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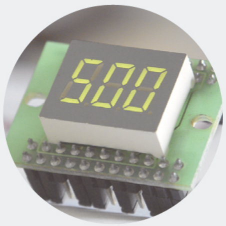


Key Corporate Process-Quality

FRANCISCO XAVIER PINTO CARDOSO
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Instituto Superior de Engenharia do Porto

Key Corporate Process-Quality

Francisco Xavier Pinto Cardoso

Master in Electrical and Computer Engineering
Specialization Area of Systems And Industrial Planning

Departamento de Engenharia Eletrotécnica
Instituto Superior de Engenharia do Porto

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Candidate: Francisco Xavier Pinto Cardoso, No. 1161253, 1161253@isep.ipp.pt

Scientific Guidance: António Almeida, aha@isep.ipp.pt

Company: Kirchhoff Auomotive
Advisor: Ricardo Castelbranco, ricardo.castelbranco@kirchhoff-automotive.com

Departamento de Engenharia Eletrotécnica
Instituto Superior de Engenharia do Porto
Rua Dr. António Bernardino de Almeida, 431, 4200–072 Porto

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Abstract

In a world with exponential technological evolution, competitiveness tends to increase and intensify. The scope of this project focuses on one of the most competitive areas of today, the automotive industry. An industry that is extremely demanding and less receptive to failure.

The times dictate that the trend is the focus on Zero Defects, and for this, cases such as complaints are taken into account and are increasingly eliminating factors for suppliers. There are annual targets that, if not met, will lead to drastic reductions in orders for those suppliers or even the termination of relationships.

Therefore, one of the biggest focuses in recent years of automotive companies has been the creation of Zero Defects programs, in which the goal is to prevent the occurrence of defects, and although it is not ideal, when they occur, must be stopped immediately after, without reaching the end customer.

The ambit of this Thesis is the creation of an analysis and quality improvement framework in the automotive industry, directly focused on the elimination of failures occurrences, in order to achieve the goal of Zero Defects.

To do this, an analysis of the complaints received by Kirchhoff Portugal will be performed, so that can be found patterns of defects, in order to develop preventive measures so that in the future, the type of defects identified will no longer occur.

In addition to the analysis of the complaints, an analysis of the incidents found within the company, before they reach the customer, with the same goal, to develop preventive measures so that these defects have less chance of occurring. After all, although detected before sending to the customer, also has associated costs of rectification or scrap. After finding the patterns, countermeasures of improvement will be proposed and analyzed if they are feasible.

To finish the entire development cycle, one of the approved countermeasures will be developed, implemented, and detailed in what it consists of and how it fits into the scope of work.

Keywords: Automotive, Industry, Quality, Cost of Quality, Claims, Internal Incidents, Prevention, Standard, Instructions, E-learning

Resumo

Num mundo com uma evolução tecnológica exponencial, a competitividade tende a aumentar e a intensificar-se. O âmbito deste projeto centra-se numa das áreas mais competitivas da atualidade, a indústria automóvel. Uma indústria que é extremamente exigente e pouco recetiva à ocorrência de falhas.

Os tempos ditam que a tendência é o foco nos Zero Defeitos, e para isso, casos como reclamações são tidos em conta e são considerados fatores eliminatório para os fornecedores. São definidos objetivos anuais que, se não forem atingidos, levarão a reduções drásticas nas encomendas para esses fornecedores ou mesmo ao fim da relação comercial.

Portanto, um dos maiores focos nos últimos anos das empresas do sector automóvel tem sido a criação de programas de Zero Defeitos, nos quais o objetivo é evitar a ocorrência de defeitos, e embora não seja ideal, quando estes ocorrem, devem ser detetados imediatamente a seguir, sem chegar ao cliente final.

O âmbito desta tese é a criação de uma framework de análise e melhoria da qualidade na indústria automóvel, diretamente centrado na eliminação de ocorrências de falhas, de modo a atingir o objetivo dos Zero Defeitos.

Para tal, será realizada uma análise das reclamações recebidas pela Kirchhoff Portugal, para que se possam encontrar padrões de defeitos, a fim de desenvolver medidas preventivas para que, no futuro, o tipo de defeitos identificados deixe de ocorrer.

Para além da análise das reclamações, será efetuada uma análise dos incidentes encontrados na empresa, antes de estes chegarem ao cliente, com o mesmo objetivo, a fim de desenvolver medidas preventivas para que estes defeitos tenham menos hipóteses de ocorrer. Afinal, embora detetados antes de serem enviados ao cliente, também têm associados custos de reparação ou sucata. Após a descoberta dos padrões, serão propostas e analisadas contra-medidas de melhoria.

Para terminar todo o ciclo de desenvolvimento, uma das contra-medidas aprovadas será desenvolvida, implementada, e detalhada no que consiste e como se enquadra no âmbito do trabalho.

Palavras-Chave: Automóvel, Indústria, Qualidade, Custo da Qualidade, Reclamações, Incidentes Internos, Prevenção, Norma, Instruções, E-learning

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List of Acronyms

AC	*Appraisal Cost*
CCC	*Checking and Control Cost*
CoC	*Cost of Conformance*
CoNC	*Cost of Non Conformance*
CONQ	*Cost of Non Quality*
COQ	*Cost of Quality*
CoQ	*Cost of Quality*
EFC	*External Failure Cost*
FPC	*Failure Prevention Cost*
IFC	*Internal Failure Cost*
PC	*Prevention Cost*
QMS	*Quality Management Systems*
QPRS	*Quality Performance Reporting System*

Chapter 1

Introduction

1.1 Contextualization

With the galloping evolution of technology, particularly within the industry, competitiveness tends to increase. In the case we propose to study, the focus will be on the automotive industry, one of the most demanding areas in the industrial branch. Cost and quality are two critical factors in evaluating a company's competitiveness in any business area. This becomes even more important in an area such as the automotive industry, where partner demands are incredibly high, and breaks or pauses in the supply chain are associated with high losses.

The expansion of data storage solutions has grown exponentially in recent years. The amount of data collected is growing every day. As we know, data speak. It tells us about the past and the present and helps to predict the future.

The automotive industry is one of the industries with more data available to be analyzed. The problem often lies in the processing that is done of this data. We are talking about an area where frequently the focus is directional to finding solutions to day-to-day problems; there is a lack of a more comprehensive analysis, such as looking at the "big picture" and extracting information so that when the reason why a failure occurred is detected, the proper mechanisms are used so that it doesn't happen ever again, focusing in the creation of preventive methods for the already documented failures.

In this sense, the analysis of the data already collected becomes fundamental to evaluating the problems and points to be improved. So that decisions can be taken based on factual data and not on directors' feelings.

The focus should not be on the control of quality after the defects are produced or the prevention of defect occurrence because quality is free if you produce well the first time.

Long gone are the times when quality was only controlled. Nowadays, the goal is the exact opposite. There is no need to control quality, following the idea of producing quality. "If we produce correct from the first time, Quality is free."

1.2 Problem Definition

KIRCHHOFF Automotive is a company operating in the automotive industry, explicitly producing complex metal and hybrid structures for body-in-white and chassis, crash management systems, and dashboards carriers.

The automotive industry is well known for its high demands on product quality. The requirements are even higher in the case of the company under study, which specializes in one of the most safety-critical areas in the car structure.

One of the most important indicators for evaluating an assessment of product quality is the number of quality complaints a company receives from its customers. Moreover, quality complaints are associated with high costs for companies. These costs can be quantifiable, such as product recalls, external sort, scrap, and rework, or non-quantifiable, such as customer dissatisfaction and loss of reputation.

Over the years, the company has been fighting against the high number of quality complaints they face for many reasons, setting maximum targets and achieving a downward trend. However, in recent years, since 2017, this downward trend has not been maintained due to showed incapacity to succeed in the main quality objective.

So, KIRCHHOFF Automotive's problem is identified – a high number of quality complaints. To solve the problem, this research proposes to study the problem and develop a solution that is less reactive to the occurrence of complaints but, on the other hand, can predict and solve the issue in the root cause and avoid non-conformities before they reach the customer, which will lead to a reduction in the number of complaints received from customers and the related costs the company is obligated to support.

1.3 Research Question

Based on the problem presented by the company, it is of extreme relevance to realize that the occurrence of a quality complaint related directly to the production of a defect that went undetected through the entire production chain and reached the customer.

Considering the goal of this thesis, the research centered on two leading questions that served as a guiding basis:

- How effective does production system performance monitoring reduce quality complaints?
- How can root-cause analysis helps to prevent non-conformities and reduce production costs?

1.4 Research Methodology

Although the problem with a large number of claims is a problem for the Europe-Asia group, the option was to perform a specific case study. Because of the proximity of access to data and information, the opportunity fell on the KIRCHHOFF AUTOMOTIVE Portugal. The methodology applied was an initially quantitative methodology to identify the focus of the study based on data, followed by a qualitative analysis of the causes of occurrences and investigation of possible solutions to them. It was decided that this work would be divided into four main phases.

In the first phase, the focus was on learning about the company's production process. To do this, the internal documentation that describes the various steps of the process and the standards were consulted and studied, in addition to informal interviews conducted with the process owners and multiple people. They work on the Shop Floor, such as Operators, Team-Leaders, Controllers, and Productive Engineers.

The second part was evaluating the type of data in the company to collect the most relevant data to analyze the problem. The data collected was the Total Cost of Quality, the Database of External Incidents (complaints), and the Database of Internal Incidents.

After the Data Collection, it was necessary to perform Data Analysis, which required Data Cleaning followed by Data Clustering to create a Data Summary where the data is aggregated and visually explanatory so that it is possible to propose actions.

With this information, a Root Causes Analysis was conducted to expose and present all the possible causes for the production of defects. This work was performed based on the history of complaints within the company and with the help of a specialist in each area. This part aimed to create a root cause classification.

After a countermeasures investigation was performed to produce valid proposals that can influence strategic and operational decisions, they finished with the final considerations, a demonstration of the accepted recommendations, and the plans for their implementation.

Chapter 2

Research Framework

2.1 Overview

To achieve what was proposed in this Thesis, it was necessary to structure a research framework. This framework is based on the case study of Kirchhoff Automotive Portugal and divided into five main parts: a literature review of the subjective and study of the company production process, collection and analysis of data, root-cause analysis, countermeasures proposal, and implementation of the proposals, as demonstrated at the diagram in Fig.2.1.

2.2 Literature Review and Company Production Process Study

Since the scope of this study is quality-related, the literature review is performed by analyzing academic documents relevant to the topic, such as theses, papers, journal articles, books, etc. Besides analyzing the norms most used in the automotive industry, such as ISO 8001 and IAFT.

The study of the company production process was performed by collecting and studying all company documentation available on the internal processes and standards adopted on the shop floor. This study was complemented by informal interviews with process owners and shop floor and support personnel.

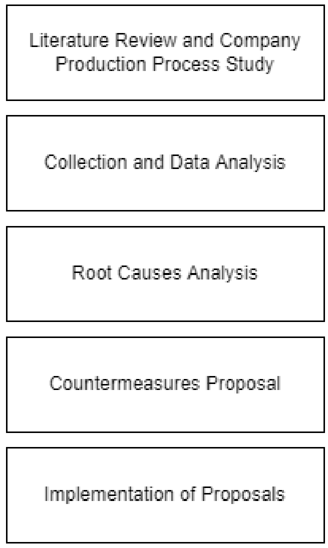


Figure 2.1: Research Framework

2.3 Collection and Data Analysis

Considering that the objective was to gain a better insight into the possibilities to reduce defects production in terms of collection and data analysis, the first step was to understand what kind of quality-related data existed within the company since it's the data associated with defects production.

The company already had a defined Cost of Quality Framework, where all the costs related to the quality department are collected. In addition, there are two different databases, one that registers the details of a customer claim, and the other focus on failures detected internally. Starting by finding out what was the percentage of net sales spent with the cost of quality, in the range from 2015 until 2020, so we can understand how it affects the company's invoicing.

As the Non-Quality Cost is divided into two sub-categories, the one related to the cost of detecting internally a failure, before delivered to the customer, called Internal Failures Costs, and the other related to receiving a complaint from a customer, the External Failure Cost, was considered relevant to investigate the relationship between the two indicators.

The first objective was to understand the direct relationship between the costs of external failures and the costs of internal failures, for this, the ratio between these two values was calculated.

After analyzing the cost of failures, it was necessary to quantify the number of incidents of these costs. And search again for a relationship between the number of incidents detected internally and externally (claims). This was possible because the company already had two databases for defect detection. One for internal defects and another for external defects. In this case, we had to reduce the time range of analysis, since the internal incident database only started to be collected at the beginning of 2018, leaving the range from 2018 to 2020.

The next step was to explore the failures themselves.

Answering questions such as:

- What is the production area that reports more defects?
- In each productive area, which technology fails the most?
- What type of defects are more frequent by technology?

To answer this question, the Data Bases were checked for missing data, and created new associations were. Created the association with the identification of a part and the machine that produces it, which in turn, allowed the creation of the area clustering, and the technology used in clustering. In the External Failures database, the information of each process that produced the defect was missing, because the part id registration only indicated the identification number final of the product before it was sent to the customer, thus losing the indication of the process that produced the defect! For this reason was necessary to analyze one by one the descriptions of the defects and question the leaders responsible for each claim.

2.4 Root-Causes Analysis

After identifying the defect clustering, proceeded with the root-causes analysis and its classification, intending to identify the most frequent causes that originated each defect in the study. The tool chosen to help achieve the goal was the Ishikawa diagram, which is the most widely used quality tool for this type of investigation. The analysis of an Ishikawa diagram includes the working people, machines, materials, methods, environment, and management evaluation.

It became necessary to collect information from similar situations, that is, the situation where the defects clusters had already been identified. Whenever the company receives a complaint from a customer or detects a non-conformity internally, it has predefined actions to solve it, such as identifying the problem, searching for the possible cause that originated the defect, and proposing measures to eliminate the defect, was possible to collect this data and use it as a starting point for the root-causes analysis.

However, this information cannot be fully considered because it is stored and recorded in the company system. Some missing documents, and incomplete information, are difficult to read because the documents are handwritten and digitized. To overcome this difficulty, working groups were created with the process owner and the technical specialists.

Based on the information extracted from the documentation and the knowledge of the working group, an Ishikawa was elaborate for each cluster found previously, with all the defects causes that were possible to identify. Then it was necessary to highlight which of these identified more often as responsible and proceed to the next step, find the root causes of these occurrences.

To find the root cause, the 5 why's technique was selected, which tells that by repeating the question "Why?" 5 times, it is possible to find the problem that can be improved and consequently eliminate the defect production. All the possible reasons were "put on the table" and then evaluated, in fact, the root causes, with the workgroup with specialists' help.

2.5 Countermeasures Proposal

After finding the root causes, the next step was analyzing the causes of the defect's appearance and investigating possible countermeasures.

For this investigation was create another work group to take into consideration some of the suggestions received during the realization of this work. The constant open line of communication with the process owner has to evaluate what could be feasible in terms of time, people, and budget.

Here the data already available at the company was taken into consideration by consulting the most common solution previously used to solve the problem we were investigating.

With this information and the knowledge of the specialist in the area, possible global solutions to end the problem in all the machines with that technology were proposed.

Some of the conclusions of this evaluation were extrapolated to other factories in the group, and one of the observations made in this work was the origin of a think tank to solve a transversal problem in the organization.

2.6 Implementation of Proposals

To close the cycle, one of the proposals approved was developed within the scope of this work.

As one of the most frequent failures was the lack of standard shop floor training and the lack of follow-up on this type of training, it was defined as a priority the creation of a training standard to be taught to the Operator upon his entry into the company and also to the ones already working on the plant.

This training was based on the processes already existing within the company, documenting them and creating a learning column so that each process associated with Zero Defects was clearly explained.

The development of this training meets the objective of the thesis because the training of operators fits the preventive measure of failures.

In addition to the creation of the training, it was also agreed that every year all operators would have a session to review this training.

Chapter 3

State of Art

3.1 Quality

The term "quality" that we use daily differs from the concept of quality used in the industry. The idea of quality commonly used refers to durable products that meet our expectations and whose inconvenience is good and will not break down. In industry, the concept relates to meeting the specifications defined by the producer and fulfilling them.

Analyzing the Norm EN ISO 9000:2015 [1] refers to an organization's quality as "An organization focused on quality fosters a culture that translates into behaviors, attitudes, activities, and process that value by meeting the needs and expectations of customers and other relevant stakeholders. The quality of an organization's products and services is determined by its ability to satisfy customers and its intended or unintended impact on other relevant stakeholders. The quality of products and services includes the intended function and performance and the corresponding perceived value and benefits to the customer."

In a competitive market such as Automotive Industry, the goal of any company is to stay in the market with a good reputation and generate profit. For that purpose, it is necessary to have a good acceptance in the market. The customer wants to acquire the product/service because it meets its needs in terms of suitability for use and reliability.

When the product/service has some defect, the consumer will demand his right to replace the product/service, he can ask for compensation for the inconvenience, and probably will not buy that brand or that product/service anymore. The company image may be highly damaged, so the cost of a defective product/service has an inestimable price for a company and is sometimes priceless. To combat this situation, companies implement *Quality Management Systems* (QMS) to continuously improve the quality of their products/services to serve the customers.

To measure the improvements introduced by QMS, the indicator that companies value the most is related to costs, in this case, *Cost of Quality* (CoQ).

3.1.1 *Cost of Quality* (CoQ)

Cost of Quality (CoQ) is not the cost of manufacturing a high-level product or service. It instead represents any cost incurred due to the effort to pursue good quality or the lack of quality, called poor quality.

Using the base of Dr. Armand V. Feigenbaum [2], created while working at General Electric Company in the 1950s, we can separate the cost of quality into four categories:

- ***Prevention Cost* (PC)** – The cost a company spends in all actions taken to investigate, prevent or reduce the quality problems from occurring. Examples are the cost of quality planning, quality control system, new products review, quality education and training, supplier audit, internal quality system audit, and improvement programs.

- ***Appraisal Cost* (AC)** – The cost a company spends to measure, evaluate, and audit products or services to achieve quality and performance requirements. Checking and Control Costs include raw-material other inspections, calibrations, measuring and test equipment, scrap from destructive testing, and final-goods inspection.

- ***Internal Failure Cost* (IFC)** – Failure cost within an organization before delivering the product to the customer. Those costs are associated with an internal sort and rework, internal scraps, internal problem analysis, re-insertions, retests, bottle-necking, and downtime.

- ***External Failure Cost* (EFC)** – Failure cost occurring after product delivery with unacceptable characteristics. Examples are the cost associated with complaint handling, external scrap, external sort and rework, customer returns, warranty costs, product recalls, and charges.

The cost mentioned above can be grouped into two categories: *Cost of Conformance* (CoC) and the *Cost of Non Conformance* (CoNC).

The *Cost of Conformance* is associated with planned activities to prevent the failures from occurring. They represent discretionary or control cost, which include the *Prevention Cost* and the *Appraisal Cost*.

The *Cost of Non Conformance* are related to the costs not planned, whit consequential or failure costs. Here are insert the *Internal Failure Cost* (IFC) and the *External Failure Cost* (EFC).

The PAF Model, which refers to Prevention (P), Appraisal (A), and Failure (F), shows the total *Cost of Quality* as the sum of *Cost of Conformance* (P and A) with the *Cost of Non Conformance* (F) [3], which can be presented as shown in the Figure 3.1:

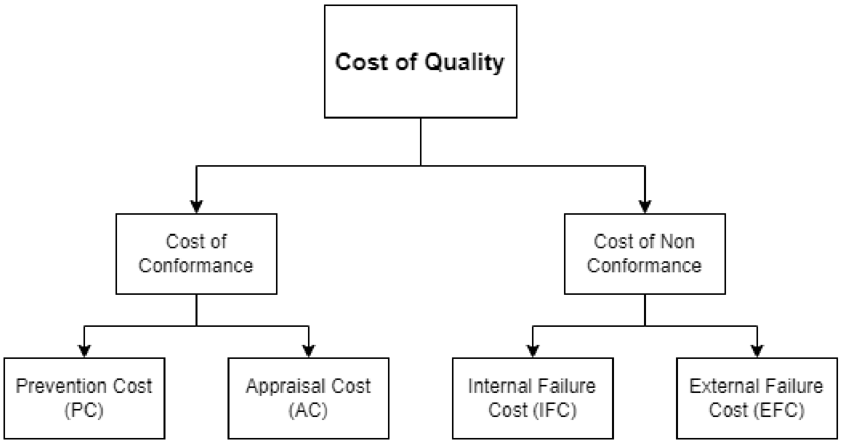


Figure 3.1: Cost of Quality

$$CoQ = PC + AC + IFC + EFC \tag{3.1}$$

These last four indicators are calculable costs, sometimes more easily calculable than others.

However, the represented indicator that is priceless, hidden, and difficult to identify by formal *Cost of Quality*, but also an essential indicator of the consequences of not assuring quality, as Customer-incurred, Customer Dissatisfaction and Loss of Reputation [4].

- **Customer-incurred** – This comes into view when the product does not fulfill the customer's requirements. Some examples are loss of productivity while the equipment is down, travel and time costs used to return defective products, and repair costs after the warranty period are over.

- **Customer Dissatisfaction** – Nowadays, customers are much more demanding to satisfy their expectations and demands. Products that were good in the past may not be good enough now and even less in the future. Therefore, companies need to be more flexible to adapt to these changes, so they can keep competing in the competitive market.

- **Loss of Reputation** – Loss of Reputation is a variable difficult to quantify, as the customer incurred and predicted the reasons for the customer's dissatisfaction. The cost incurred due to loss of reputation may change or develop from customer dissatisfaction cost in that they depend on the final customers.

The only way to eliminate these costs is by eliminating all the external failures [5].

Rule 1:10:100

There is an old maxim in quality that tells the sooner the problem is detected, the much less its impact.

The more expensive position in the industry occurs when the customer finds a defect or faults in the product, getting all the power to make whatever demands he wants, such as recalls, free parts in future deliveries, opening a lawsuit, etc. [6].

If the manufacturing company finds the defect through some inspections, tests, and checking, it will result in fewer expenditure conditions. Suppose the company has a targeted quality program to prevent defects and continuous improvement efforts. In that case, the defect and cost associates can be minimized, leading to a condition that is more desirable [7].

This means that investing in preventive measures offers the best return. The 1:10100 rule helps us understand the cost of failure increasing as we move on to the manufacturing process [8].

As shown in Figure A.1, every euro spent on prevention is worth ten paid-for appraisals, 100 on internal failures, and 1000 on external failures.

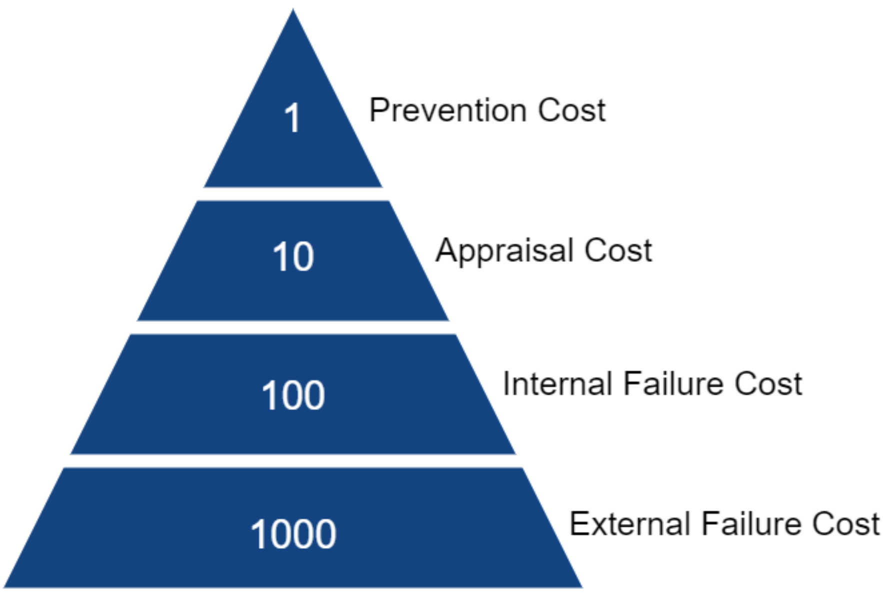


Figure 3.2: 1/10/100 Rule

We can conclude with this data that the investment in prevention will, firstly, reduce the appraisal costs and finally reduce failure costs (internal and external), as represented in the following Figure 3.3.

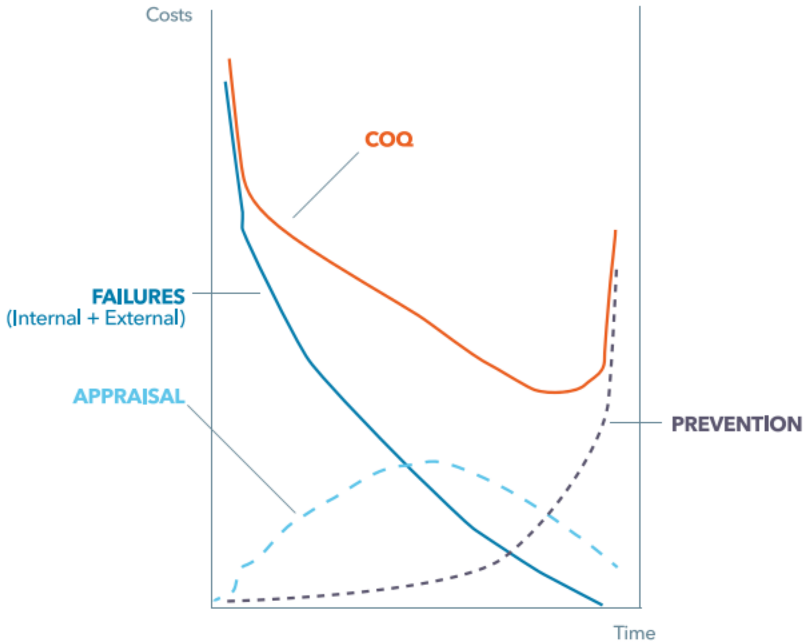


Figure 3.3: Total *Cost of Quality* [9]

The objective of a Cost of Quality system is to design a strategy in order to facilitate the continuous quality improvement effort that can lead to find the right opportunities to reduce costs. Campanella [3] propose a simple strategy for using Quality Cost which consists in four steps:

1. Take direct attack on failure cost in an attempt to drive them to zero
2. Invest in the right preventive activates to bring about improvement
3. Reduce the appraisal cost according to the obtained results
4. Continuously evaluate and redirect prevention efforts to gain further improvements

3.2 Quality Tools

3.2.1 Pareto Chart

The Pareto chart is a vertical bar that represent arranges information in a way that makes prioritizing problems evident and visual. It is possible, for example, to make a Pareto diagram to detect the main types of defects of a certain product and later, another diagram with the main causes that originate the main defects.

The Pareto Principal gets its name from the economist Vilfredo Pareto who observe that 80% of the lands were the property of 20% of the population [10]. Joseph Juran, in honor of him, nominated the diagram as a Pareto diagram, making a relationship with the problems and their causes, showing that 80% of the problems are related to 20% of the causes [11].

The result of Pareto analysis is represented in a Pareto chart, which is a vertical bar chart, organized in descending order of relative frequency of errors, that helps to down a large problem into small parts, thus allowing a choice of starting point for problem-solving [12]

This solution invite to focus on what is more important in detriment of what is less important, increasing the efficiency of the analysis and the resources allocation, by focusing on the problem that can bring more benefit. In this way, relatively few points are attacked, and it is possible to solve a large part of the problems. In Figure 3.4 it's possible to see an example of a Pareto Chart.

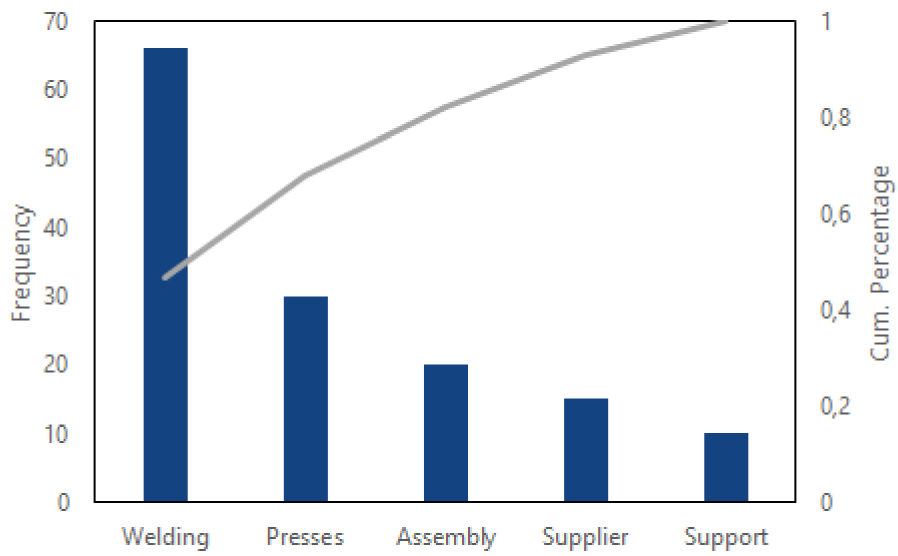


Figure 3.4: Pareto Chart Example

3.2.2 Ishikawa Diagram

An Ishikawa diagram (also known as Fishbone or Cause and Effect Diagrams), is used to quantitatively express the relationship between a given problem and its root causes [13].

As it is possible to see in Fig.3.5, the design of the diagram looks much like a skeleton of a fish and it is a graphical representation that logically structures and organizes the potential causes for a specific problem and effect, and groups the ideas into various categories.

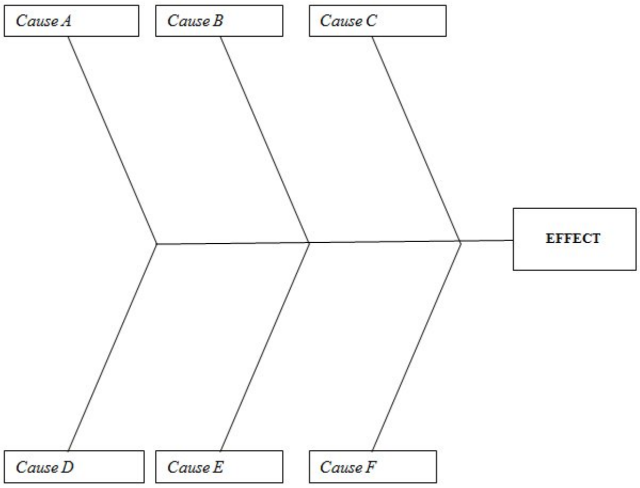


Figure 3.5: Ishikawa Diagram Example [14]

Normally, the categories that can be associated with a problem are classified as machines, methods, material, people, and environment [13]. However, the categories can be changed, depending on the type of problem that is begin investigated.

The main stages in the elaboration of the Ishikawa diagram are [15]:

1. Identify the problem
2. Work out the major factors involved
3. Identify possible particular causes
4. Analyze your diagram

3.2.3 5 Why's Tool

When looking to solve a problem, it is a good option to start with the result, reflect on what caused that, and question the answer [16]. The five whys technique is a tool used to drill down to the root causes of a problem. The concept is very simple, a series of questions, starting with the word "why". This helps to create relationship groups when the causes and the actual problem are. The five Whys technique is used for troubleshooting, quality improvement, and problem-solving. This technique was developed by Sakichi Toyoda for the Toyota Industries Corporations. The five why's technique is done by:

1. Identify the problem
2. Asking why this happen. Coming up with all the possible causes of it
3. For each of those causes identified, ask again why this happen
4. Repeating processes 2 and 3 until the root causes are identified

5. Find solutions and countermeasures to fix the root causes

Chapter 4

Data Driven Analysis

This chapter focuses on the initial approach to the case study, beginning with an explanation of the defined approach, followed by an explanation of the data collection and subsequent data analysis. It ends with a brief summary of the conclusions obtained by the data-driven analysis.

4.1 Approach Definition

The process of Cost of Quality Management used in several industries is described in the following diagram 4.1. Therefore, it was the base defined to be followed to make the study of this Thesis.

The main goal of this process is to use the Cost of Quality as an influence strategic or operational decision [9].

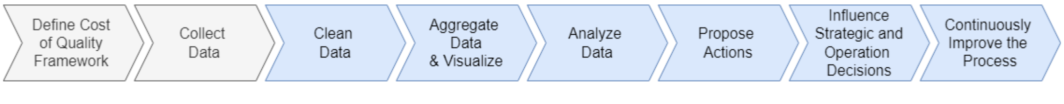


Figure 4.1: *Cost of Quality* Management

At Kirchhoff Portugal, the first two-step was already implemented, the definition of a *Cost of Quality* framework and the Collection of Data. Therefore, the major focus of this study will be on the next steps, but not without an overview of how the already created processes are implemented in the company.

4.2 Framework of *Cost of Quality*

As mentioned above, the company already implemented the Framework of *Cost of Quality* and Data Collection. Furthermore, the collection and management in the company are detailed and described in the internal document "Cost of Quality."

The basis for creating this framework was the ISO/TS 16949 [17]. The *Cost of Quality* is defined as was mentioned in the State of Art, with just a few minor differences in vocabulary.

The *Appraisal Cost* is mention as *Checking and Control Cost* (CCC), the *Cost of Conformance* are *Cost of Quality* (COQ) and the *Cost of Non Conformance* are the *Cost of Non Quality* (CONQ). All these small changes are presented in Figure 4.2.

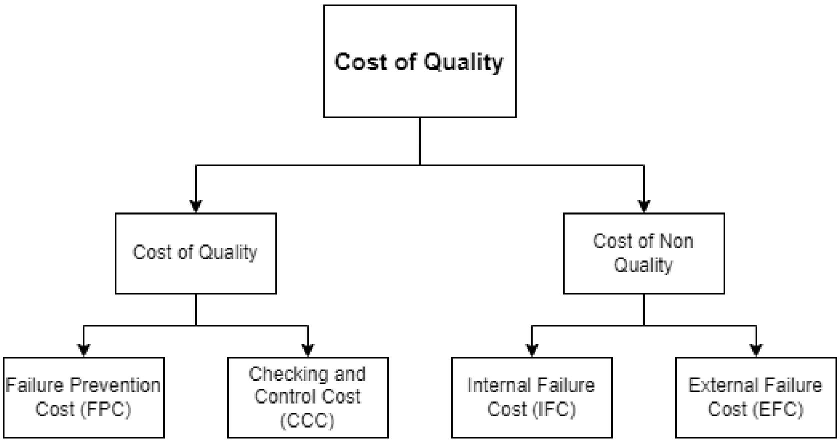


Figure 4.2: *Cost of Quality* in Kirchhoff

The costs allocation can be seen below:

4.2.1 *Failure Prevention Cost* (FPC)

- Salary of all salaried staff in the Quality Department
- Cost of quality training
- Cost of supplier development
- Cost of setup and maintenance of Quality Management System
- Cost of product quality-related liability insurance
- Cost of Quality Department administration
- Cost of Advance Product Quality Planning (APQP)

4.2.2 *Checking and Control Cost* (CCC)

- Salary of all hourly staff in the Quality Department

- Cost of all full-time hourly indirect labor performing an offline quality inspection on the shop floor and in the laboratory
- Cost of inspection performed by temporary direct labor outside of the correct cost model in addition to the proper crew size is included
- Cost of inspection performed by direct labor within the correct cost model with the proper crew size is excluded
- Cost of measuring and testing products, both internal and external
- Cost of maintaining measuring machines, test equipment, and check fixtures

4.2.3 *Internal Failure Cost* (IFC)

- All costs incurred in-house due to failure to conform to customer requirements
- Internal labor costs raised by any additional work such as sorting and rework
- Cost of external contractor for in-house sorting and rework
- Cost of scrapping WIP and FG due to non-conformity found in-house

4.2.4 *External Failure Cost* (EFC)

- All costs incurred, such as sorting, reworking, and scrapping parts at customer or other off-site locations due to failure to conform to customer requirements
- 3rd party charges for sort, rework, containment, and certification at customer or other off-site locations
- Customer invoices due to delivery of non-conforming parts and traveling expenses to resolve customer complaints
- Charge-backs from customers due to product quality issues in terms of warranty claims or product recalls

The *Quality Performance Reporting System* (QPRS) is Kirchhoff Automotive's guide to summarizing *Cost of Quality* and associated indicators, that is, the data collection document. This report is prepared monthly and analyzed to identify the origins of the main costs, establish improvement objectives, and trigger the necessary corrective actions.

4.3 Collection of Data

Initially, it was defined that the first approach of the analysis would focus on collecting and analyzing the *Cost of Quality* between 2015 and 2020, so it would be possible to evaluate the reality of the company's situation.

The percentage of the ratio of *Cost of Quality* by Net Sales in this period is represented in Figure 4.3:

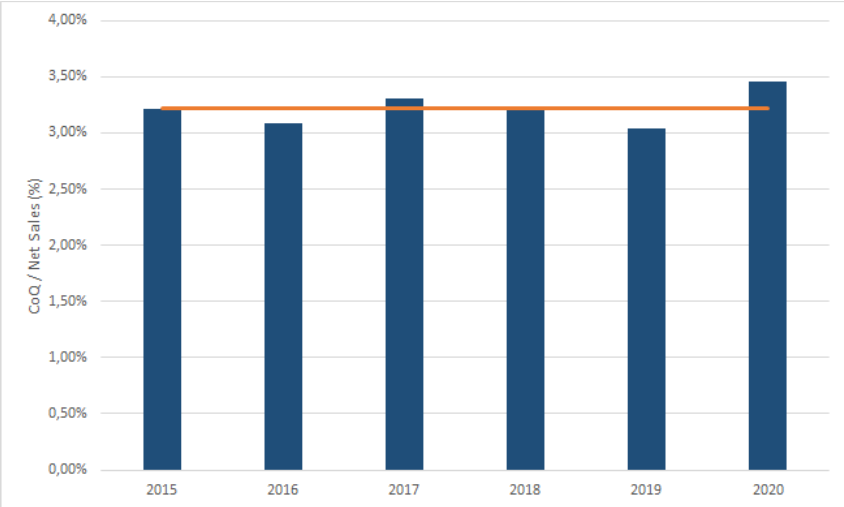


Figure 4.3: Total *Cost of Quality* 2015-2020

The mean of this cost corresponds to 3,22% of the Net Sales value annually. The graph allows us to conclude that there is a tendency of stagnation in terms of *Cost of Quality*.

Since it is important to know which categories have the highest added costs, the five-year average was calculated, and the percentage of the *Cost of Quality* is divided among the sub-category Failure Prevention Cost, Checking and Control Cost, Internal Failure Cost, and External Failure Cost, Fig.4.4:

This information shows us positive indicators of how the allocation of quality resources is applied in the company. With a clear focus on quality production, 60% (FPC and CCC), to the detriment of failures corrections, 40% (IFC and EFC). Showing the goal "If we produce correct from the first time, Quality is free" [16] is a clear target for the company.

However, there is always room for improvement and refinement, and the focus needs to be on reducing the cost associated with producing the error. As was mentioned in the State of Art, 1 euro spent on prevention can account for a saving of 100 euros if the same error is only detected after in-house production, and can even reach 1000 euros when detected after being shipped to the customer.

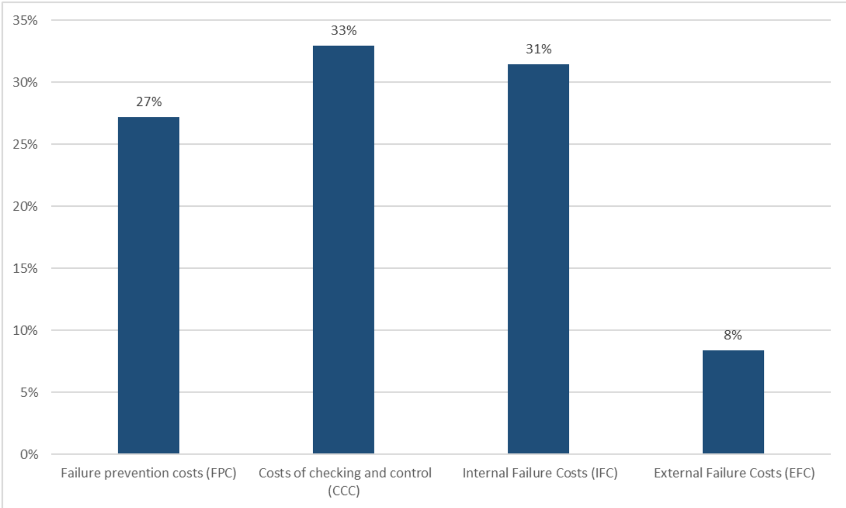


Figure 4.4: *Cost of Quality* vs *Cost of Non Quality* 2015-2020

In the cost of failures, there are two different types, internal failures, the defects that are detected before being shipped to the customer, and external failures, which are defects detected by the customer, that can lead to claims and even compensation.

By analyzing the graph 4.4, we can conclude the largest share of failure expenses corresponds to *Internal Failure Cost* with a 31% of the total quality cost, and *External Failure Cost* only corresponds to 8% of it.

This data can be analyzed from two perspectives: the positive one indicates that the company is able to detect the errors produced internally, preventing them from reaching the customer. And the negative point is that the company is wasting resources on defect detection when it should focus on defect prevention.

Also, it's possible the company is overzealous with the parts produced, rejecting parts that would not be rejected by the customer, Fig.4.5.

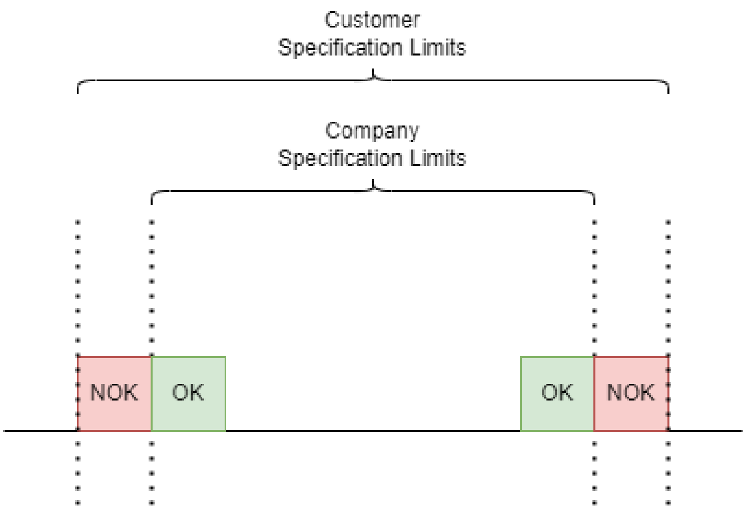


Figure 4.5: SPC Specification

With this information in mind, was agreed the study would consider comparing internal and external failures. Now, not only the monetary issue but also the number of incidents occurring.

This point of the work aimed to find a pattern in the type of defect, so we can group them and create a general approach to mitigate them. For that, an analysis of the type of failures was conducted.

The first step was to collect all the data available on the company related to internal and external failures. At Kirchhoff Portugal, there is an internal failure report stored on a SharePoint page and an external failure report stored in an Excel document.

Since the current internal incident report only started to be used at the beginning of 2018, we were forced to shorten the analysis between 2018 and 2020.

The number of occurrences of internal and external failures was compared, and we created a correlation between the two indicators. One is related to the already mentioned cost of external and internal failures, and the other is related to the number of occurrences.

We did the mean of the *External Failure Cost* and the *Internal Failure Cost*, and the ratio relationship found between these two categories is 1:4, meaning, for each euro spent on external incidents, the company spent 4 in internal failures.

Also, the total number of internal and external incidents was taken into consideration, and the final ratio is 1:13, meaning that for each external failure, there are 13 internal ones. It can be interpreted as 13 opportunities to detect the failure and correct it before it reaches the customer. This can indicate that the company, when detects the defect, is not focusing on creating a prevention solution that will not allow the defect to be produced again.

After collecting all the data from 2018 to 2020, was necessary to clean it in order to find a pattern of defects.

4.4 Data Clean

At this point, it becomes suitable to detail the data collected in the reports to understand what cleaning data needed to be done, why it needed to be cleaned, and how it was used to create clustering.

Data Available in the Reports indicates the identification of the product with the defect, the type of defect, the description of the defect, and some other variables that were not considered relevant for this analysis.

Some of this information was corrupted, and it was necessary to contact the responsible for the reports and search for the missing information. The biggest problem was identifying the parts because a lot of identification was lacking in the process indication. The part identification on Kirchhoff is shown in Fig.4.6.

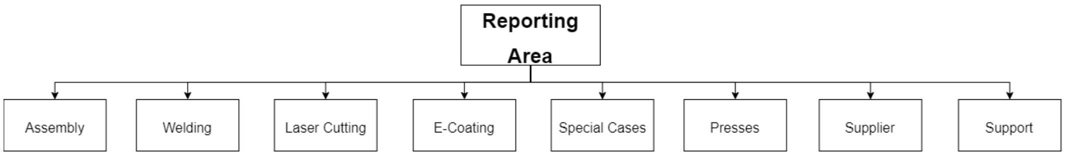


Figure 4.6: Part Identification Example

As said above, the problem was in the lack of identification of the process, so it was necessary to investigate the operation that caused the failure. Using the defect description and comments in the report and the knowledge of the quality engineers who had been in charge of analyzing the incident, it was possible to make the association to the original process of the defect.

This was necessary to make possible the association of the part identification with the machine where the part was produced. With this information, we could associate the machine with the technology the machine uses.

4.5 Aggregate Data and Visualize

The first clustering defined was created to filter the main defects that occur in the Productive Area. For this was necessary to associate the origin of the failure.

As was explained in the sub-topic Data Clean, the process number of the part identification was associated with the CC, which is the machine identification, which in turn was associated with the productive areas, using the category of machines according to their technology. This is based on the TIS Grouping classification used at Kirchhoff and can be seen in Fig.4.7.

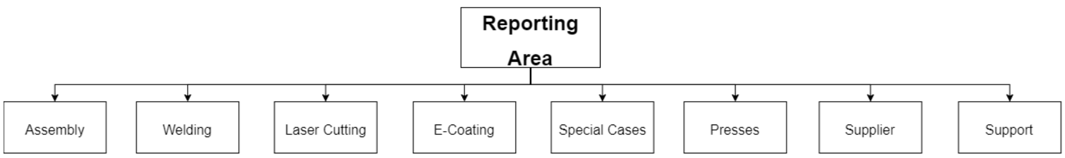


Figure 4.7: TIS Grouping - Reporting Area

As we can see in Pareto's charts shown below in Fig.4.8 and in Fig.4.9, there is a significant difference between the area that generates more external and internal failures.

In the case of External failures, Welding is the area with the highest number of defects, corresponding to 51%, and Presses with 19%.

In the case of Internal failures, the main area corresponds to Presses (Stamping Area), with 55% of the total internal failures, and Welding with approximately 30%.

The difference between the number of internal accidents detected in the Presses and those found in Welding is explained by the fact that the Stamping process

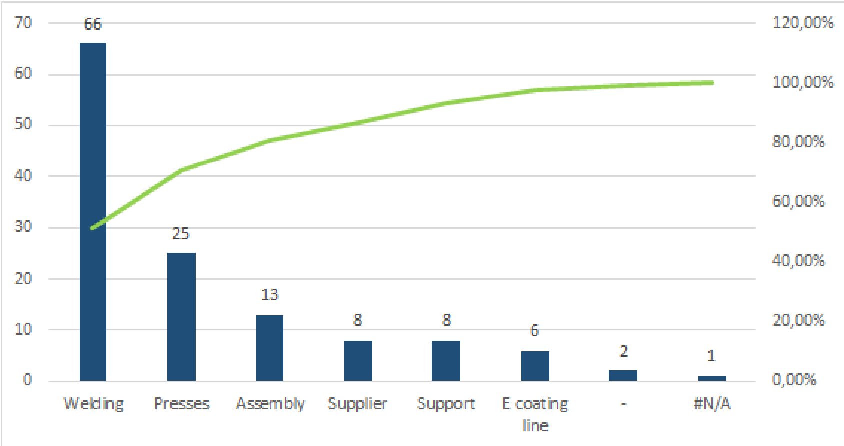


Figure 4.8: External Failures by Productive Area

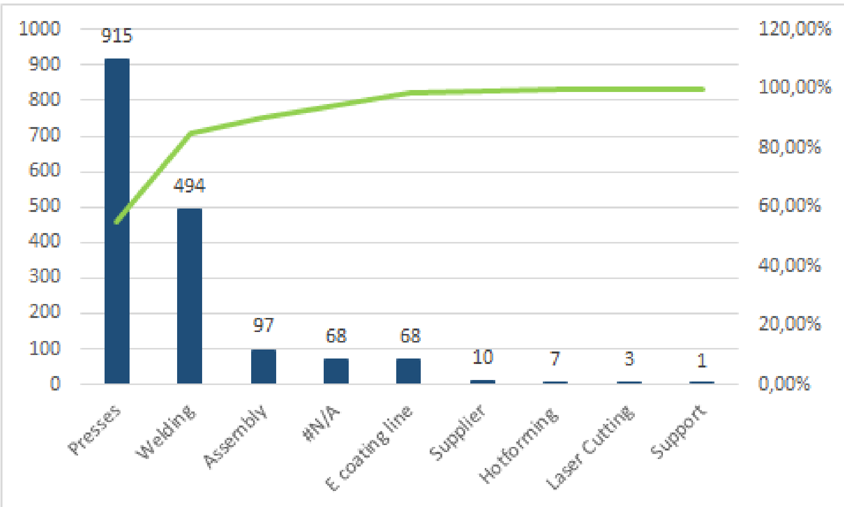


Figure 4.9: Internal Failures by Productive Area

precedes the Welding process, thus allowing the error to be detected further down the production chain.

This is in contrast to Welding, which usually does not go through the painting process and is sent to the customer right after the last welding process, with no more error detection gates.

Applying the Pareto rule, the main process where failures occur is the Stamping, and Welding processes, so the first clustering is found, the main areas where the errors originated.

From this point, the analysis was conducted in two separate routes: Stamping and Welding processes.

4.5.1 Data Analysis - Welding Process

As the main cause of external failures was in the Welding, and following the logic of Rule 1:10:100, we started by focusing on those areas to try to understand why the company methods are failing on the defection of NOK parts before delivering to the customer.

With the information available on the external failure report and the internal failure report, we had the reference of the defective part. With this information was possible to find to associate the part produced with the machine that produced it.

This information is too general, so it was necessary to group the type of machines according to their technology. The TIS Grouping, as already mentioned, is a classification implemented by Kirchhoff to group its machines according to their technology. Below is possible to observe the TIS Grouping used on the Welding, Fig.4.10:

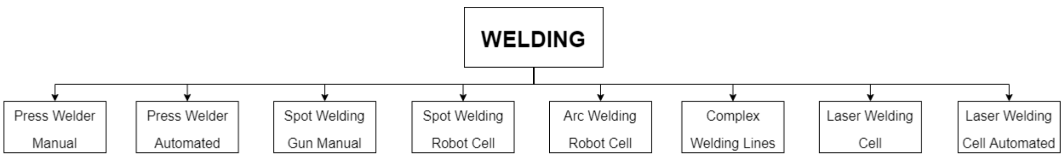


Figure 4.10: TIS Grouping - Welding

The analysis of the Welding technology that as more defect associated was performed, and the result can be seen in the following Graphs 4.11 and 4.12, the External and Internal failures, respectively:

The conclusions of this analysis are:

- The main failure-causing technology in Welding Area is Press Welder Manual, with a percentage of failures of 53% at External failures and 62% at Internal failures.
- The second technology that fails the most is Arc Welding Robot Cell.

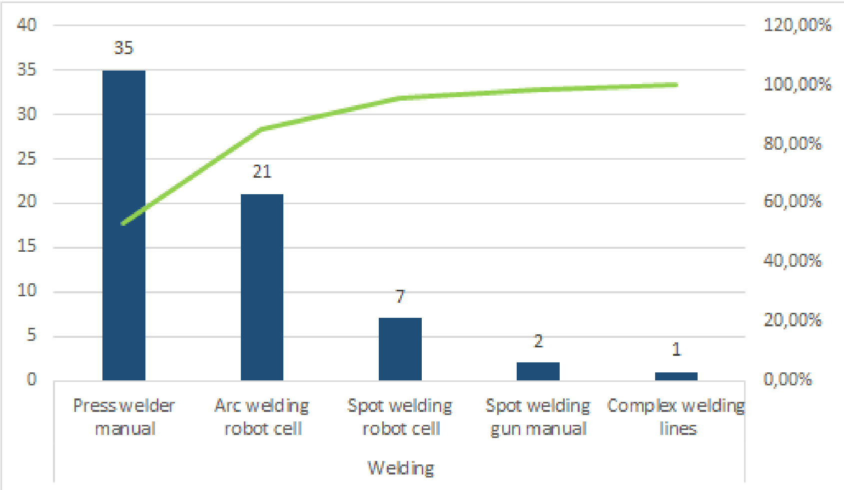


Figure 4.11: External Failures by Welding Technology

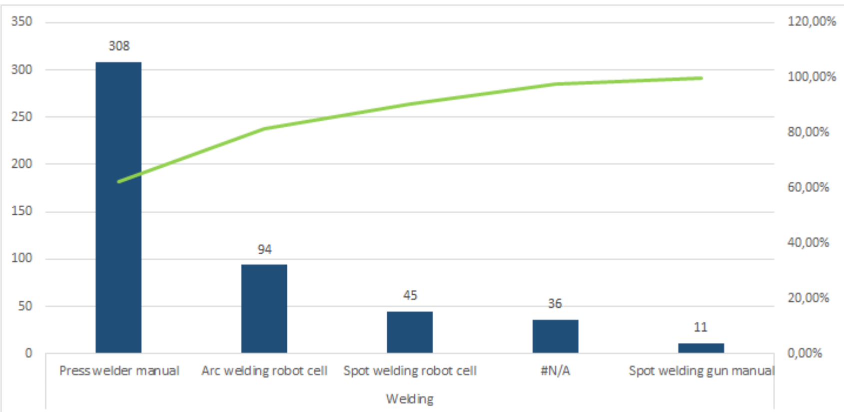


Figure 4.12: Internal Failures by Welding Technology

- For each External failure received because of a failure in a Press Welder Manual, there were 9 Internal incidents (1:9), which means that there were 9 opportunities to prevent the defect from happening before it was sent to the customer.

Focusing on the technology that accounts for more than 50% of welding failures, the Press Welder Manual, more clustering attempts were made. The first hypothesis was related to the possibility that the age of the machine was directly associated with the number of defects.

This theory was not confirmed because it was impossible to find a directly proportional relationship between the number of failures and the age of the machine since failures occur in both older and newer machines.

Another considered theory was: "Would the current technology be relevant for the occurrence of the defects?". But, after analyzing the type of the number of machines available in the company by the current type, the number of machines with different technologies was not enough to make a correlation between these two indicators.

Other data available was the defect code with which the fault had been classified. The table of defects codes used can be seen in the following Fig.4.13, the code, and the code description.

Code	Reas. Reason f. movement
0001	deadstock./newdraw
0002	perm.stockcorrect.
0010	damages
0011	marks
0012	cracks
0013	scratches
0014	transportdamage
0015	storagedamage
0020	dimensionnok
0021	truetogage
0022	anglenok
0023	burrs
0024	flatnessnok
0030	destructiveinspect.
0031	macro-eximinationsp
0032	Laboratorysaltexam
0040	spotweld
0041	weldseamnok
0042	pores(MAG)
0043	burn-through(MAG)
0050	processstepmissing
0051	componentmissing
0052	labelmissing
0053	holesmissing
0060	materialnok
0061	beginning/endo.coil
0062	coverblank
0070	boilingvessel/spots
0071	defectcoatingrack
0072	othercoatingdefect
0073	pack.handlingnok
0074	downtime
0080	subcontracting
0090	riggingparts
0091	tool/devicenok
0092	machine/feednok

Figure 4.13: Code Defects Table

This data allowed us to identify the most reported defect in the Press Welder Manual when it is an External Failure, as shown on the Pareto Chart in Fig.4.14, and when it is an Internal Failure, as shown on the Pareto in Fig.4.15

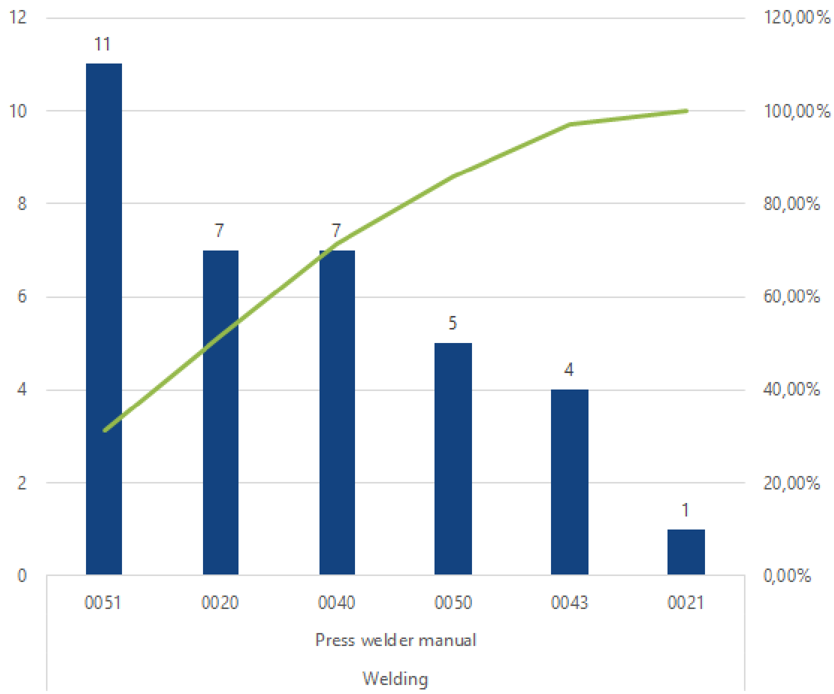


Figure 4.14: External Failures in Press Welder Manual by Defect Code

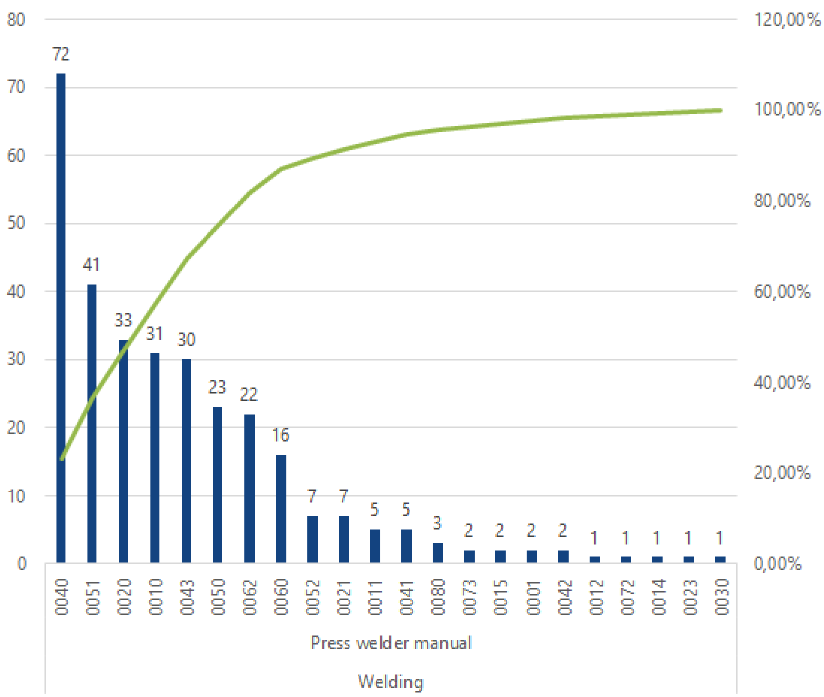


Figure 4.15: Internal Failures in Press Welder Manual by Defect Code

In terms of percentages, the defects at External Failures at Press Welder Manual represent:

- Component Missing (0051) - 31,43%
- Dimensions NOK (0020) - 20%
- Welding NOK (0040) - 20%
- Work Step Missing (0050) - 14,29%
- Weld Splatter (0043) - 11,43%

Regarding Internal Incidents, these same defect codes correspond to:

- Component Missing (0051) - 13,31%
- Dimensions NOK (0020) - 10,71%
- Welding NOK (0040) - 23,88%
- Work Step Missing (0050) - 7,47%
- Weld Splatter (0043)- 9,74%

After resorting to the descriptive error comments in both the internal and external incident database, it was observed that the code for Dimensions NOK (0020) was not correctly applied, containing descriptions of missing components and poorly welded components. Therefore, this code was not taken into consideration in the remaining analysis.

Welding Process - Conclusion

The conclusion of the Welding process failure assessment process is that the main focus of the failures is located in the technology of the Press Welder Manual, and within this technology, the more frequent types of fault are: Component Missing, Welding NOK, Work Step Missing and Weld Splatter. Those four defects represent 77,15% of the External Failures and 53,9% of the Internal Incidents of the total error at the Press Welder Manual technology.

Given these findings, with the aim to understand what is creating these failures to create prevention action for them, a Root Cause Analysis was defined as necessary for each failure type. This analysis is explained in the chapter: "Root Causes Analysis - Press Welder Manual."

4.5.2 Data Analysis - Stamping Process

A more in-depth analysis of the Stamping area was also performed. Although it only represents 19% of external failures, this figure rises to 55% when we talk about internal failures.

As mentioned earlier, this can be justified by the flow of the production process of the factory.

However, it also serves as an indicator of the difficulties the factory has in preventing the production of failures, and therefore a factor to be taken into account for the development of preventive processes for the occurrence of failures. The failure is detected, but it is allowed to occur, and the company's mindset should be focused on prevention and not detection.

As with the Welding process, the Stamping process was also analyzed according to press stamping technology using the internal categorization TIS Grouping. Below is possible to observe the TIS Grouping used in the Stamping Process, 4.16.

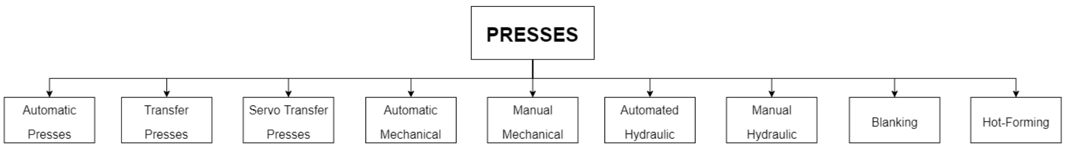


Figure 4.16: TIS Grouping - Presses

The Pareto's showing the relationship between the number of failures detected externally or internally by the Stamping Presses technology can be seen in Fig. 4.17 and Fig.4.18.

The conclusion of this analysis is:

- The Transfer Press is the technology with more External Failures, 46,43%, and the Progressive Press is the second one, with 35,71%.
- In the case of Internal Incidents, the scenario is reversed. Progressive Press technology is the one with more occurrences, 54,53%, and the Transfer Presses at second with 41,86% of the failures.
- There is no considerable difference between the two technologies, so both should be considered for analysis

Considering the two technologies, the following analysis was the same as performed in the Welding Process, finding the Defect Codes used more frequently for each technology.

Starting with the Transfer Presses, the Defect Codes more frequently reported can be seen in the following Pareto Charts, Fig.4.21 the associated with the External Failures and Fig.4.22 the Internal Failures.

In term of percentage it represents, for the External Failures:

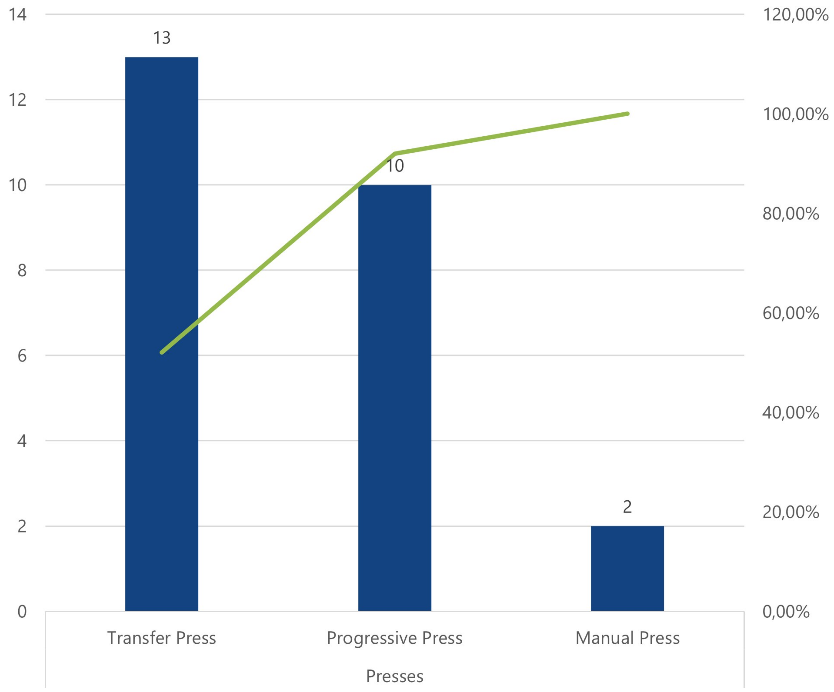


Figure 4.17: External Failures in Stamping by Technology

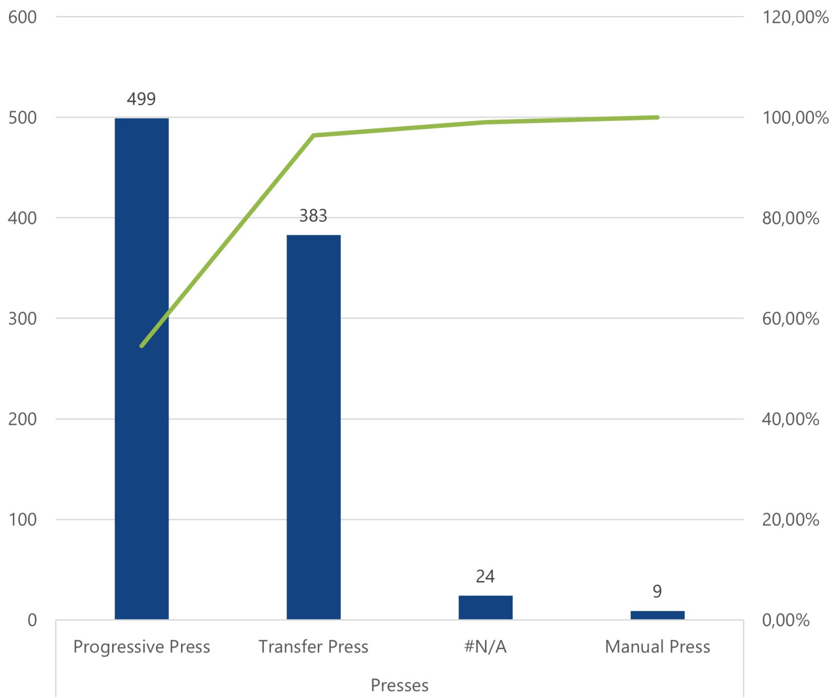


Figure 4.18: Internal Failures in Stamping by Technology

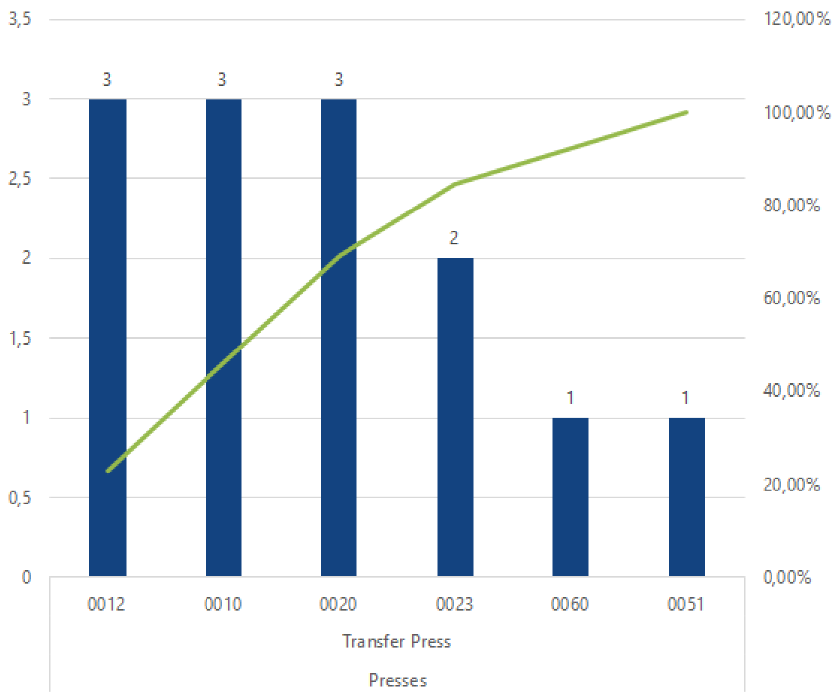


Figure 4.19: External Failures in Transfer Presses by Code Defect

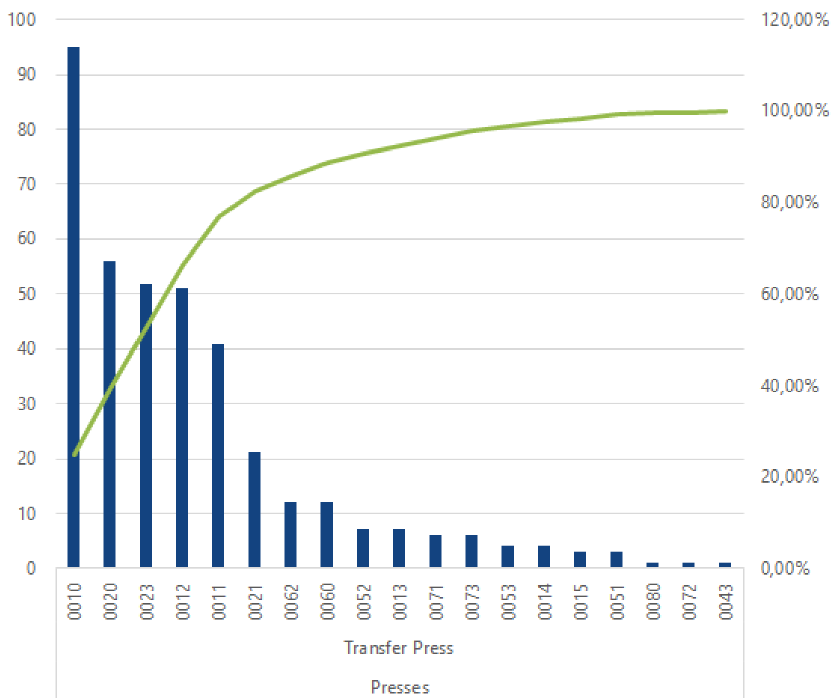


Figure 4.20: Internal Failures in Transfer Presses by Code Defects

- Dimension NOK (0020) - 23,08%
- Damages (0010) - 23,08%
- Crack (0012) - 23,08%

In Internal Failures, these defects correspond to:

- Dimension NOK (0020) - 14,62%
- Damages (0010) - 24,80%
- Crack (0012) - 13,32%

Regarding Progressive Presses, the Pareto Chart in Fig.1.4 reference to the External Failures and in Fig.1.4 is related with the Internal Failures.

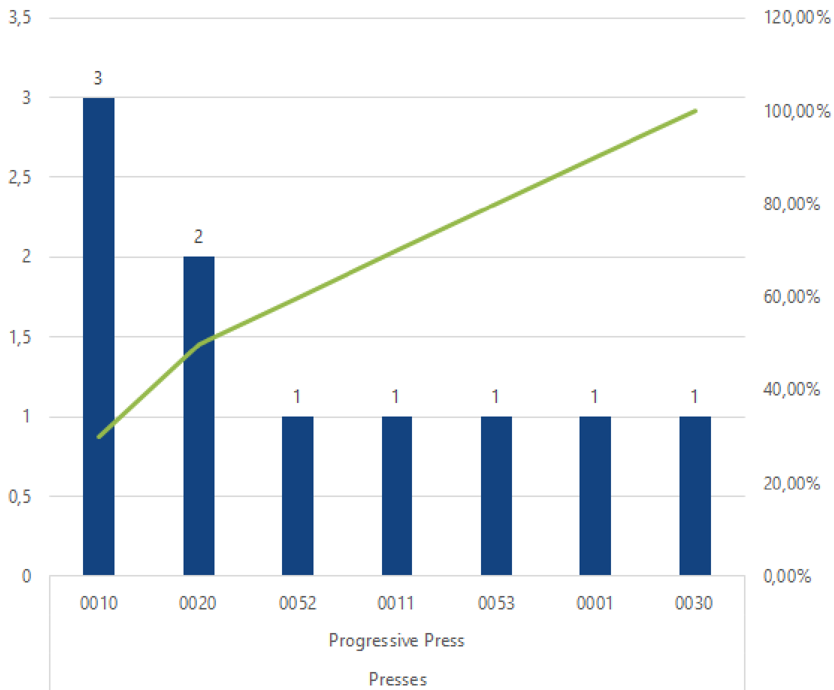


Figure 4.21: External Failures in Progressive Presses by Code Defect

The information visualized on Pareto's Charts, in terms of percentages, at External Failures correspond to:

- Damages (0010) - 30%
- Dimension NOK (0020) - 20%

And in the Internal Incidents:

- Damages (0010) - 42,84%

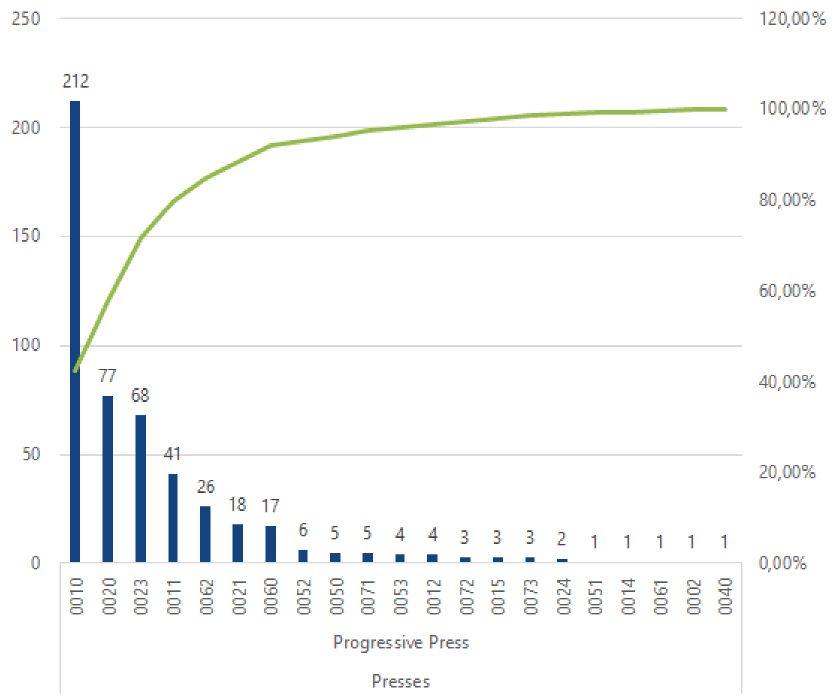


Figure 4.22: Internal Failures in Progressive Presses by Code Defects

- Dimension NOK (0020) - 15,43%

For the same reason found that the defect of the dimensional errors was not taken into consideration in the welding, incorrect associations of this code were also observed in the stamping, and for this reason, it was also not taken into consideration in the following analysis.

Stamping Process - Conclusion

The conclusion drawn from the available data regarding failures in the Stamping area is that there is one main defect associated with this area, damages, both in Transfer Presses and Progressive Presses. So the focus should be regarding this defects on all the Stamping area.

For prioritizing the area with more failures, in this case the Welding process, more specifically the Press Welder Manual, a Root Causes Analysis at Stamping area will not be taken into consideration, however, the recommendation is to open a working group to study why this type of defect occurs so frequently and to propose improvement measures to prevent its occurrence.

Final Considerations

After concluding this data-driven analysis, some recommendations have been proposed in order to improve the data collection and the data processing, with a view to influence strategic and operation decision. Those recommendation are listed below:

- Add to the reports of External and Internal Failures the obligation to field the number of the part with all the identification of the part, including the process indication.
- Create in the reports a field where it's possible to allocate the machine number.
- Train the people who fill the reports to correctly identify the Defect Code related to dimensional deviations (0020).
- Add to monthly report (QPRS) analyses where it indicates the technology that fails more and the defect associated on that month.

Chapter 5

Root Causes Analysis - Press Welder Manual

This Chapter will be dedicated to analyzing the problems concerning the Press Welder Manual technology. It is divided by the type of defect identified in the previous Chapter as the most frequent. A Root Causes Analysis will be applied to each defect and a Countermeasure Proposal to mitigate the defect.

5.1 Overview

For each of these defects identified in the last Chapter, as the most frequent on the Press Welder Manual technology, was developed Root Cause Analysis. It consists of elaborating on an Ishikawa diagram, which contemplates all the possible causes that led to the appearance of the defect, based on observation at the workstation, informal interviews with team leaders and operators, and part defect data available in the external failures database and in the internal documentation available where records of incidents, causes, and possible remedies are stored, called 3G's Line , at appendix A for Internal Failures and PSP's, at Appendix B to the External Failures.

After selecting the most common cause of the defect, a 5 Why analysis was conducted to understand why that occurs.

These two separate approaches: one to search for the reason why the failure occurred, and another to understand why the failure was not detected right after it was produced. The focus of this analysis will be on the causes of the occurrence since the ambit is to propose preventive and not corrective measures. However, it was considered relevant to mention the causes of non-detection, to be used in the future as a database of defect causes.

5.1.1 Work Step Missing

The work step missing is a defect generated because the part in production skips one of the production steps.

The Ishikawa related to the occurrence of this defect can be seen below, Fig.5.1. As it's possible to see on the image legend. The causes are separated by the ones who let the defect occur and the ones why the productive system did not detect the defect after being produced.

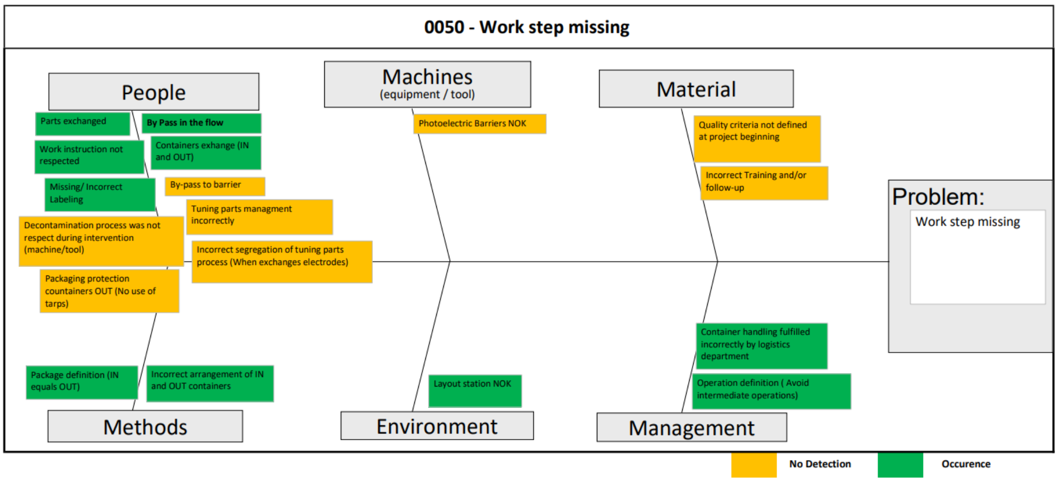


Figure 5.1: Ishikawa - Work Step Missing

Related to this failure, the most common cause identified for it to occur was the bypass of the part in the workstation. This means that the part passes from the "container in" directly into the "container out" without going through the welding process itself.

With this conclusion, all the possibles reason to let this occur were placed on the table, and after consulting the documentation available and having discussions with the area specialists, we came up with two of the most probable hypotheses, which are described in the following 5 Why's Analysis, Fig.5.2 and Fig.5.3.

The bypass occurs because the parts were directly put on the container, out-passing the welding process. Because there is a machine intervention or a break, the part in the production is left at the workstation and not scrapped or put back in the container as the work standard indicates. This is due to the lack of follow-up on this standard. That is, we can say that although there is a theoretical standard, in practice, there is no way to validate this standard.

5 Whys
By-pass
Parts were put at the container out
There was no protection on the container during break/intervention
The standard to covering the container was not respect (IT_DQ_239)
Incorrect follow-up
There is no standard defined for follow-up

Figure 5.2: 5 Why's - By-Pass

Counter-Measure Proposal: Create a special checklist on the terminal the Operator use to register the intervention code, and after any machine intervention, the Operator is asked if we did the correct segregation of the part. This will work as a reminder to the Operator of what he has to do whenever there is an intervention.

5 Whys
By-pass
After reset the machine the parts went to cointaner OUT whitout pass the process
Barrier go up after reset
The program allow this error
The standard that defines that the barrier cannot go up after reset was not respect.

Figure 5.3: 5Why - Bypass

Very similar to the one above, but this time is related to the barrier that each machine has to prevent this type of error. After the machine restart goes up, making possible for the operator to take part on the workstation and put it directly on the "container out" without confirming if the part passed the welding process.

Consoling the internal documentation related to this type of occurrence was detected that it has already been identified multiple times because the standard instruction to program the machine's controller only indicates the need to program the barrier without explaining how to do it so that the barrier does not rise when the machine is reset.

Counter-Measure Proposal: Improve the instruction for programming the controller, focusing on barrier programming, by exemplifying how to do it. The controller instruction to program the controller details how to do all the standard programming with code examples but fails to detail how to program the barrier, stating only the needs to be done without the associated code explained as in the rest of the instruction.

5.1.2 Missing Component

In terms of the failure associated with the Missing Component, it is a problem where the part did not pass a welding process ahead, it has gone through the welding process, but for some reason, the component has not been welded or has been poorly welded. The Ishikawa of this type of defect can be seen below, 5.4.

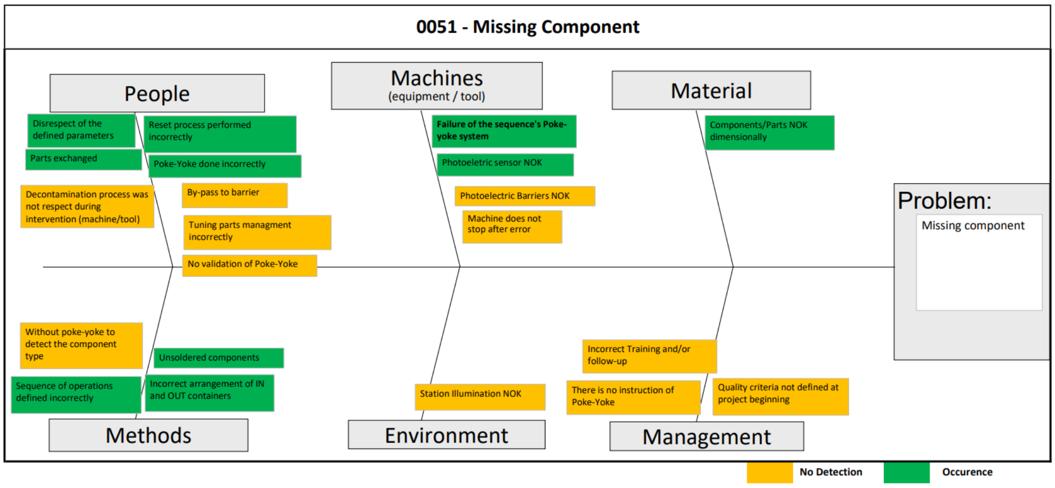


Figure 5.4: Ishikawa - Missing Component

After covering all the hypotheses that originate this error, the main reason pointed for this is correlated with the Poka-Yoke not being correct. The two main hypotheses found are shown in the following 5 Why's, Fig.5.5 and Fig.5.6.

5 Whys
Poke-Yoke NOK
The poke-yoke height sensor was not defined to detect of the nut is upside down
There is no standard indicating what type of poke-yoke should be implemented for each type of component

Figure 5.5: 5 Why's - Poka-Yoke NOK

The Poka-Yoke did not cover all the possible flaws it should have because there is no standard mentioning all the possible flaws that should be taken into consideration during the development of a Poka-Yoke part.

For example, some of the Poka-Yoke observed in the factory only covered if the component was missing, without covering if it was the correct component being welded.

Counter-Measure Proposal: Define a Standard to define which type of Poke-Yoke should be implemented depending on the components to be welded. For example, if it's a screw being welded, must have a Poka-Yoke that detects that the component is present, that it is not upside down, and that it has the right component height so that you are not soldering a similar but not correct part.

5 Whys
By-pass
Poke-Yoke sensor out of tune
Poke-yoke parts damages
The standard defined to validate periodically the poke-yoke parts is wrong (low frequency)

Figure 5.6: 5 Why's - Poka-Yoke NOK

The other hypothesis was related to the Poka-Yoke sensor being out of tune, associated with the wear of the Poka-Poke part, which with intensive daily use wears out because the standard currently used for periodically validating or replacing the Poka-yoke parts is overextended; it's done one a year only.

Counter-Measure Proposal: Make a study of the wear of these Poka-Yoke parts and set a periodicity depending on the results obtained. Or, if there was no possibility to conduct the study, increase the frequency of Poka-Yoke parts validation. Currently, it is annual, and the proposal would be to increase it to bi-annually.

5.1.3 Weld Splatter

The Weld Splatter defect, as the name indicates, it is a problem related to weld excess. Here the same approach as the other defects was taken. The Ishikawa has been created with the help of data collection and specialists, which report all the possible causes. It's possible to see the Ishikawa in Fig.5.7.

In this type of defect, it was concluded that the most common causes for the appearance of this defect are:

- Incorrect blow after Welding
- Parameters NOK

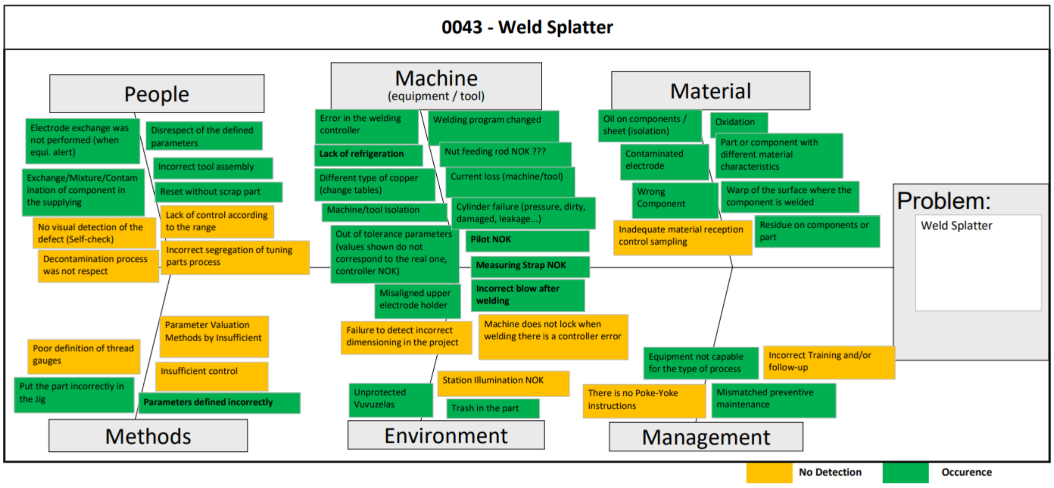


Figure 5.7: Ishikawa - Weld Splatter

- Pilot NOK
- Measuring Strap NOK
- Refrigerator NOK

With this information, the next step was to start to analyze the reasons why these defects causes occur.

Starting with the development of the 5 Why's of the cause of Incorrect blow after welding, which can be seen in Fig.5.8.

5 Whys
No blow or incorrect after welding
There is no standard that requires the need for post weld blow on all machines
There is no consensus about when the blow should be done (during or after welding)

Figure 5.8: 5 Why's - No blow after Welding

Was found that not all the machines were programmed to have a blow on the part after the welding because there is no standard indicating the necessity to program the machine to do it, and this leaves it up to any industrialization Engineer to decide how they prefer to do it, with no guidance.

Internal tests were performed that indicated that if we put the blow before and after the welding, the results tend to improve a lot in the non-occurrence of splatter on the part, and there is no financial barrier to this implementation.

Counter-Measure Proposal: Define a standard to all the Press Welder Manual, where the during and after blow is required to prevent the splatter from appearing.

Another reason for this failure was the parameters being not correct because there were set incorrectly for two different reasons. The first one is presented in Fig.5.9, the second in Fig.5.10

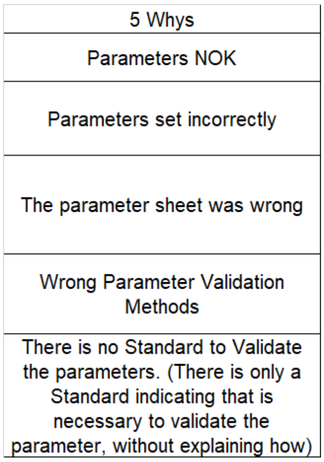


Figure 5.9: 5 Why's - Parameters NOK

Most of the time, because the parameters sheet was wrong, with most problems in the limits values shown, because the method to validate the parameters is wrong, it's not standardized, there is only a standard indicating the necessity to validate the parameters, but without explaining how to do it.

There is no mention of the minimum of parts that should be tested at the destructive and non-destructive tests, depending on the type of part being produced.

There is no register of the test performed on the parts when the parameters are used with the max and min values defined on the parameters sheets, only with the nominal values, which can lead to that when there is a need to adjust the values within the defined limits, these values will produce NOK parts because they were never validated.

Counter-Measure Proposal: Create a standard where the validation method for the parameters is detailed, such as the number minimum of parts that should be tested at the destructive and non-destructive tests, register the limit values validation, define a process to validate the electrodes lifetime.

The other possible reason for this cause was that the parameters were set incorrectly because the parameters sheet was not respected, and the values were not validated in the controller.

Nowadays, the validation of the parameters is done one time a day by a Team Leader, who is in charge of checking on the controller all the values and writing them down on a record sheet, opening the possibility that the registration is not

5 Whys	5 Whys
Parameters NOK	Parameters NOK
ımeters set incorrectly	Parameters set incorrectly
The parameter sheet was not respect	The parameter sheet was not respect
The values were not validated in the controller	Outside the allowed limits

Figure 5.10: 5 Why's - Parameters NOK

rigorous, and being done only once a day, and not at the beginning of each shift, with the risk that during the day, in a different shift, and when changing tools, the parameter program to be called has been changed, and maybe the incorrect one for the part in production.

Counter-Measure Proposal: Implement a system for tracking the parameters. Controlling tolerance values, alerting when they are off the range defined. In the short term, the most practical solution would be to have the Operators validate the program number called by the controller at the beginning of the shift.

The refrigeration of the machines was also pointed as one of the possible causes of the appearance of splatter on the parts, and the reasons can be seen in Fig.5.11 and in Fig.5.12.

5 Whys
Refrigeration NOK
During the productive cycle there was wear in the refrigeration process
The standard that indicate to verify periodically the refrigeration is wrong

Figure 5.11: 5 Why's - Refrigeration NOK

The refrigeration of the machines is considered a cause of this defect due to the possibility of wear and tear in the cooling process during the production cycle because the standard defined to verify the refrigeration periodically is incorrect, the frequency of verification is too low, it's only performed when the machine is taken to the preventive maintenance and should be confirmed more often. In addition, there is no instruction on how to do that validation, if it should be by measuring the temperature in the inlet or outlet of the machine.

Counter-Measure Proposal: Create standard instructions to verify the refrigeration system and a training process to teach the Operator how to do it so that it can be performed more often.

5 Whys
Refrigeration NOK
Plant Refrigeration system does not have the capacity for the number of machines
There is no standard to re-evaluate the plant refrigeration system when the number of machines increases

Figure 5.12: 5 Why's - Refrigeration NOK

There is also another possibility, the capacity of the plant refrigeration does not have the capacity for the number of machines in the production line because there is no standard to reevaluate the plant refrigeration system when the number of machines increases.

Counter-Measure Proposal: Define a standard to reevaluate the refrigeration capacity after a certain number of new machines are added to the production line.

Another problem with the appearance of splatter on the parts is that the pilots are not in the best condition, that is, worn out. Fig.5.13 shows the 5 Why's of this cause.

5 Whys
Pilot NOK
Throughout the productive cycle there was wear in the pilot
The standard that defines the period to verify the pilot condition during the productive cycle is wrong

Figure 5.13: 5 Why's - Pilot NOK

During the productive cycle, there is wear in the pilot, and the standard defined to verify the pilot conditions during the production cycle is incorrect. The periodicity of it is too high for a component that wears out quickly, it is only verified when the machine goes to preventive maintenance, and it should be more often verified. Also, there is no standard indicating how to perform the validation of a pilot and how to calibrate it.

Counter-Measure Proposal: Creation of a Standard instruction indicating how to verify if the pilots are correctly calibrated and define a more frequent period of time to validate their conditions.

The cause measuring strap not being in perfect condition is another of the causes pointed out, and the problem is detailed in Fig.5.14.

5 Whys
Measuring Strap NOK
The parameters shown by the controller (measuring strap) do not correspond to the correct ones
The standard to calibrate the measuring systems of the machines is wrong

Figure 5.14: 5 Why's - Measuring Strap NOK

The measuring strap of the machines sometimes is not reading the correct values, which means that the parameters shown on the controller do not correspond to the real ones. This happens because there is no instruction on calibrating the measuring system. It's only indicated on the prevention maintenance the necessity of verifying it.

Counter-Measure Proposal: Create an instruction that explains how to calibrate the measuring systems for each Press Weld Manual and makes it part of the maintenance process.

5.1.4 Weld NOK

By exploring this defect, the main conclusion is that it had very similar reasons to the Weld Splatter defect, as it's possible to see on the Ishikawa 5.15. This is because the difference between the two codes is not clearly perceptible.

The main causes detected for this type of defect are similar to the ones indicated on the Weld Splatter, only differing in the problem associated with the blowing after or before welding, the pilot not being in condition to produce, and adding a new one, current loss.

- Parameters NOK
- Measuring Strap NOK
- Refrigerator NOK
- Current Loss

The problem associated with the current loss is related to the problem of the machines not being correctly isolated, and it is shown in Fig.5.16 the reasons for this happening.

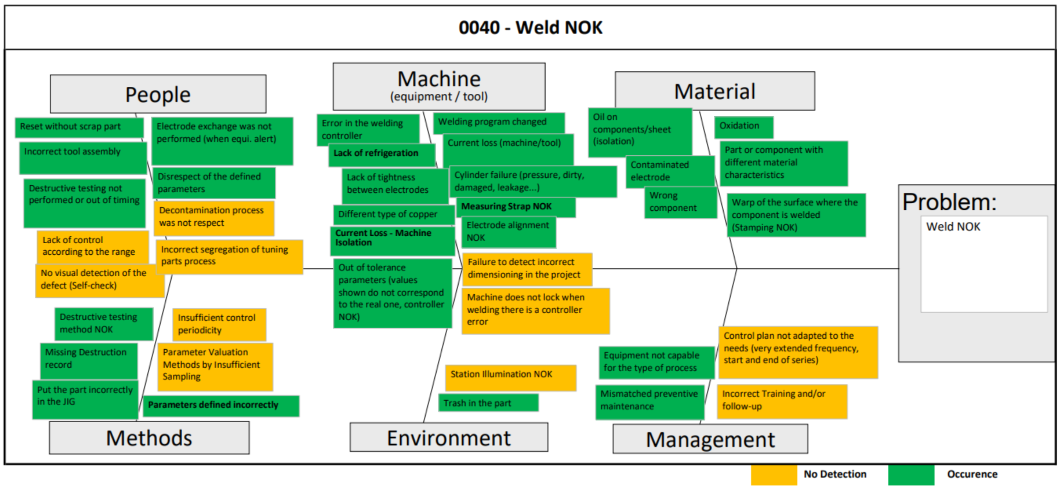


Figure 5.15: Ishikawa - Weld NOK

5 Whys
Current loss
The machine/tool was not properly isolated
The isolation standard was not correct
The standard only refer “Each support to the main fixture frame needs to be isolated” without explaining how to perform the validation of that

Figure 5.16: 5 Why’s - Current Loss

The isolation standard used by the company is not correct because the standard only refers that "each support to the main fixture frame needs to be isolated" without explaining how to perform the validation of that isolation.

Counter-Measure Proposal: Add the validation method instruction to the standard based on an electrical isolation test. Isolation resistance measurements may be achieved using a high input impedance ohmmeter, digital multimeter (DMM), or current-limited Hipot test instrument.

5.1.5 Lesson Learned

After having the meeting with the production directors of each department, one of the conclusion has that some of the problems were already known for a long time, and also were some of the proposed solutions.

Some of the countermeasures were even already implemented in some machines. The problem is that the vision when there is a defect detection is daily analysis, and the objective is to solve the problem where it was found without having a roll-out to do implementation in the other machines that use the same technology.

The end goal of this proposal is to be implemented in all machines belonging to the same technology, or others do not correct only one machine and leave all the others of the same technology uncorrected and able to produce the defect.

With these recommendations, the objective is also to help change the mindset regarding the correction of defects so that the vision of a defect is extended to the entire range of the same technologies and not just the focus on eliminating the defect on the machine in which it has been reported.

Another of the lessons learned is that the vast majority of defects happen due to a lack of documentation or knowledge about it by those in charge of performing the tasks. Many of these processes are the responsibility of the Operators.

For these reasons, it was proposed to create a training standard for operators, in which the basic processes for quality assurance would be explained and demonstrated in a more attractive way than just the theoretical explanation and documentation on standard parers. The development of this operator training standard will be discussed in the next chapter.

Chapter 6

Skilled Operator Standard Creation

This chapter focuses on developing the Skilled Operator standard. First, there will be presented all the processes need to be dominated by the Operator, and the process will be explained. Then the workflow of the processes per shift will be present. And this it finishes with an explanation of the E-learning creation.

6.1 Overview

After the analysis made previously, and with the conclusions drawn, within the scope of a larger project to be implemented within the Kirchhoff group, called Zero Defect, a project that has as its vision the non-production of defects, it was decided that one of the key points for improvement in this field would be the standardization of the processes that an operator needs to master to be a qualified operator and to know without error all that is under his responsibility so that the goal of Zero Defects is achieved!

This fits perfectly in the scope of this work because, besides being a preventive measure, it is also comprehensive to all technologies used in the group since the goal is to create processes that are standard in whatever technology the operator will be working with.

6.2 Definition of the Quality Basics for a Skilled Operator

The analysis explained above allowed us to conclude that there is a serious gap in the training of operators and their follow-up over time. With that information in mind, was identified the need to create a global standard for operator training. The main objective of this definition was to identify all standard processes at the production Operator level.

The first goal was to clarify which basic quality principles an operator needs to master to be considered a qualified operator, and a study of the actual processes being performed by the Operator was done and analyzed.

After all the procedures were identified as essential so an Operator could do his work right the first time, the Skilled Operator diagram was created.

That Skilled Operator diagram can be seen in Fig.6.1.

Figure 6.1: Skilled Operator

Of all these processes, the only one already standardized was the TPM 1.0. The rest was necessary to build from scratch.

It also includes an explanation of the TPM, considering that it has relevant in the development of the rest of the process standardization.

6.2.1 TPM 1.0

TPM stands for Total Productive Maintenance, an approach to improve the condition and performance of the machines through simple, repetitive maintenance tasks.

TPM tasks are performed by Operators, setters with TPM cards, and by maintenance technicians (with checklists). The goal was to aggregate the production and the maintenance with the same objective of keeping the machines in good condition for production.

The benefits of TPM are higher run time, identification of problems and waste, elaboration of a short-term solution for the most critical problem, and avoid accidents and breakdowns.

From the Operator's perspective, it is necessary for him to check the TPM shift cards and perform the tasks described in the card at the beginning of the shift.

In every machine, there is a TPM Board, as the one shown in Fig.6.2 with the corresponding cards with the instruction to perform the machine maintenance.

Figure 6.2: TPM Board Example

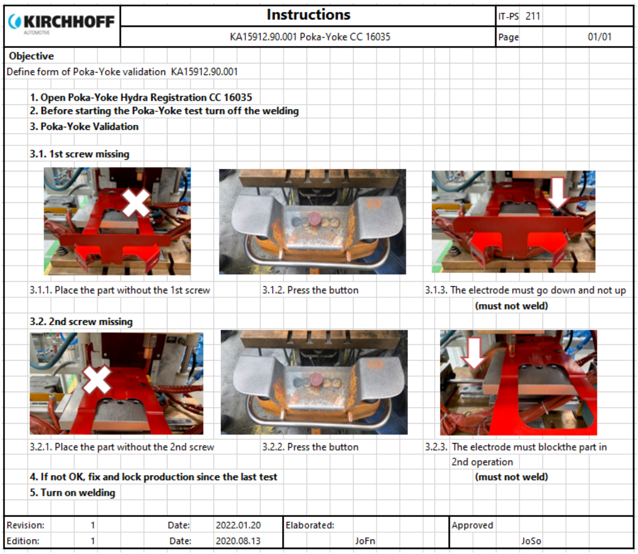
6.2.2 OK Poka-Yoke

Poka-Yoke is a technical system designed to prevent errors from occurring if an incorrect action or decision is made. To be sure the Poka-Yoke is working properly, it is necessary to perform periodic validations of the system, we call this the OK Poka-Yoke.

A simple example of a Poka-Yoke used in the company can be seen in the Poka-Yoke Instruction 6.3.

This specific Poka-Yoke checks if the screws are missing. But here are more options, for example, checking if it is the correct component being welded, if the component is upside down, etc.

Was defined two responsible for this process, the Operator, that will perform the Poka-Yoke validation, and the Setter, that will control and reset the machine. It's necessary a key that only the Setter can use to reset the machines after the validation test.



KIRCHHOFF AUTOMOTIVE

Instructions — IT-PS 211

KA15912.90.001 Poka-Yoke CC 16035 — Page 01/01

Objective

Define form of Poka-Yoke validation KA15912.90.001

1. Open Poka-Yoke Hydra Registration CC 16035
2. Before starting the Poka-Yoke test turn off the welding
3. Poka-Yoke Validation

3.1. 1st screw missing

3.1.1. Place the part without the 1st screw
3.1.2. Press the button
3.1.3. The electrode must go down and not up **(must not weld)**

3.2. 2nd screw missing

3.2.1. Place the part without the 2nd screw
3.2.2. Press the button
3.2.3. The electrode must blockthe part in 2nd operation **(must not weld)**

4. If not OK, fix and lock production since the last test
5. Turn on welding

Revision:	1	Date:	2022.01.20	Elaborated:	Approved
Edition:	1	Date:	2020.08.13	JoFn	JoSo

Figure 6.3: Poka-Yoke Instruction Example

The frequency of performing the OK Poka-Yoke depends on the part being produced. It is always performed at the initial production phase of each shift and can be, depending on what was defined for that part, in defined periods of the day or week. And it's also mandatory to be performed whenever an extraordinary intervention occurs.

To perform the OK Poka-Yoke, the Operator needs to follow the Poka-Yoke Instruction validation, a document available near the machine, Fig6.3.

If the Poka-Yoke validation goes as planned, the Setter will reset the machine and register the OK validation on the Hydra terminal.

Otherwise, if the Poke-Yoke is wrong, the Operator has to stop the production and must block all parts produced since the last validation.

6.2.3 OK Process Parameters

Process Parameters is a measurable characteristics of process inputs and their interaction that affect the process output, E.g., current, pressure, force, etc. The OK Process Parameters is a process created to verify the process parameters used during the production are correct.

This process is the Operator's responsibility, and it is always performed at the beginning of the shift, right before initiating the production. Needs to be also performed at the start of the production of a new part.

The procedure confirms that the program number indicated on the controller, Fig.6.4 corresponds to the one indicated on the parameter sheet, Fig.6.5 of the part to be produced.

If the numbers match, the Operator only needs to write the number on the parameters sheet and is authorized to start the production. If not, the Operator

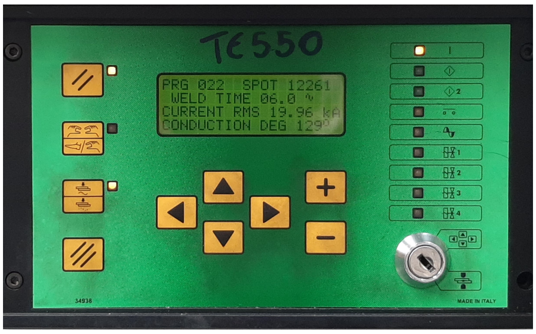


Figure 6.4: Controller Example

KIRCHHOFF AUTOMOTIVE	Process Parameters		Revision	Date	Made by: PaCo
	PROCESS:	Resistance Welding	2		In place by:

Identification		Supplies			
Product (Internal nº)	KA9626	[X] Electrodes	[ ] Bocal	[ ] ______	
Cost Center	16043	Type	Lower + Upper		
Operation	70-10 Weld 2 nuts	Replacement	1500 pts		

Program nº 22	Units: KA / ms / per / bar		Tolerances		Description last revision			Tolerances	
nº Par.	Description	Value	-	+	nº Par.	Description	Value	-	+
1	Work mode	IK	-	-	13	Min. Angle [º].	100	-	-
2	Control mode	All			14	Max. Angle [º]	140	-	-
3	Approach [per]	30	-	-	15	Contact manometer [bar]	2	-	-
4	Ramp up [per]	0	-	-	16	Pressure [bar]	3	2,5	3,5
5	Welding [per]	7	6	8	17	Cylinder position	1/2 Cylinder	-	-
6	Power [kA]	15	14	16					
7	Impulse [kA]	1	-	-					
8	Cold weather [per]	0	-	-					
9	Maintenance [per]	10	-	-					
10	Pause [per]	0	-	-					
11	Min. current [kA]	13,5	-	-					
12	Max. current [kA [kA] Curr.	16,5	-	-					

Figure 6.5: Parameters Sheet Example

should initiate the escalation process by alerting the Setter, saying the is a problem with the process parameters, and not start the production.

6.2.4 OK Incoming Material

The OK Incoming Material is a process used to confirm that all the necessary components to produce the final product are in the work area and of the correct reference.

It is performed by the Operator before starting the production, at the beginning of the shift, and when the production of a new part starts.

This process is done by checking the reference on coils/labels, Fig.6.6 with the indicated on the BOM List, Fig.6.7.

Figure 6.6: Incoming Material Labels Examples

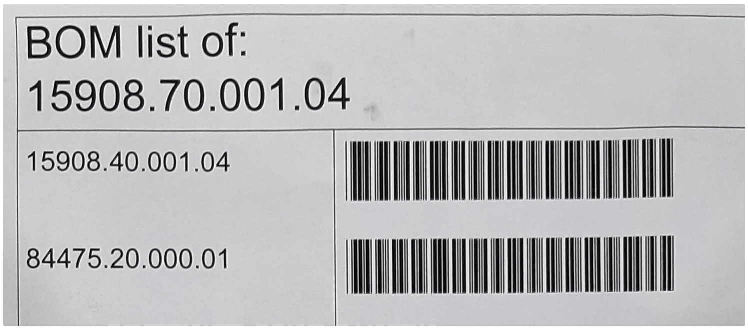


Figure 6.7: BOM List Example

When the referent process is correct, the Operator only needs to scan the bar code of the BOM List in Hydra Terminal.

In another case, it's mandatory to initiate the Escalation Process, which means alerting the Setter and not initiating production. The Setter will help the Operator to find a solution.

6.2.5 OK First/Last Part

The OK First/Last Part is a procedure created to control if the first or last part is dimensionally correct and display it in a place near the machine.

The Operator should perform this procedure right after initiating the production to validate the first part, or right before ending production to validate the last part. It is also necessary to be done when a new part initiate production and when it's the end of a part production series.

To perform the OK First/Last part is necessary to produce the and then validate it on the valid control equipment, following the control equipment operating instructions, an example can be seen in Fig.6.8.

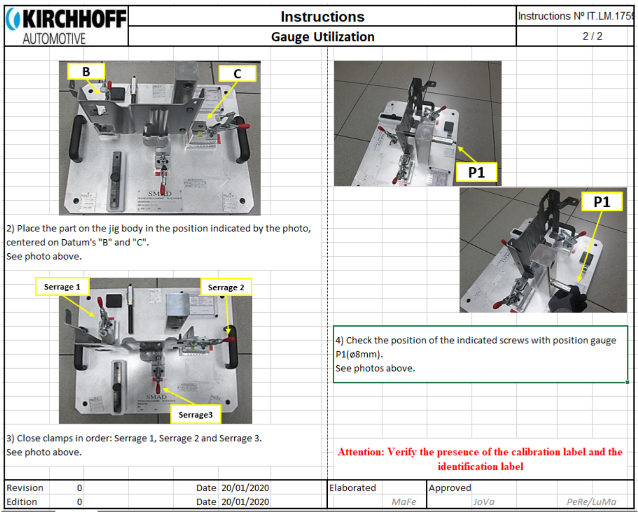


Figure 6.8: Control Equipment Instruction Example

In case of successful validation, the Operator needs to sign, date, and display the part, as shown in Fig.6.9.

Figure 6.9: Part Validated Displayed Example

Otherwise, he has to initiate the Escalation Process by alerting the Setter about the problem and stopping the production. The Setter will help with the solution to solve the problem.

6.2.6 OK Labelling

The OK Labelling is a process to identify the containers with labels that allow the identification of the parts that are in that container.

It is performed by the Operator only when a container is completed.

To perform the OK Labelling, it's necessary to place the pre-printed label at the container when the number of parts produced is reached, as demonstrated in Fig.6.10.

Figure 6.10: Labelling Example

When the labelling is correct, the Operator only needs to replace the full container with an empty one and after continue the production.

In case of a wrong label, the Operator has to initiate the Escalation Process, alerting the Setter and stopping the production.

6.2.7 OK Red Bins

The OK Red Bins is a concept of placing NOK parts in a place called a Red Bin that is sized to accommodate the maximum number of possible NOK parts. The red bins need to be located near the production line. Fig.6.11 shows an example of a Red Bin.

The OK Red Bins should be performed during the shift whenever the Operator has a NOK or suspect part. To help the operator know the type of defect that exists, there is a defects catalog, Fig.6.12, which should always be consulted at the beginning of the shift or when a new part starts production to remind the Operator of the type of possible defects in the part that is in production.

The rules for a correct proceed are: Red Bins must be emptied at the beginning of the shift and near the machine. Whenever a NOK or suspect part is found, must

Figure 6.11: Red Bin Example

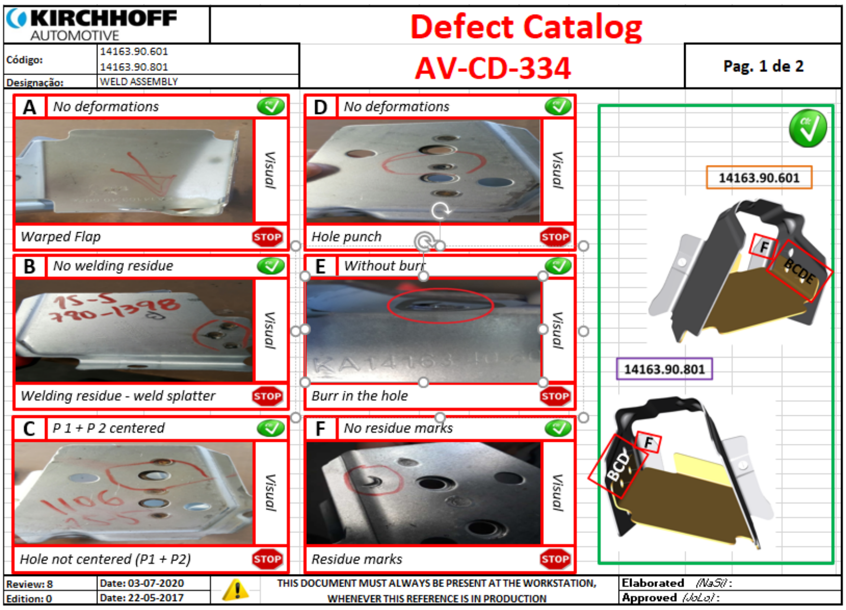


Figure 6.12: Defects Catalog Example

put the part in the Red Bins. And at the end of the shift, the Operator has to pick the parts in the Red Bins and put them in the big scrap container.

There is a maximum number of NOK parts detected before stopping production and initiating the escalation process. After that value is reached, it's mandatory to stop production and do the Escalation Process by alerting the Setter and stopping production.

6.2.8 OK Escalation Process

The OK Escalation Process is a clear and simple communication description in production that answers the question: "What to do if an incident occurs?".

It is the operator's responsibility to initiate this process whenever he detects the occurrence of an incident.

The severity of the incident defines if it is critical or non-Critical, and depending on the severity, the escalation process varies, as shown in Fig.6.13.

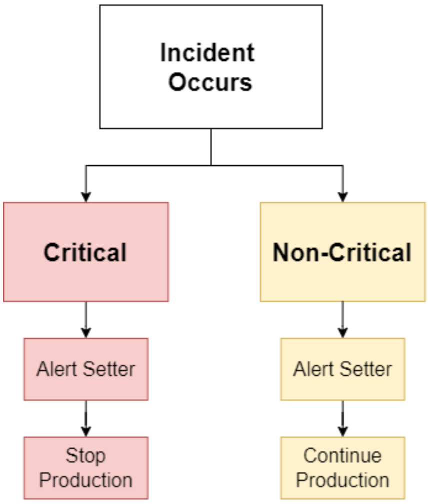


Figure 6.13: Escalation in Critical and Non-Critical Incidents

Meaning in critical incidents, the Operator should escalate the problem by alerting the Setter and stopping production.

On the other side, in non-critical incidents, the Operator should also alert the setter, but he can continue the production.

The escalation process of all the processes mentioned above for the Skilled Operator standard are classified as critical or non-critical, as shown in the following diagram:

6.2.9 OK Rework Process

The OK Rework Process is a process created to eliminate a defect on a defective produced part.

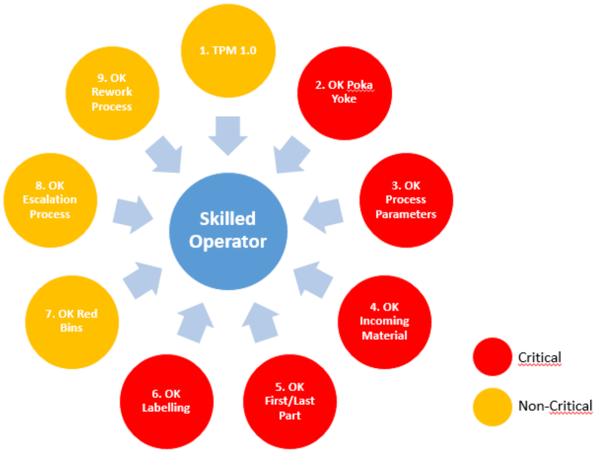


Figure 6.14: Skilled Operator Processes Escalation Severity

The Operator's responsibility in this process involves detecting a defect and analyzing whether is suitable for rework or not by consulting the Rework Instruction, Fig.6.15.

If the Rework Instruction mention that the defect is re-workable, the Operator should record the number of defects by marking them and placing the part on the work area designated to be reworked.

KIRCHHOFF	Rework Instruction	KA	Index	Drawing number	CC	Elaborated	Approved	IT-PR
		16278.70.001	1	-	e-CMP	PeFe	PeRe	55
	Process	Client	Desc. Rev.:	Validation welding parameters		Edition: 0	Revision: 1	Page
	Rework Welding MAG	PSA				10/02/2021	19/02/2021	2/4

2 -Tipo de defeitos de soldadura e acções a realizar

	Characteristics		Acceptance Criterion			Action
Caract. Nº	Description	Image	Lower Limit	Objective	Upper Limit	
D	Discontinuous weld or bead failure		Not applicable	Does not exit	Not applicable	Rework
M	Bites		Not applicable	Does not exit	0,4 mm (20% minimum thickness)	if >0,40 SCRAP
F	Surface cracks and end with crater and fissure		Not applicable	Does not exit	Not applicable	SCRAP
P	Superficial Pores		Not applicable	Does not exit	0,4 x of smallest material thickness: 1mm Max: 2 pores per strand [see PAG.3/3]	REWORK
C	Final Crater		Not applicable	Does not exit	Allowed if no cracks	IF CRACKED SCRAP
B	Hole in the weld		Not applicable	Does not exit	Not applicable	SCRAP if gnawed components REWORK if components are ok
S	Splashes		Not applicable	Does not exit	Some Splashes except in Matching zones	REWORK
EP	Excess Penetration (Root Convexity)		Not applicable	Does not exit	1 mm + 0,1*b	If height exceeds upper limit SCRAP

Figure 6.15: Rework Instruction Example

After, an Operator qualified to perform rework will be in charge of doing it. Without further intervention by the Operator, who detected the defect.

6.3 Process Workflow per Shift

The production process per shift is shown in the following Fig.6.16, focusing on the Operator's point of view, with all the processes that the Operator must perform and when they must be performed during the shift.

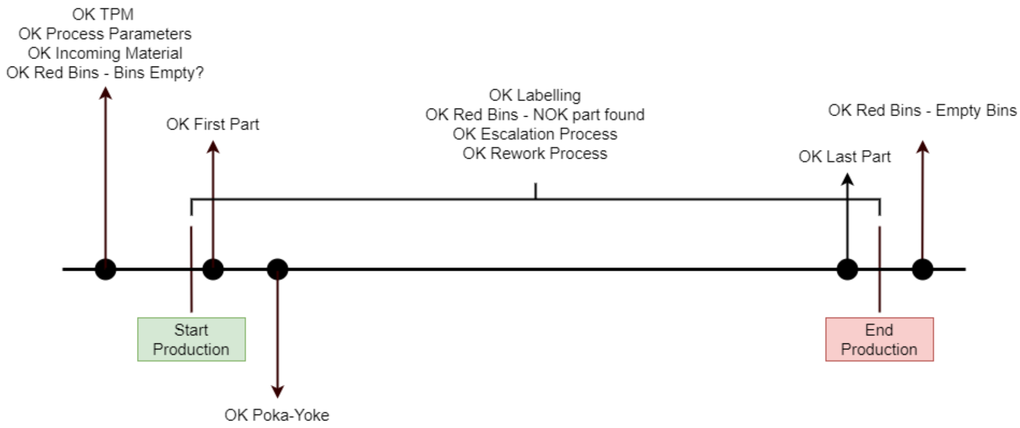


Figure 6.16: Rework Instruction Example

It can be observed that four processes that need to be performed before starting production are OK Incoming Material, OK Process Parameters, OK TPM, and OK Red Bin - checking if the Red Bin is empty.

Right after the start of production, the OK First Part must be done to validate that the machine is producing OK parts.

Followed by the OK Poka-Yoke, which is a process that requires the supervision of the Setter, and for that reason, it was given a period of 2 hours after production start-up so that the validation of the OK Poka-Yoke process could be done.

The processes to be performed during production are necessary, such as OK Labeling, so that whenever a container is complete, it is identified and ready for shipping. And processes that will only be performed if necessary, such as the OK Red Bin, which will only be called when a part considered scrap appears, the OK Rework Process, similar to the previous one, but in this case a part that can be reworked, and the OK Escalation Process, in the event of an incident occurs that requires the Operator to notify his supervisor.

Before ending the production, it is necessary to perform the OK Last Part to validate that the last part produced is also within the standards and that those parts produced during the shift can continue their route without being blocked for future analysis.

After finishing the production, at the end of the shift, it is necessary to complete the OK Red Bin, taking the scrap parts, if any, and placing them in the large general scrap container.

6.4 E-learning's creation

After identifying and detailing all the necessary procedures to enable an Operator with all the knowledge and tools to be a qualified Operator and perform his function to the fullest, it was necessary to find the ideal solution for this information to be easily transmitted.

Kirchhoff has a software tool called TTS, a system that allows the creation of tutorials, usually more directed to the IT solutions, such as software tutorials, where with simple steps, it is possible to document a process step-by-step with interactive action that repeats the step to perform the task correctly.

The challenge, in this case, was to do something similar but a solution for a non-IT tutorial.

This tool allows the development of interactive E-learning, which encourages more practical and appealingly learning instead of the typical theoretical explanation, merely describing the steps to be taken without using visual examples to help to understand, usually described on paper.

These standards are also often associated with a lack of awareness of their existence due to a lack of information regarding this document. And if a standard is created, but it is not known, it is equivalent to a not existing standard.

In this case, the Skilled Operator standard, a general E-learning was developed and subdivided into sub-topics, each one explaining the processes described above and detailing how to perform them correctly.

Wherever possible, images have been inserted to illustrate the documentation to be consulted in each process and the places where this documentation required should be available. Also, whenever a process could be filmed and documented in this way, this was done as well. The goal was to be as clear and objective as possible.

Note that at the end of each E-learning, there is a short questionnaire of 3 questions to consolidate information.

Some screenshots of the E-learning can be seen in Fig.6.17, Fig.6.18 and Fig.6.19.

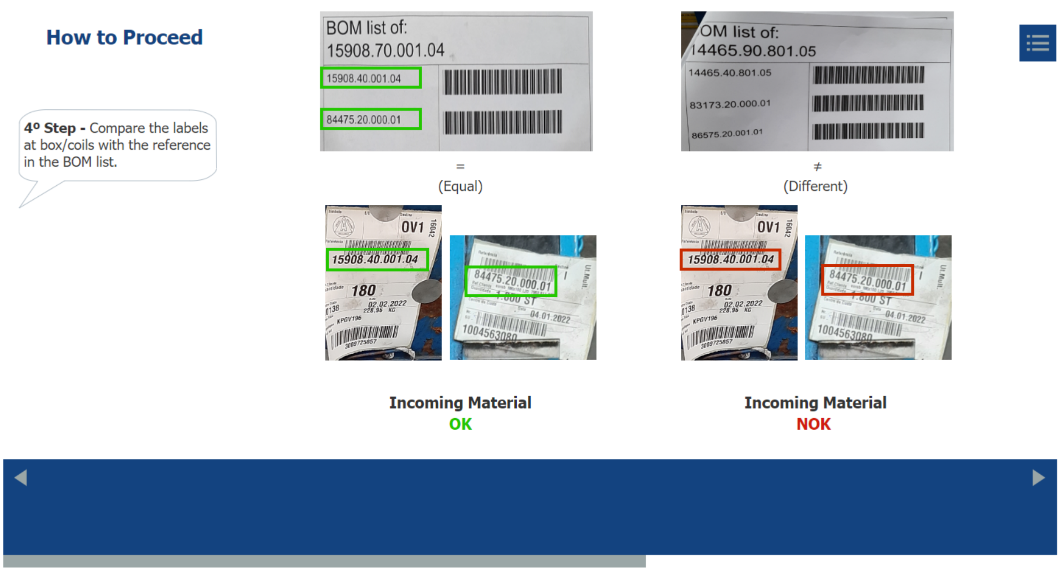


Figure 6.17: E-learning Example

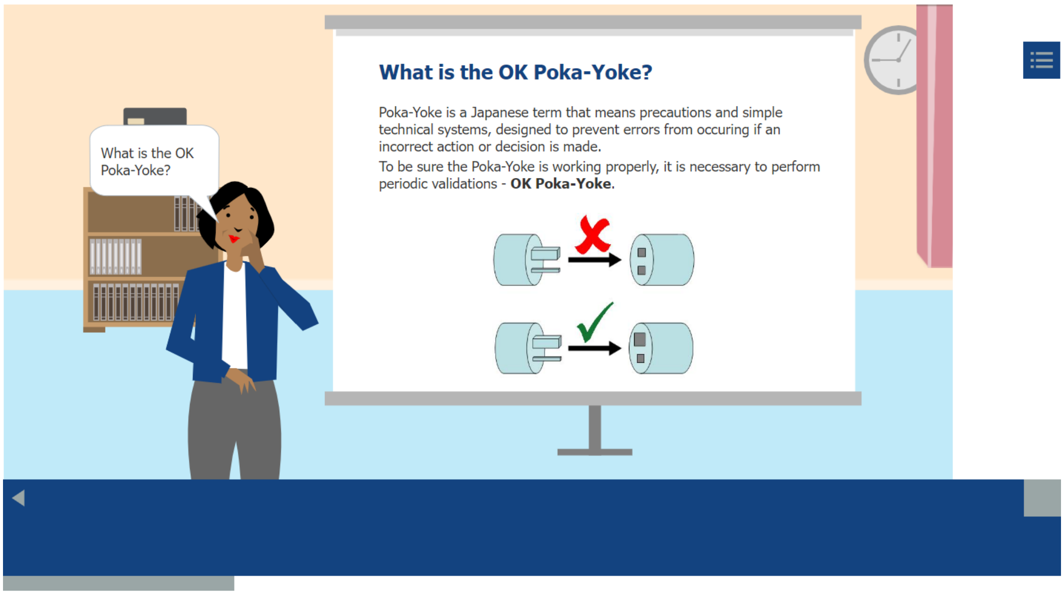


Figure 6.18: E-learning Example

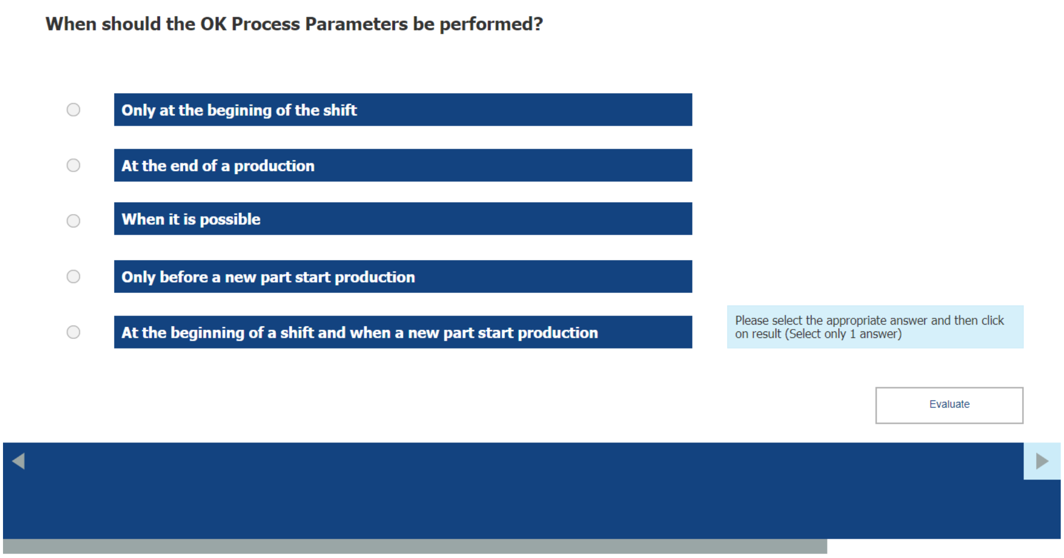


Figure 6.19: E-learning Example

Chapter 7

Conclusions

The conclusions reached in this Thesis should be based on the answers to the questions initially posed when defining the problem and the research questions. The first question was: "How effectively does production system performance monitoring reduce quality complaints?"

Through the analysis conducted in this work, it was possible to conclude that the production control system and the allocation of resources related to obtaining quality products are aligned with the company's philosophy, focusing on prevention rather than on the resolution of failures since the largest share of the quality budget is in the area of prevention and detection and not in the areas of correcting failures.

However, it was also possible to conclude that there are several points to be taken into consideration in order to improve this work philosophy further. Namely, the focus should be on solving problems by technology and not only on the machine that produces the defect.

Extending the correction of defects to a wider area than just not the place of occurrence but also to all machines with the same technology in the company. As suggested in the Data-driven analysis chapter, by adding indications about the technology and defect that were most reported during a given month and allowing the creation of monthly work groups to find measures to combat these defects

The second question was: "How can root-causes analyses help to prevent non-conformities and reduce production costs?"

As was demonstrated in this work, it was possible to find patterns of failures throughout that were detected, and that was through the data-driven analysis. After finding these patterns, the production line groups them into clusters.

The root-cause analyses helped detect the defect's actual cause, and with that information was possible to propose countermeasures that could mitigate the defects by creating preventive measures. That lead to a reduction of production cost, especially the cost associated with producing defective parts, which will be reduced when the prevention measures are implemented.

In addition, an Operator training solution was developed, which allowed documenting all the processes that an Operator must master not to be responsible for creating defects preventive. And also document the step to develop an appealing and easy-to-teach standard. This standard fits the proposed scope of the work since it is the creation of a preventive measure which focuses on the non-production of defects from the Operator's point of view.

7.1 Future Work

After finishing this analysis, it was defined that some of the countermeasures would be developed in the scope of the proposed countermeasures. At the moment, there is already a working group working on a standard for the definition of welding parameters, which will be detailed the number of parts that need to be tested before validating the parameters sheet, as well as the record of the tests of the minimum and maximum values identified on the sheet.

Some of the suggestions for improving the reports of external and internal failures were in the phase of approval and implementation.

The Skilled Operator standard will be implemented in all the Kirchhoff group as the initial training an Operator receives when the company arrives. Every year there will be a review of the contents.

The is also a new work group created to define the Press Welder Manual standard, where will be identified and summarized all the programming, features, and tools needed to have a Press Welder Manual function entirely, with all the instruments needed to prevent the occurrence of defects.

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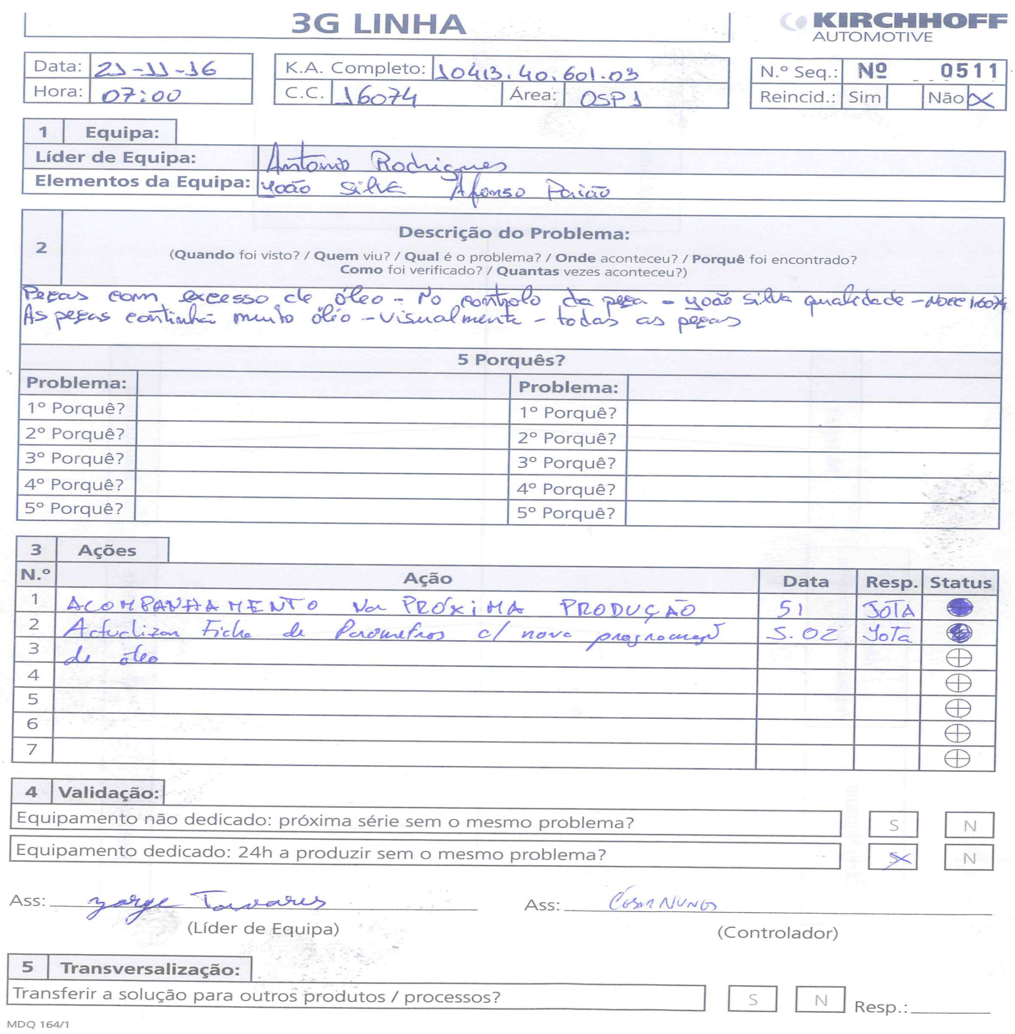
Appendix A

3G's Line



3G LINHA

KIRCHHOFF AUTOMOTIVE

Data:	21-11-16	K.A. Completo:	10413.40.601.03	N.º Seq.:	Nº 0511
Hora:	07:00	C.C.	16074 Área: OSP1	Reincid.:	Sim / Não X

1 Equipa:

Líder de Equipa:	Antonio Rodrigues
Elementos da Equipa:	João Silva Afonso Paixão

2 Descrição do Problema:

(**Quando** foi visto? / **Quem** viu? / **Qual** é o problema? / **Onde** aconteceu? / **Porquê** foi encontrado? **Como** foi verificado? / **Quantas** vezes aconteceu?)

Peças com excesso de óleo - No controlo da peça - João Silva qualidade - Nº 16074
As peças continham muito óleo - visualmente - todas as peças

5 Porquês?

Problema:		**Problema:**	
1º Porquê?		1º Porquê?	
2º Porquê?		2º Porquê?	
3º Porquê?		3º Porquê?	
4º Porquê?		4º Porquê?	
5º Porquê?		5º Porquê?	

3 Ações

N.º	Ação	Data	Resp.	Status
1	Acompanhamento na próxima produção	51	Jota	●
2	Atualizar Ficha de Parametros c/ novo programação	S.02	Jota	●
3	de óleo			⊕
4				⊕
5				⊕
6				⊕
7				⊕

4 Validação:

Equipamento não dedicado: próxima série sem o mesmo problema?	S	N
Equipamento dedicado: 24h a produzir sem o mesmo problema?	S X	N

Ass: Jorge Tavares (Líder de Equipa) Ass: César Nunes (Controlador)

5 Transversalização:

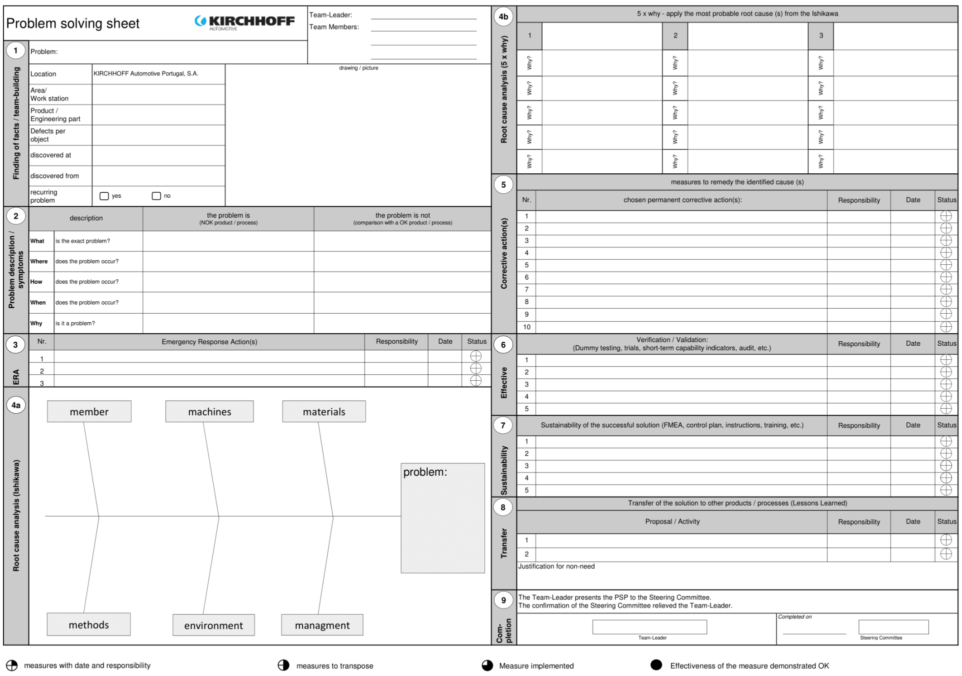
Transferir a solução para outros produtos / processos? S N Resp.:

MDQ 164/1

Figure A.1: 3G's Line Example

Appendix B

PSP



Problem solving sheet KIRCHHOFF AUTOMOTIVE

Team-Leader:
Team Members:

1 Finding of facts / team-building

Problem:

Location	KIRCHHOFF Automotive Portugal, S.A.	drawing / picture
Area/ Work station		
Product / Engineering part		
Defects per object		
discovered at		
discovered from		
recurring problem	☐ yes ☐ no	

2 Problem description / symptoms

description		the problem is (NOK product / process)	the problem is not (comparison with a OK product / process)
What	is the exact problem?		
Where	does the problem occur?		
How	does the problem occur?		
When	does the problem occur?		
Why	is it a problem?		

3 ERA

Nr.	Emergency Response Action(s)	Responsibility	Date	Status
1				
2				
3				

4a Root cause analysis (Ishikawa)

member, machines, materials, methods, environment, managment, problem:

4b Root cause analysis (5 x why)

5 x why - apply the most probable root cause (s) from the Ishikawa

1		2		3	
Why?		Why?		Why?	
Why?		Why?		Why?	
Why?		Why?		Why?	
Why?		Why?		Why?	
Why?		Why?		Why?	

5 Corrective action(s)

measures to remedy the identified cause (s)

Nr.	chosen permanent corrective action(s):	Responsibility	Date	Status
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

6 Effective

	Verification / Validation: (Dummy testing, trials, short-term capability indicators, audit, etc.)	Responsibility	Date	Status
1				
2				
3				
4				
5				

7 Sustainability

	Sustainability of the successful solution (FMEA, control plan, instructions, training, etc.)	Responsibility	Date	Status
1				
2				
3				
4				
5				

8 Transfer

Transfer of the solution to other products / processes (Lessons Learned)

	Proposal / Activity	Responsibility	Date	Status
1				
2				

Justification for non-need

9 Com-pletion

The Team-Leader presents the PSP to the Steering Committee.
The confirmation of the Steering Committee relieved the Team-Leader.

Completed on

Team Leader | Steering Committee

measures with date and responsibility — measures to transpose — Measure implemented — Effectiveness of the measure demonstrated OK

Figure B.1: PSP Example