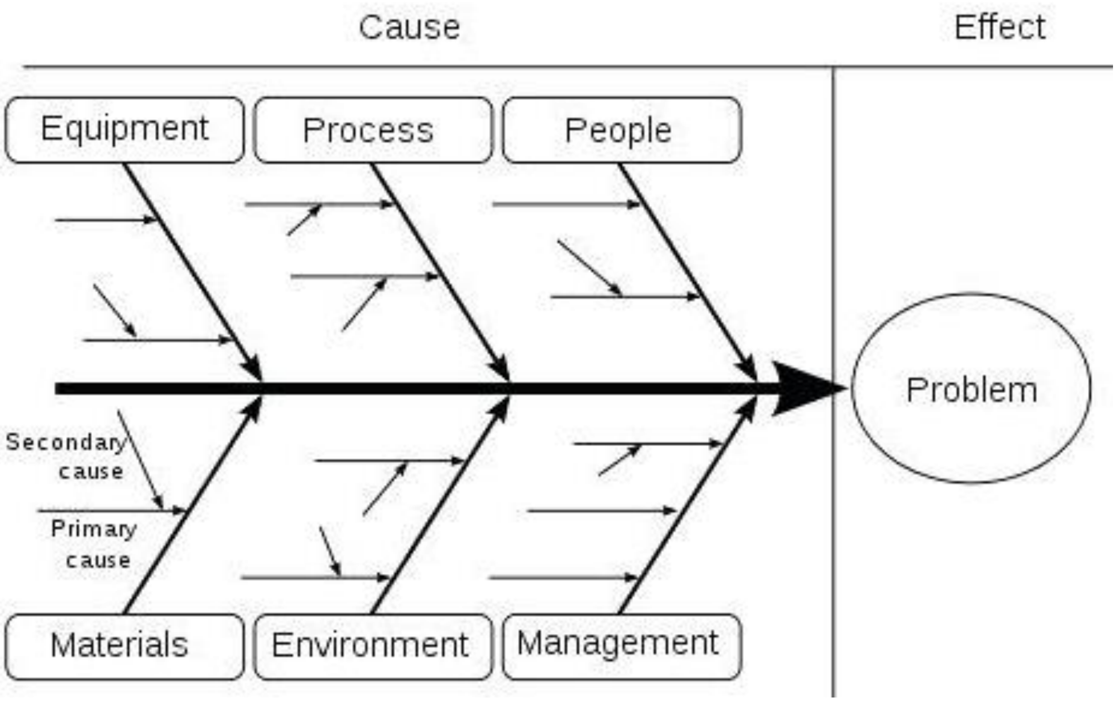


Fig. 1. Frame model Fishbone (Ishikawa).

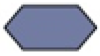
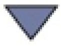
According to RAMOS [4], the cause and effect diagram is a figure composed of lines and symbols that represent a significant relationship between an effect and its possible causes. This diagram describes complex situations that would be very difficult to describe and interpret only in words. "There are probably several categories of major causes. Often these fall into one of the following categories: Measurement, Machines, Methods, Materials, Environment and Manpower.

Flow Chart

From the process steps, the flowchart has as a function to show sequentially how they are related by means of symbols that follow a pattern (Table 1) and that can be clearly recognized, thus being able to differentiate operations of process [11].

According to PEINADO [5], flowcharts are ways of representing, by means of graphic symbols, the sequence of steps of a work to facilitate its analysis. A flowchart is a visual resource used by production managers to analyze productive systems, seeking to identify opportunities to improve process efficiency.

Table 1. Table with standard symbology for flowchart.

Title	Symbol	Represents
Terminal		Start and end of flow point
Processing		Manual Operations
Document		Reports, forms, cards, etc.
Documents emission.		Documents issued to computer or manually
Decision		Possibility of alternatives
Predefined Process		Point of intersection between processes
Defined File		Permanent file of materials or documents
Provisional File		Provisional file of materials or documents

According to Oliveira [6],The main aspects of a flowchart are as follows: (i) Standardize the representation of administrative methods and procedures; (ii) More rapid description of administrative methods; (iii) Facilitate reading and understanding; (iv) Facilitate the location and identification of the most important aspects; (v) Greater flexibility; (vi) Best level of analysis.

FMEA - Failure Mode and Effects Analysis.

This tool is widely used in automotive industry and aims to assess and minimize risks by analyzing possible future failures and their effects, i.e. what is raised within this tool is a forecast of occurrences that may arise throughout the process, its degree of severity and what will be the proper treatment for them.

According to Capaldo [7],The FMEA "is a tool that seeks, in principle, to avoid, by means of analysis of potential failures and proposals for improvement actions that failures in product or process design occur". The basic objective of this technique is to detect possible failure before a part and/or product is produced (turning to the production area) and, with its use, decrease the chances of process or product to fail, that is, to increase reliability.

Implementation of FMEA depends heavily on the level of knowledge about the analyzed process, it is of great importance the prior study on this so that a quality FMEA can be elaborated, according to Berger [8], "Failure represents a fundamental concept for reliability analysis, and failure is defined as the end of an item's ability to perform a required function. Quality of a reliability analysis depends heavily on the ability of the analyst to identify all functions carried out by components and possible faults with potential for occurrence."

Development.

Use of quality tools is the focus of this case study to analyze and eliminate failures due to assembly process (only operational failures) referring to Transmission Tree Subsystem, which is a system composed of carding shafts (Figure 2) which transmit engine torque to the 1st rear axle and from this same axle to the 2nd rear axle of a truck (6x4 vehicle where the two rear axles are tractive) (Figure 3). Due to its functionality, it is a critical item, both for assembly on production line and for the use and safety of the final customer. The purpose of this study is to analyze only failures that occur in cardam assembly station that is located among the rear axles, for the assembly of cardam in the 1st rear axle is already a stable process, which has already had previous work.

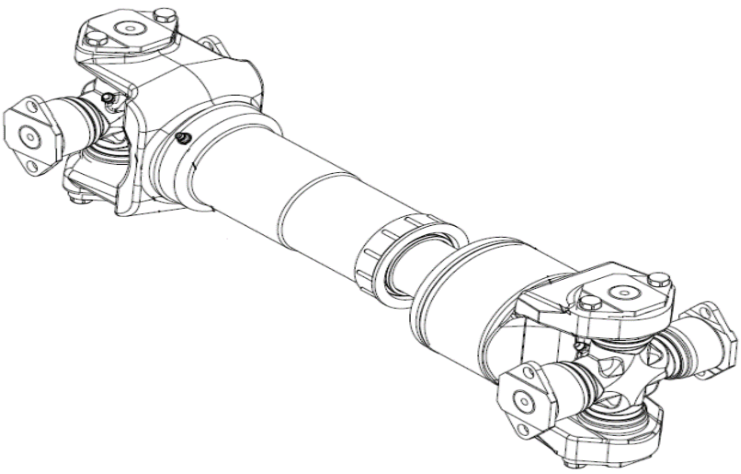


Fig. 2. Cardan shaft.

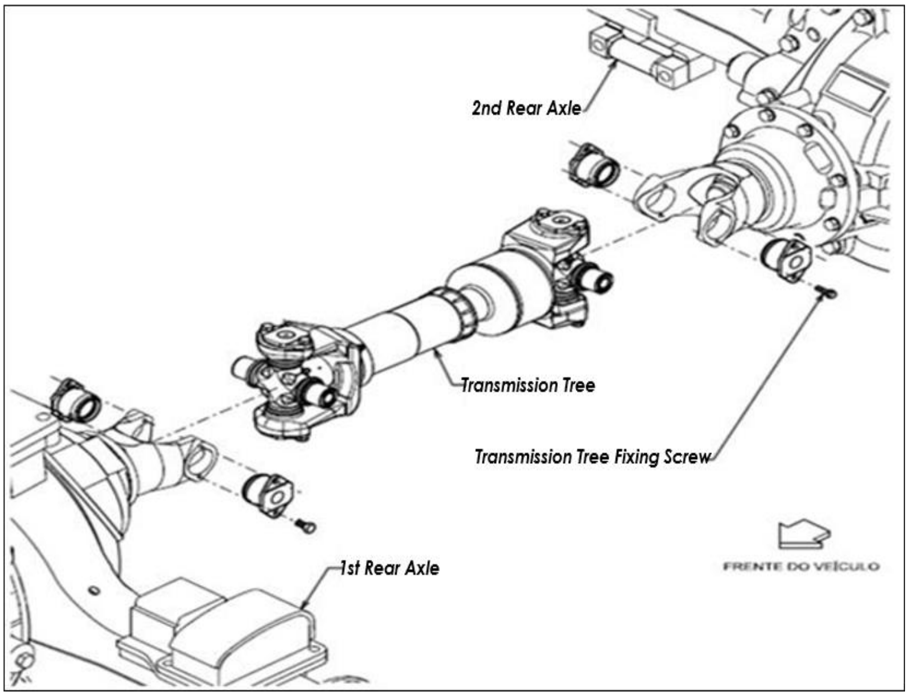


Fig. 3. Assembly of cardan between the rear axles of a 6x4 vehicle.

Data entry takes place through an inspection point that exists at the end of the assembly line of the company, ie before the vehicle is delivered to the final assembly line and process inspectors. This inspection point is called Q.G. (Quality Gate I), which has two inspectors, where they are oriented one to inspect fixation of components (nuts, bolts, torque markings) and the other in electrical roadmaps, pneumatic pipes, interferences and quality of parts. The occurrences found by the inspectors are filled in an Excel spreadsheet (Table 2 - Sample) and posted to a Server (folder in the company network) with data related to the truck model, part/location, fault code), area, shift and date of occurrence, generating, at the end of the day, a report with the mentioned occurrences.

From this worksheet, considering the history provided by the company of the year 2014, an analysis of items was carried out with the purpose of eliminating failures due to quality of parts/supplier and engineering items such as interferences/assembly concepts.

A stratification of occurrences of all the year 2014 was carried out, placing a filter in the 6x4 models, then selected another filter only in failures of Transmission Tree (Between-Axis) items. With this data and taking advantage of analysis previously performed by the company on types of failures (operational failure/quality breakdown/assembly problems), another filter was created selecting only failures generated by Production, that is, operational, which is the target of this study.

Table 2. Spreadsheet of occurrences stratified by operational failures (Sample).

Inspection of faults - Quality Gate (Internal)							
Model	Subsystem	Part / Location	Failure	Analyze	Turn	Date of occurrence	Opening Time
C	Transmission tree	CARDAN	Loose screw	Operational failure	1st turn	06/01/2014	13.06.08
B	Transmission tree	CARDAN	Missing	Quality problem	2nd turn	07/10/2014	16.28.03
C	Transmission tree	CARDAN	Loose screw	Operational failure	2nd turn	08/01/2014	17.43.55
C	Transmission tree	CARDAN	Loose screw	Operational failure	2nd turn	08/01/2014	17.58.11
C	Transmission tree	CARDAN	Loose screw	Operational failure	2nd turn	08/01/2014	18.06.22
B	Transmission tree	CARDAN	Low Torque	Operational failure	1st turn	10/01/2014	15.39.33
A	Transmission tree	CARDAN	Inverted	Operational failure	2nd turn	14/01/2014	16.27.40
E	Transmission tree	CARDAN	Assembly not in order	Operational failure	2nd turn	14/01/2014	16.43.46
A	Transmission tree	YOKE of Axle	Loose screw	Quality problem	2nd turn	22/01/2014	19.37.31
D	Transmission tree	CARDAN	Missing	Quality problem	1st turn	17/10/2014	22.30.09
D	Transmission tree	CARDAN	Loose screw	Operational failure	2nd turn	25/01/2014	22.48.50
E	Transmission tree	CARDAN	Missing	Operational failure	2nd turn	10/02/2014	23.58.25
E	Transmission tree	CARDAN	Assembly not in order	Operational failure	1st turn	11/02/2014	07.54.05
B	Transmission tree	CARDAN	Loose screw	Operational failure	1st turn	13/02/2014	09.21.50
C	Transmission tree	CARDAN	Low Torque	Operational failure	2nd turn	20/02/2014	17.21.27
B	Transmission tree	CARDAN	Loose screw	Operational failure	2nd turn	20/02/2014	22.12.29
A	Transmission tree	CARDAN	Missing	Operational failure	1st turn	21/03/2014	07.00.00
A	Transmission tree	CARDAN	Assembly not in order	Operational failure	1st turn	21/03/2014	08.09.32

By means of Excel itself, a table was created and consequently a dynamic chart, which was augmented with the use of a prioritized quality tool for decision making and actions, called the Pareto Chart. This tool shows a scale to the left of faults pointed with the number of occurrences and a scale to the right with frequency, all ordered in order of failures (the largest from left to right). The Pareto Chart is shown below (Figure 4).

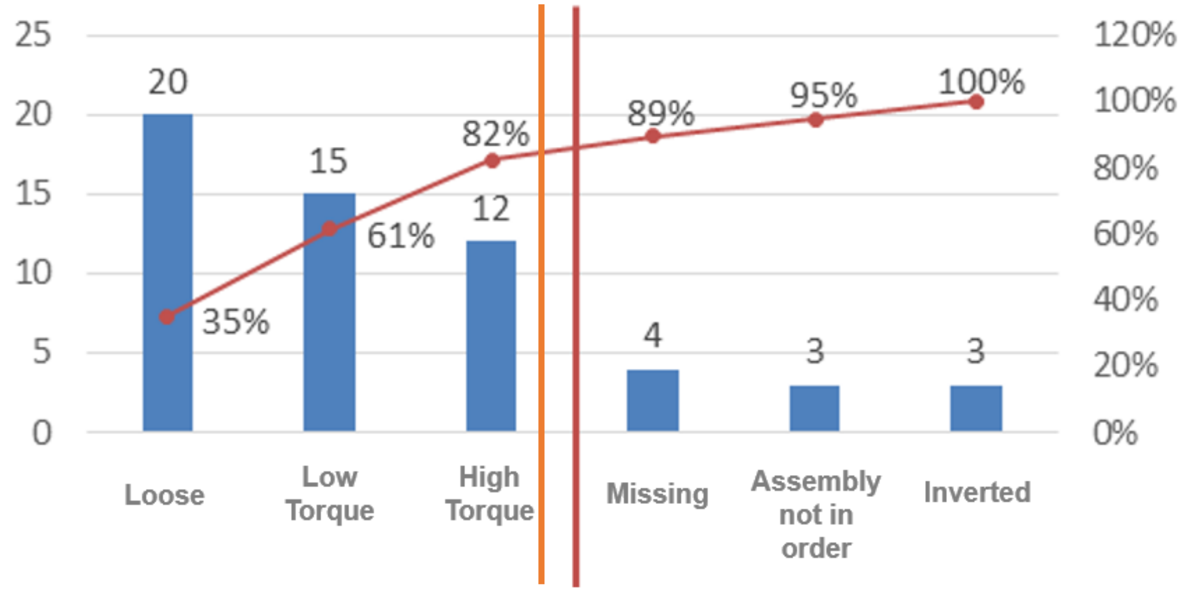


Fig. 4. Pareto Graph of Operational Failures of Transmission Tree Subsystem.

An exponential line to demonstrates in an accumulated way the percentage of each type of operational failure in which they occur to provide an experience in a clear and objective way, making it clear that approximately 80% of failures are divided into 3 main occurrences: loose, low torque and high torque, showing that these require priority in the analyzes and actions taken.

It was necessary to use another quality tool to deepen the analysis of main occurrences, the Cause and Effect Diagram, capable of presenting the relationship between a result of a process (effect) and the factors (causes) of process.

The Cause and Effect Diagram was used for TOP 3 of Transmission Tree subsystem items, which together account for approximately 80% of occurrences. The 3 faults were placed as an effect, individually in their respective diagrams, representing the operational failure to be eliminated. Then, 6 categories were created that link to the effect (Measurement/Labor/Method/Environment/Machines/Raw Material) and the analyses were done for each of the items of 3 faults with the highest incidence. Following is the result of 3 diagrams:

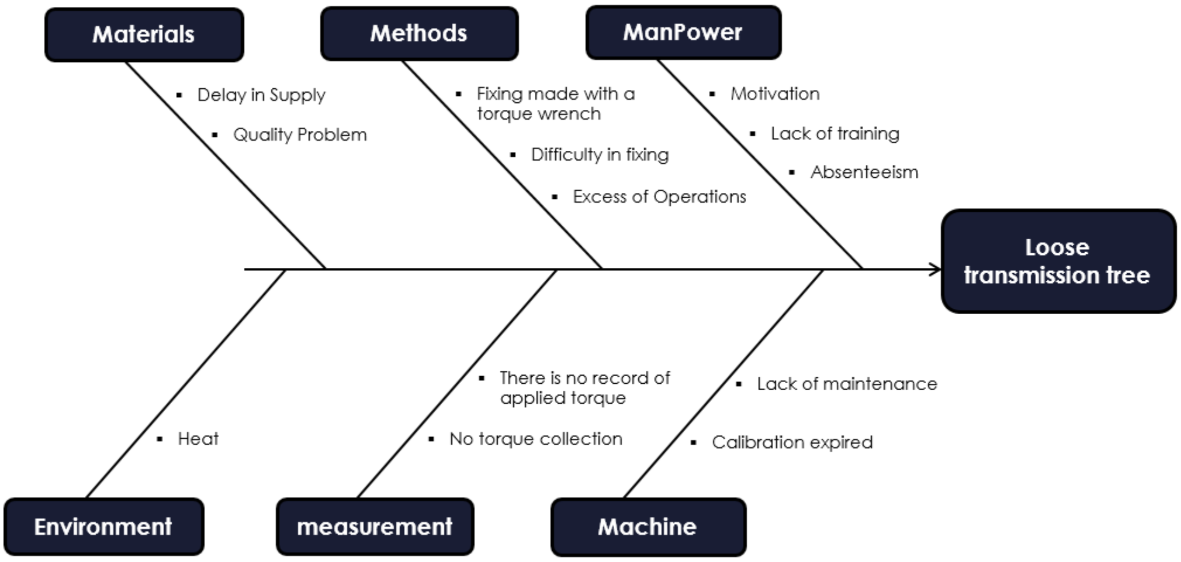


Fig. 5. Fault: Loose transmission tree.

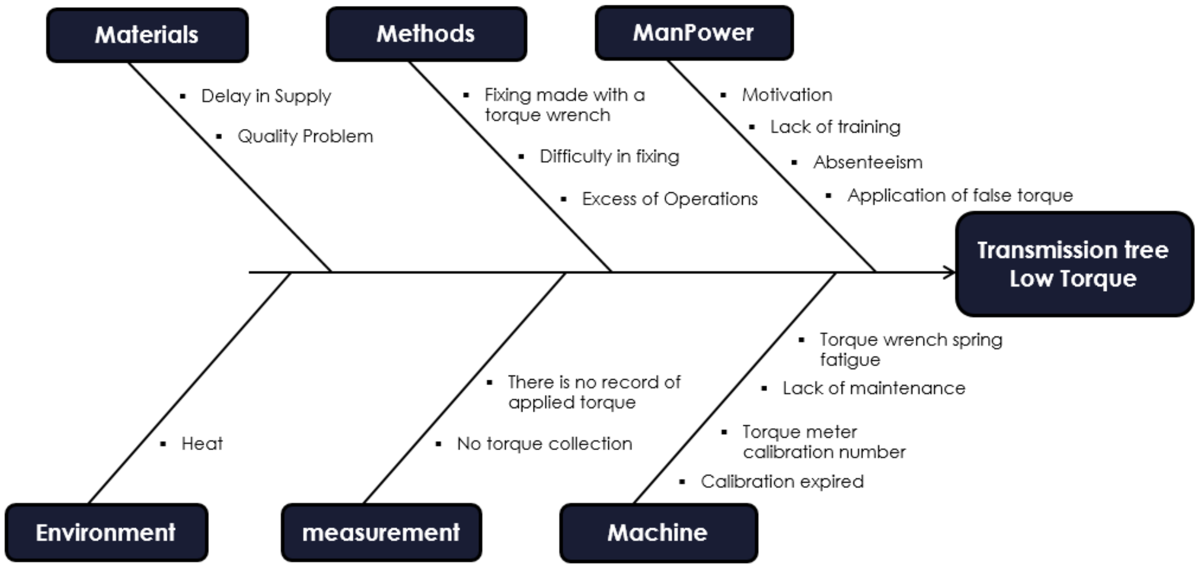


Fig. 6. Fault: Transmission shaft with low torque.

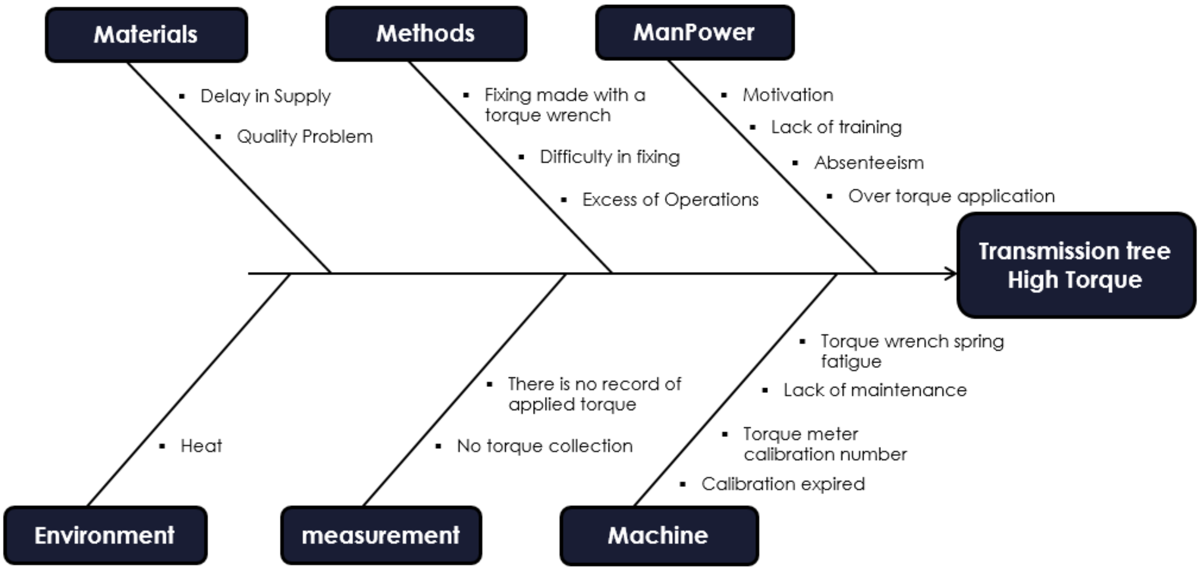


Fig. 7. Fault: Transmission shaft with high torque.

From elaboration of the Cause and Effect Diagrams, it is already possible to verify the various causes such as lack of training, material and inadequate method, high index of operations in the same post, among others, lead to occur operational failures and the aim of this case study is to eliminate these causes, however in a systemic way, working in prevention of failures, throughout the entire process, also taking into account the operator and the Final Customer security, as it could reach the customer some failure that did not reproduce within the company, but that could happen to the end user.

Due to the need to use, at this stage, a quality tool with greater weight and functionality, which provides elimination of failures effectively, a primordial tool to eliminate chances of operational failures that may have impacts both inside company and in final client, which is the PFMEA, or FMEA of Processes.

From this moment on, with the history of occurrence of Transmission Tree system, analysis of the Cause and Effect Diagram, it is possible to evaluate risks by means of a method of identifying severity of potential effects of failure, identify measures to reduce risk, to estimate probability of occurrences of causes of failures and their resulting failure modes, thus improving the reliability of process.

A multidisciplinary team was formed by the PFMEA responsible in the Company, involving representatives from each area, such as: Engineering, Quality, Manufacturing, Work Safety and Continuous Improvement [12].

A Process Flowchart (Figure 8) was elaborated, with the purpose of sequentially showing the process steps, to assist in the scope and progress of the analyzes to be made.

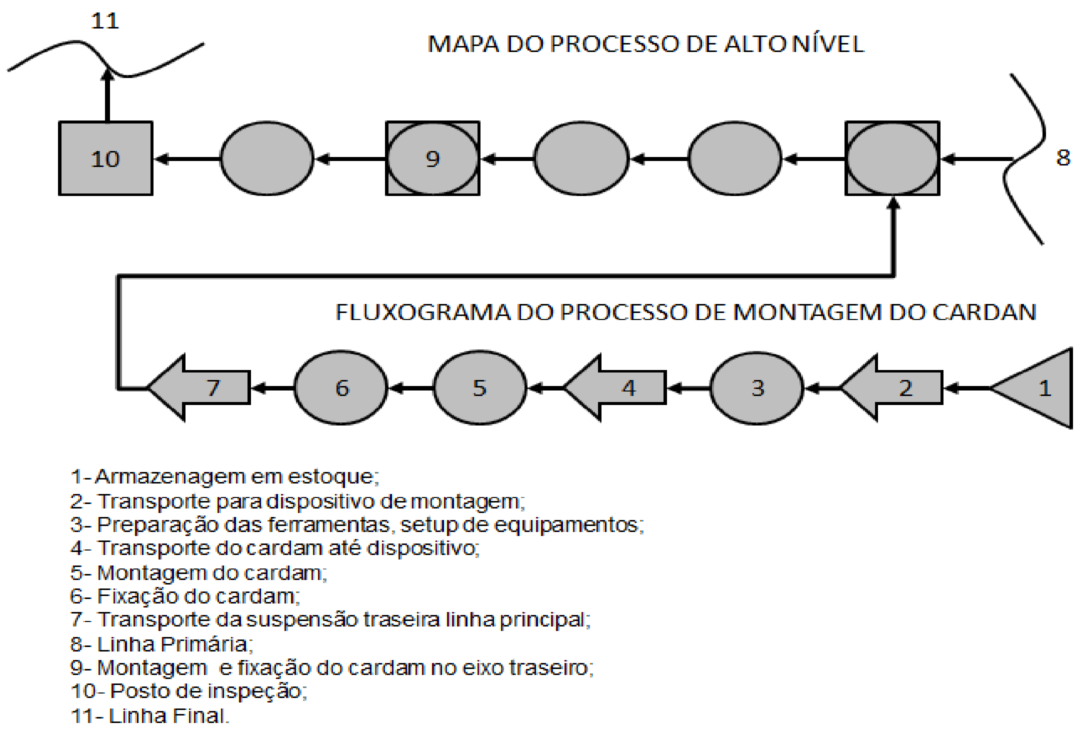


Fig. 8. Process flowchart of the cardan mounting station between the axes and the chassis line.

The following items were used as inputs for the preparation of this PFMEA:

- Non-internal and external conformities of the Transmission Tree Subsystem;
- A general Flow Chart of Process and a specific of the activity performed;
- DFMEA (PowerTrain System Design FMEA);
- Engineering specifications (torques, criticalities, special features);
- Working Instructions (Operation Sheets).

The next step was the preparation of PFMEA form for Transmission Tree Subsystem (Figures 9 and 10). Depending on the process steps, the types of operations and stages with requirements specified by Engineering as torque bands, criticality of fixations, procedures and process sheets were related and analysed. Thus, along with all entries that were raised, it was possible to describe the potential modes and effects of failure, as well as their severity and special characteristics, defining their causes still in current process, analysing controls and mechanisms of prevention and detection based on history, occurrences and ability to detect failure.

The scores assigned to the items of severity, occurrence and detection are a consensus of the whole group and analyzed on top of tables provided in the Reference Manual 4th Edition FMEA - Analysis of Mode and Effects of Potential Failure.

After these assignments, the "RPN" Field or Risk Priority Number must be filled with the result of multiplication of grades obtained in severity, occurrence and detection. The priority to take actions that decrease the above indexes are the steps with severity 9 and 10. The Final Customer has limited by 100 points, ie, what is beyond an RPN even if it is not being severity 9 or 10 should also enter a plan of immediate action.

For all the steps taken in the PFMEA, actions were defined with deadlines and responsible, seeking to reduce notes of occurrence preferably, since it is to act preventively while detection is a little more complex the actions because the focus is to make the Poka-Yoke process, or either error-proof or capable of accurately detecting the fault and not letting it continue, and severity can only be reduced at a design change.

It is estimated the results of actions after implementation of the Action Plan (Figure 11) and recalculated the RPN, and the same being within the client's need (of this company is 100) the action is justified and the investment enters the list of requests of the company.

Summary. After several group discussions about which quality tools would be used in this case study and how we could connect them to a better result in the improvement of the study process, we were able to reach our goal of improving the productive process of the transmission tree, with the use of only 5 quality tools.

At the end of this case study, it is evident how important it is to make improvements in production process. It is also clear that there are financial investments to be made in the workplace so that the changes can occur. However, these investments will be rewarded with the financial gain that the company in question will have with the reduction of rework and patio actions to verify the mentioned failures. As the actions and investments are still being implemented, there are no real values in which we can measure the size of the gain in productivity, safety and quality, the latter being for our internal or final customer due to the criticality of the assembly and use of the component transmission tree.

In general, we got the connection of different quality tools that, when they were added together, complemented each other and provided the necessary information so that we could use the next tool. The stratification of items by means of fault control worksheet, prioritization of failures to be studied by the Pareto Diagram, identification of causes of failures prioritized by the Ishikawa Diagram, the flowchart of process for the understanding of assembly flow and the PFMEA to describe the stages of process and to identify possible actions to be taken to solve problems evidenced with the use of previous tools, were of paramount importance for us to arrive at a satisfactory result in the improvement of productive process of the tree streaming.

This study demonstrates how it is possible to use quality tools for improvement and control of productive processes.

Process / function step	Affected Class	Requirement	Potential failure mode	Potential Failure Effect (s)	Item Severity	Greater Severity	Ranking	Fault Potential Cause (s)	Current process				PNR	Recommended Action	Liability and Intended Completion Date	Result of actions					Suggestion for Future
									Controls Prevention	Occurrence	Ccontrols Detection	Detection				Actions implemented Date Completed	Item Severity	Occurrence	Detection	PNR	
1) Carry cardan to the rear axle	A/B/C/D/E	Carry the cardan with the use of the carving with tape	Do not use the hoist to transport the cardan to the rear axle (fall of the drive shaft)	**Under End Client** There is no	1	10	C	The operator does not use the hoist for transporting the transmission tree	There is no	1	There is no	10	100	Elaborate process sheet to use the hoist / training 100% of the operators / Audits	Process Engineering Week 22	Revisão das folhas de processo/ treinamento dos operadores/ implementada sistemática de auditorias pelos Líderes 1 vez por semana SEM 22	10	1	8	80	-
				Impact on line - Internal customer Fall of the cardan, delay of the line for exchange	7		S														
				Operator safety Risk of falling cardan (Beat Against)	10		R														
2) Fit the inter-axle cardan	A/B/C/D/E	Assemble the cardan according to OPRE sequencing and mounting position	2.1- Assemble the cardan of another model	**Under End Client** Reduced level of traction performance	5	6	N	Operator does not check the OPRE with part code	Refer to the process sheet and the correct	1	Operator visual inspection (self control)	6	36	On The Job Training 100% of Operators and Leaders	Manufacturing Week 21	Treinamento de todos os operadores pelos Líderes SEM 21	6	1	6	36	-
				Impact on line - Internal customer Rework	6		N														
				Operator safety There is no	1		N														
			2.2- Mount the inverted cardan	**Under End Client** Reduced level of traction performance	5	5	A	Instruction in process sheet is unclear to operator	There is no	3	Inspector visual inspection	8	120	Process sheet update with new image or photo and retraining training	Process Engineering Week 20	Revisão das folhas de processo/ treinamento dos operadores/ SEM 21	5	3	8	120	Develop Poka-Yoke Mounting Device
				Impact on line - Internal customer Rework	4		D														
				Operator safety There is no	1		N														
			2.3- Do not mount all 8 bolts of the transmission tree	**Under End Client** Reduced level of traction performance	5	5	A	Operator does not follow the correct sequence of assembly according to process instruction	There is no	4	Operator visual inspection (self control)	6	120	On The Job Training 100% of Operators and Leaders	Manufacturing Week 20	Treinamento de todos os operadores pelos Líderes SEM 20	5	4	6	120	
				Impact on line - Internal customer Rework	4		D														
				Operator safety There is no	1		N														
3) Fixation of the transmission tree	A/E	Fasten the 8 bolts of the transmission tree by applying a torque of 150 to 200 Nm	3.1- Fasten Bolts with torque above specified (Screening / Screw Breaking)	**Under End Client** Releasing the drive shaft due to screw rupture	10	10	A	Loss of calibration of the pneumatic screwdriver and digital torque wrench	Periodic maintenance / training of technicians who perform equipment maintenance and programming	1	Visual alarm, sound and vibration alarm during attachment with the digital torque wrench, in addition to the sequence in the HMI panel (Programming with JOB Blocking)	3	30	Implement angle study	Process Engineering Week 35		10	1	2	20	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Component change (production delay)	4		N														
				Operator safety There is no	1		N														
			3.2- Fix Screws with Torque Below Specified	**Under End Client** Drive shaft release due to gradual loss of torque	10	10	A	Loss of calibration of the pneumatic screwdriver and digital torque wrench	Periodic maintenance / training of technicians who perform equipment maintenance and programming	1	Visual alarm, sound and vibration alarm during attachment with the digital torque wrench, in addition to the sequence in the HMI panel (Programming with JOB Blocking)	3	30	Implement angle study	Process Engineering Week 35		10	1	2	20	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Screw reattachment (delay in the production)	2		N														
				Operator safety There is no	1		N														
			3.3- Do not fix all 8 screws	**Under End Client** Screw release, drop of drive shaft	10	10	A	Do not follow the orientation of the clamping sequence shown on the HMI of the digital torque wrench	Employee training on how to use the digital torque wrench and follow the sequence of the anchorages in the torque wrench HMI panel	3	Visual alarm, sound and vibration alarm during attachment with the digital torque wrench, in addition to the sequence in the HMI panel (Programming with JOB Blocking)	3	90	New training with 100% of the employees and Leaders on the procedure of fixing the screws of the transmission shaft	Manufacturing Week 20	Reciclagem de treinamento de todos os operadores pelos Líderes SEM 20	10	3	3	90	-----
				Impact on line - Internal customer Fixing missing screws (production delay)	2		N														
				Operator safety There is no	1		N														

Fig. 9. PFMEA for the Transmission Tree Subsystem.

Process / function step	Affected Class	Requirement	Potential failure mode	Potential Failure Effect (s)	Item Severity	Greater Severity	Ranking	Fault Potential Cause (s)	Current process: Controls Prevention	Occurrence	Ccontrols Detection	Detection	PNR	Recommended Action	Liability and Intended Completion Date	Result of actions: Actions implemented Date Completed	Item Severity	Occurrence	Detection	PNR	Suggestion for Future
3) Fixation of the transmission tree	C/D	Fasten the 8 bolts of the transmission tree by applying torque of 51 to 65 Nm	3.4- Fasten Bolts with torque above specified (Screening / Screw Breaking)	**Under End Client** Releasing the drive shaft due to screw rupture	10	10	A	Loss of calibration of the pneumatic screwdriver and digital torque wrench	Periodic maintenance / training of technicians who perform equipment maintenance and programming	4	Torque validation included in the equipment setup procedure, before production	6	240	Open Purchase Request for equipment capable of controlling, registering, storing applied torques and blocking of NOK	Manufacturing Planning Week 25		10	4	3	120	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Component change (production delay)	4		N														
				Operator safety There is no	1		N														
			3.5- Fix Screws with torque below specified	**Under End Client** Drive shaft release due to gradual loss of torque	10	10	A	Loss of calibration of the pneumatic screwdriver and digital torque wrench	Periodic maintenance / training of technicians who perform equipment maintenance and programming	4	Torque validation included in the equipment setup procedure, before production	6	240	Open Purchase Request for equipment capable of controlling, registering, storing applied torques and blocking of NOK	Manufacturing Planning Week 25		10	4	3	120	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Screw reattachment (delay in the production)	2		N														
				Operator safety There is no	1		N														
			3.6- Do not fix all 8 screws	**Under End Client** Screw release, drop of drive shaft	10	10	A	Do not follow the instruction in the process sheet	There is no	4	Inspection with manual conference device at Quality Gate (inspection post)	6	240	Open Purchase Request for equipment capable of controlling, registering, storing applied torques and blocking of NOK	Manufacturing Planning Week 25		10	4	3	120	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Fixing missing screws (production delay)	2		N														
				Operator safety There is no	1		N														
	B	Fasten the 8 bolts of the transmission tree by applying torque of 16 to 23 Nm	3.7- Fasten Bolts with torque above specified (Screening / Screw Breaking)	**Under End Client** Releasing the drive shaft due to screw rupture	10	10	A	Loss of calibration of the pneumatic screwdriver and digital torque wrench	Periodic maintenance / training of technicians who perform equipment maintenance and programming	4	Torque validation included in the equipment setup procedure, before production	6	240	Open Purchase Request for equipment capable of controlling, registering, storing applied torques and blocking of NOK	Manufacturing Planning Week 25		10	4	3	120	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Component change (production delay)	4		N														
				Operator safety There is no	1		N														
			3.8- Fasten Screws with Torque Below Specified	**Under End Client** Drive shaft release due to gradual loss of torque	10	10	A	Loss of calibration of the pneumatic screwdriver and digital torque wrench	Periodic maintenance / training of technicians who perform equipment maintenance and programming	4	Torque validation included in the equipment setup procedure, before production	6	240	Open Purchase Request for equipment capable of controlling, registering, storing applied torques and blocking of NOK	Manufacturing Planning Week 25		10	4	3	120	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Screw reattachment (delay in the production)	2		N														
				Operator safety There is no	1		N														
			3.9- Do not fix all 8 screws	**Under End Client** Screw release, drop of drive shaft	10	10	A	Do not follow the instruction in the process sheet	There is no	4	Inspection with manual conference device at Quality Gate (inspection post)	6	240	Open Purchase Request for equipment capable of controlling, registering, storing applied torques and blocking of NOK	Manufacturing Planning Week 25		10	4	3	120	Implement Statistical Process Control /M.S.A.
				Impact on line - Internal customer Fixing missing screws (production delay)	2		N														
				Operator safety There is no	1		N														

Fig. 10. PFMEA for the Transmission Tree Subsystem.

System: PowerTrain
subsystem: Transmission Tree

STAGE) ACTIVITIES	PLAN START	PLAN DURATION	REAL START	REAL DURATION	PERCENTAGE COMPLETED
1- Elaborate process sheet to use the hoist / training 100% of the operators / Audits	22	1	22	1	100%
2.1- On The Job Training 100% of Operators and Leaders	21	1	21	1	100%
2.2- Process sheet update with new image or photo and retraining training	20	1	21	1	100%
2.3- On The Job Training 100% of Operators and Leaders	20	2	20	4	100%
3.1- Implement angle study for torque of 150-200 Nm	33	2	33	2	100%
3.2- Implement angle study for torque of 150-200 Nm	33	2	33	2	100%
3.3- Recycling training of the operators on the fixing of the screws of the transmission shaft	20	1	20	1	100%
3.4- Open Request for Purchase of equipment capable of controlling, registering;	24	1	24	2	100%
3.5- Open Request for Purchase of equipment capable of controlling, registering;	24	1	24	2	100%
3.6- Open Request for Purchase of equipment capable of controlling, registering;	24	1	24	2	100%
3.7- Open Request for Purchase of equipment capable of controlling, registering;	24	1	24	1	100%
3.8- Open Request for Purchase of equipment capable of controlling, registering;	24	1	24	1	100%
3.9- Open Request for Purchase of equipment capable of controlling, registering;	24	1	24	1	100%
2.2- Open Request for Purchase of a Poka-Yoke Device to Mount the Transmission Tree	30	1	30	1	100%

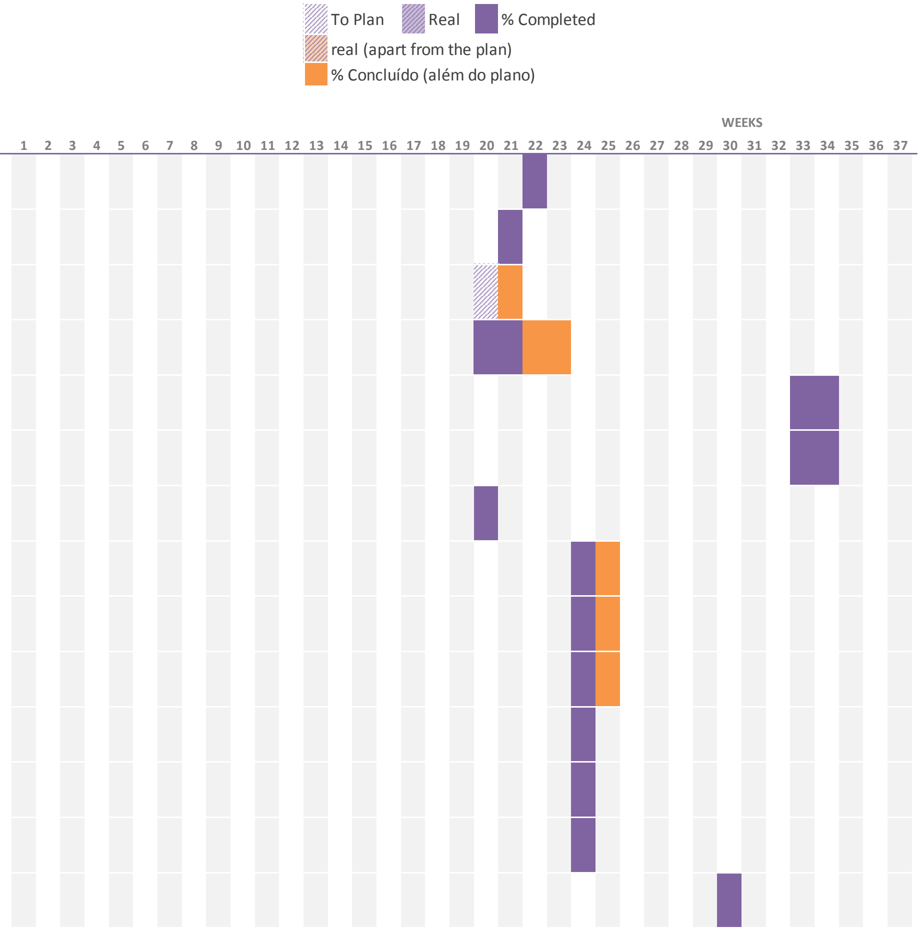


Fig. 11. Schedule of the PFMEA Recommended Action Plan.

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