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Study of the Extrusion and Painting Process of Aluminum Profiles of a Metal-Mechanical Industry Located in the South of Santa Catarina

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Abstract

In the competitive scenary of the 21st century, organizations need to deal with the reality that in order to obtain an above-average return, it is necessary to be willing to meet high quality standards. This article consists of studying the extrusion and painting processes of an aluminum profiles and frames manufacturer, located in the south of Santa Catarina, in order to analyze and measure, through the use of quality tools and statistical software, faults and errors arising from this process. In this context, the research methodology adopted for this study is characterized as exploratory-descriptive, with a quantitative character. The methodological procedure started with an analysis and mapping of the extrusion and painting processes of aluminum profiles, seeking and interpreting information relevant to the study. Then the data was collected and analyzed, where it was possible to apply the Pareto Diagram and identify the most frequent non-conformities. A statistical analysis was then performed using the IBM Statistical Package for the Social Sciences (SPSS) version 21.0 software, comparing and associating the collected data in order to identify and understand the root causes of the defects that occurred. With the results obtained from the analyzes carried out, it became possible to draw up an action plan, using the 5W2H quality tool, containing suggestions and proposals for improvements, with a focus on reducing the scrap generated from the defects identified in the processes of extrusion and painting of aluminum profiles.

Keywords: Quality management. Productive system. Aluminum Extrusion. Quality tools.

1. Introduction

Every day, the market becomes progressively more demanding and competitive. This scenario demands that organizations are able to meet high quality standards and are willing to constantly improve their processes and products.

According to Campos (2014), for a company to guarantee its survival in the market, its main concern must be to satisfy people's needs. It is necessary, for the organization, that its consumers feel satisfied for a long period after using its services or products. In this context, the objective of using quality control methods is precisely to create favorable conditions for the long-term survival of companies.

One of the ways to meet customer expectations and prove competent in terms of quality, is through the use of techniques and tools that help managers to identify and, later, solve possible flaws in the production process. There are a large number of techniques and tools that assist quality management. Most of these tools are simple to operate and their proper use allows better management of the process, in terms of reducing errors and optimizing times and processes.

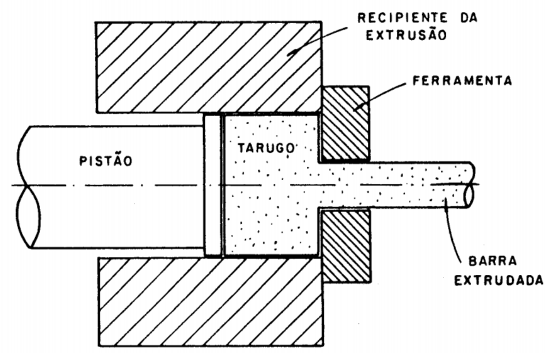
The metal-mechanic sector encompasses both companies that supply intermediate goods and services, such as foundries and forges, as well as industries that work with the manufacture of the final product, such as suppliers of machines, vehicles and other consumer goods (MACEDO; CAMPOS, 2001).

According to Macedo and Campos (2001), the metal-mechanic sector is nationally recognized for encompassing goods and services originated from the transformation of metals, through metallurgical and mechanical processes. Due to the complexity and variety of technologies used in their production processes, companies that operate in this segment may belong to different production chains.

The main components of an aluminum frame are its profiles. The aluminum profile is produced through the extrusion process. According to Dieter (1981), extrusion is a process of mechanical conformation, where a given material is forced to flow through the orifice of a die or tool, under high pressures. Generally, the extrusion process is used in the production of bars or tubes of different materials, however it is also possible to obtain profiles with complex and irregular shapes using materials that are easier to be extruded, as is the case of aluminum profiles.

Figure 1 illustrates the extrusion process used in the production of aluminum profiles.

Figure 1 - Illustration of the extrusion process.



Source: Bresciani Filho et al (2011).

Extrusion can be carried out cold or hot. In the case of the production of aluminum profiles, the hot extrusion process is used, where the aluminum billet is heated to a temperature that can vary from 340ºC to 530ºC (ABAL, 2008).

Carvalho and Paladini (2012) defined quality management as a set of actions that make it possible to manage the organization with a focus on planning, control, guaranteed and quality improvement. To better understand this concept, it is necessary to visit the past and analyze its historical evolution.

Throughout the 20th century, quality management has undergone a great evolution and has gone through four striking stages, namely: product inspection, process control, quality assurance systems and total quality management or Total Quality Management (TQM). One of the results of this evolution was the quality management systems of the ISO 9000 series, which until today are used by countless companies as a way to increase their competitiveness in the market (CARPINETTI; MIGUEL; GEROLAMO, 2011).

According to Carvalho and Paladini (2012), at the beginning of the 20th century, the customers' need was not a priority when the products were manufactured. On the Ford assembly line, for example, between the years 1908 and 1927, cars of only one model were produced, in just one color. However, it was also at that time that the concept of quality control underwent a major evolution. In 1924, Walter A. Shewhart created the control charts, and also proposed the PDCA cycle (plan-do-check-act), tools that provided the analysis of productive activities with a focus on solving problems. From then on, several techniques, control tools, and specific norms that did not exist existed until then.

Until the beginning of the 1950s, for a product to be considered of quality it was necessary that it had total technical perfection. Only after the publication of works by authors such as Joseph Juran, Deming and Feigenbaum, began to associate quality not only with technical perfection, but also with customer satisfaction and the suitability of the product for use (CARPINETTI; MIGUEL; GEROLAMO, 2011) .

It was also in the 1950s, after the development of the total quality control system (TQC - Total Quality Control), that quality began to be treated systemically within organizations (CARVALHO; PALADINI, 2012).

TQC is an improved control measure in Japan that is based on the participation of all sectors of the company in the pursuit of total quality. To guarantee the company's survival, it became necessary for everyone to use control methods and techniques, as a way to achieve customer satisfaction and obtain continuous profit (CAMPOS, 2014).

Over time, the concepts of quality have undergone significant changes. Quality is no longer seen only as making small improvements in simple manufacturing processes, and is now considered a fundamental element within organizational management, serving a highly relevant role (CARVALHO; PALADINI, 2012).

Lobo and Silva (2014), state that it is difficult to define precisely the word quality due to the fact that it is not a technical term, but a term in the public domain. According to Paladini (2012), to understand the term quality it is necessary to consider it as a set of elements that integrate a product or service. Quality is usually associated with the consumer's need. In this sense, some of the well accepted concepts are:

● "Quality is the necessary condition of fitness for its intended purpose" (EOQC - European Quality Control Organization, 1972 apud Paladini, 2012).

● "Quality is suitability for use" (Juran and Gryna, 1991 apud Paladini, 2012).

● "Quality is the degree of adjustment of a product to the demand it intends to satisfy" (Jenkins, 1971 apud Paladini, 2012).

According to Carpinetti, Miguel and Gerolamo (2011), the quality of a product is determined by several characteristics and parameters. The analysis of these parameters can help the manufacturer to make improvements in its products and become more competitive in the market. Table 1 presents the main parameters that confer the quality of the product.

Table 1 - Product quality parameters.

Technical or functional performance	Degree to which the product fulfills its basic mission or function.
Ease or convenience of use	Includes the degree to which the product fulfills secondary functions that supplement the basic function.
Availability	Degree to which the product is available for use when required (for example: it is not "broken", it is not under maintenance, etc.)
Reliability	Probability that the product, if available, will be able to perform its basic function without failing for a predetermined time and under certain conditions of use.
Maintainability	Ease of conducting maintenance activities on the product, being an attribute of the product design.
Durability	Average product life, considering the technical and economic points

	of view.
Compliance	The degree to which the product meets the design specifications.
Installation and usage guidance	Guidelines and facilities available for conducting product installation and use activities.
Technical assistance	Factors related to the quality (competence, courtesy, etc.) of technical assistance and customer service (pre, during and after sales).
User interface	Quality from an ergonomic, life-threatening and user communication point of view with the product.
Interface with the environment	Impact on the environment during production, use and disposal of the product.
Aesthetics	User perception of the product from their sensory organs.
Perceived quality and brand image	User perception of product quality based on the brand image and reputation, as well as its manufacturing origin (for example, made in Japan).

Source: Carpinetti, Miguel and Gerolamo (2011).

As can be seen in Table 1, the parameters range from aesthetics and technical performance of the product to the quality perceived from the brand's reputation.

Decades ago, quality tools were created by the same thinkers who started the total quality process. These tools materialize the idea that decision making must be based on data and facts, which help in choosing the best path to be followed (VIEIRA FILHO, 2003).

One of the first thinkers to present techniques that would assist in the control and improvement of production processes was Kaoru Ishikawa. An engineer, born in 1915, Ishikawa was responsible for the development of Basic Quality Control Tools (LOBO; SILVA, 2014).

According to Toledo et al (2014), the basic tools of quality serve to increase efficiency in the use of data, mainly numerical, through the creation of auxiliary procedures in the collection and analysis of data. These tools allow to identify and prioritize, by degree of importance, the main problems occurring in the production system.

One of the tools used to collect information related to a problem is brainstorming, which means a storm of ideas. Brainstorming is a participatory tool, where the objective is to bring together a group of people and raise as many ideas and suggestions as possible about a certain subject or problem. It is a relatively simple tool, where everyone has the right to express their opinion without receiving criticism (VIEIRA FILHO, 2003).

It is a technique that can be used as support for other management tools, seeking ideas that address the causes or solutions of the problem that is being highlighted. Brainstorming is usually carried out with groups of 6 to 8 people, with the presence of an "external animator" who will guide the meeting and make sure that everyone is understanding the problem at hand. After all the ideas are raised, only the most interesting and feasible ones are filtered and selected (TOLEDO et al, 2014).

Another quality tool used quite frequently to assist in the classification and organization of data is the Pareto Diagram. According to Lobo and Silva (2014) the Pareto Diagram is a tool that helps in the identification of the items that constitute the largest share of losses. One of the problems related to quality is losses during the process, which usually appear through defective items. By identifying such losses, it becomes possible to concentrate efforts to guarantee their eliminations and optimize the process.

According to Campos (2014), the Pareto Diagram allows a large problem to be divided and classified into smaller problems. Thus, it is possible to separate and prioritize items between those who have a great influence and those who have little influence on the problem to be solved.

According to Toledo et al (2014), the diagram starts from the foundation that 20% of the causes are responsible for 80% of the defects. Priority should be given to this small percentage of causes found, which are called vital causes. The diagram is represented by a bar graph that orders the observed occurrences in relation to the frequency that they occur, allowing to identify the priority aspects of the problem.

According to Lobo and Silva (2014), the 5W2H method emerged to facilitate the identification of variables, causes and objectives to be achieved within a given process. The acronym is of English origin and has the meaning:

- What - What: What is the action?
- Who - Who: Who is responsible for this action?
- Where - Where: Where will it be conducted?
- When - When: When will the action be taken?
- Why - Why: Why is this action necessary?
- How - How: How to perform this action?
- How much - How much: How much will the execution of this action cost?

The 5W2H tool consists of an action plan that will determine, through planning, what actions should be taken to solve a problem. In order to apply this tool, it is necessary to answer the seven questions described above, so that all the basic fundamental aspects for planning are found.

According to Vieira Filho (2003), the 5W2H tool is easy to use and plays an important role in defining and planning the actions to be carried out to achieve the defined objectives.

Some companies have to deal with a large volume of non-compliant products. The inappropriate destination of these products can cause a major financial problem for the organization. In this case, it is important to implement a quality management system that allows decisions made regarding the destination of non-compliant products to balance the considerations of customer satisfaction and costs (JURAN, 2009).

The use of specific software or quantitative tools is not always sufficient to solve problems in production. The Problem Analysis and Solution Method (MASP) was developed in Japan, and can be used by several professionals in several areas to solve generic problems. This method can serve as both a corrective and an improvement tool, allowing decisions made to always be based on facts, thus seeking to achieve performance goals (TOLEDO et al, 2014).

Table 2 presents the steps to be followed to solve a problem through MASP.

Table 2 - MASP steps and objectives.

Steps	Objectives
1. Problem identification	Clearly define the problem and recognize its importance. That is, to evaluate what is lost and what can be gained with the solution of the problem.
2. Observation	Investigate the specific characteristics of the problem, with a broad view, from various points of view, and in a participatory way.
3. Analysis	Identify the most important causes, the cause and effect relationship between them and, among these, the root cause.
4. Action plan	Discuss and develop a possible action plan that eliminates or controls the root cause.
5. Action	Eliminate, control or block the root cause.
6. Verification	Monitor the results of the process and verify that the action and control of the cause were effective. Observe the possible generation of undesirable side effects. If the desired effects have not been generated, return to step 2.
7. Standardization	Standardize or adapt existing standards (product and process) to prevent the problem from reappearing.
8. Conclusion	Review and discuss all the experience of the problem solving process (application of MASP) to generate and disseminate learning for future applications of the method. Plan to address remaining problems, related to the studied problem, or to focus on further improvements to the studied problem or to new identified problems.

Source: Toledo et al (2014).

If these steps are implemented correctly, consistent results will be obtained that provided improvements to the analyzed process (TOLEDO et al, 2014).

The general objective of this article is to study the non-conformities that occur most frequently, in the extrusion and painting processes of profiles of a company that manufactures aluminum frames. To achieve this purpose, the following specific objectives were presented: to study the extrusion and painting processes of aluminum profiles; identify the main non-conformities of the process and classify them according to their frequency; analyze the cause of the identified non-conformities; propose solutions to the problems encountered by drawing up an action plan.

The company object of this study is in the metal mechanic branch, located in the south of Santa Catarina, and operates in the development and commercialization of aluminum profiles and frames.

2. Methodological Procedures

In this section, the methodological procedures adopted during the study will be presented, based on a detailed description of the data collection, treatment and analysis process. According to Gil (2008), research is a formal and systematic process that aims to find answers to problems through the application of scientific procedures.

2.1 METHODOLOGICAL FRAMEWORK

This study was applied to the extrusion and painting process of a company that manufactures aluminum profiles and frames. The company, considered medium-sized, currently has about five hundred employees and has a remelting unit, where it manufactures its own aluminum billet. Subsequently, this billet is sent to the extrusion unit, where the profiles that make up the frames are manufactured. After extruded, the profiles go through a treatment process and electrostatic powder painting.

We sought to identify the main non-conformities that occurred in the extrusion and painting process of aluminum profiles through the use of quality tools. From there, it was possible to apply the method of analysis and problem solving, which acted as an intermediary for the elaboration of improvement proposals for the process.

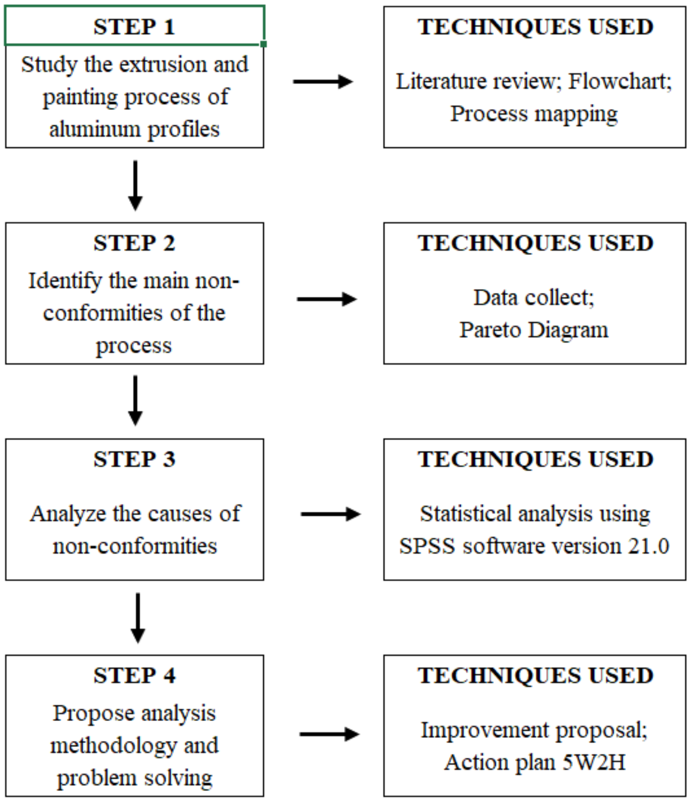
The research methodology adopted in this work is characterized as exploratory-descriptive, of a quantitative character, since it sought to investigate the causes of problems within a production process, based on a detailed study, which described the characteristics of the data collected, demonstrating the relationship between variables and control tools.

According to Silva and Menezes (2005) research with a quantitative approach seeks to transform the information and data collected into numbers, with the purpose of analyzing and classifying them. In these researches are used resources and statistical techniques. For descriptive research, we seek to describe the characteristics of a certain phenomenon and define how often it occurs, without having to manipulate it . Exploratory research, on the other hand, is the approach adopted to provide greater familiarity with the problem, in order to obtain a new perception of it and build hypotheses for further studies.

2.2 DATA COLLECTION AND ANALYSIS PROCEDURE

The research procedure proposed to achieve the objectives was based on the Problem Analysis and Solution Method (MASP), divided into 4 stages. The steps and techniques used throughout the work are shown in Figure 2.

Figure 2 - Research steps and techniques used.



Source: Adapted from Guimarães Filho (2003).

As seen in Figure 2, the achievement of the proposed objectives depended mainly on the proper use of the quality tools presented. Initially, an analysis and mapping of the entire extrusion and painting process of aluminum profiles was carried out, seeking and interpreting all information about the process.

In the second stage, data collection was carried out in order to identify the non-conformities of the process. Data collection was carried out within a one-year horizon, covering the months of April 2019 to April 2020. The data were taken from spreadsheets that are fed monthly by the extrusion sector. The spreadsheets identify the types and frequency of non-conformities in the sector and the quantity in kilograms of scrap generated. The data collection instrument can be seen in Table 3.

Table 3 - Non-conformity worksheet.

Month __ / Year ____									
Item	**Profie Number**	**Color**	**Qty.**	**Measure**	**Origin**	**Line**	**Date**	**Scrap Weight (kg)**	**Defect**

Source: Research Data (2020).

After collection, the data were quantified and analyzed in detail. The quantification allowed to demonstrate the frequency of non-conformities through the Pareto Diagram, being able to obtain a wide view of the problems that occurred and to identify the most critical.

In the third stage, a sampling was carried out, including all the data from the collected aluminum frame profiles, considering the sampling procedure of the census collection. Profiles with less than 15 annual discards were excluded from statistical analysis. Of the 173 profiles analyzed, only 12 presented more than 15 annual discards.

The collected data were analyzed using the IBM *Statistical Package for the Social Sciences* (SPSS) version 21.0 software . Qualitative variables were expressed by means of frequency and percentage, with quantitative variables being expressed by median, minimum and maximum.

Inferential statistical analyzes were performed with a significance level of $\alpha = 0.05$, that is, with a 95% confidence interval. The normal distribution of quantitative variables was investigated using the Kolmogorov-Smirnov test.

The comparison of measures of central tendency of quantitative variables was performed using the Kruskal-Wallis H test followed by Dunn's post-hoc test when statistically significant differences were observed. The association between qualitative variables was assessed by applying the Linear Association by Linear test, followed by residue analysis when statistical significance was observed.

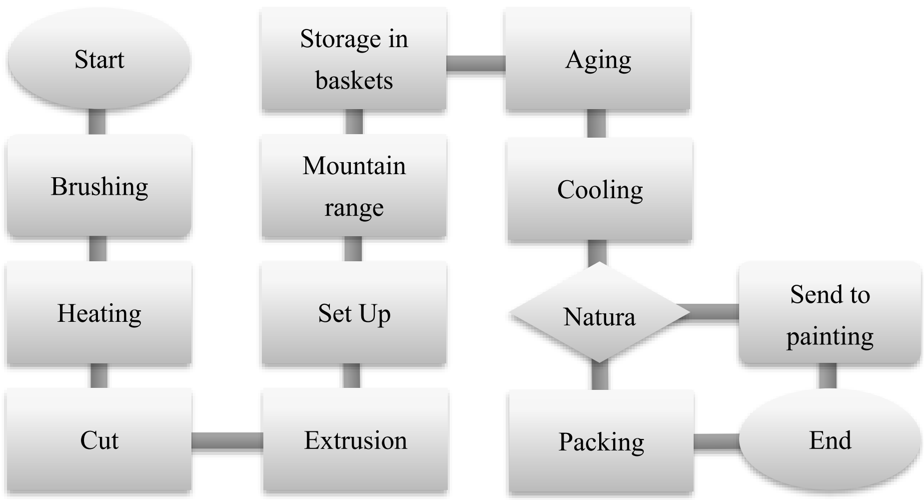
In the fourth and final stage, with the results of the Pareto Diagram and statistical analysis in hand, it was possible to draw up an action plan using the 5W2H quality tool and propose suggestions for improvements to the process.

3. Results and Discussions

In this section, the results obtained during the research through the application of the proposed methodology will be presented.

The sectors chosen as focus during the research were extrusion and painting. After an analysis and mapping of each process has been carried out, the respective flowcharts can be elaborated. Figures 3 and 4 illustrate the flowcharts of the extrusion and painting processes of aluminum profiles of the company under study.

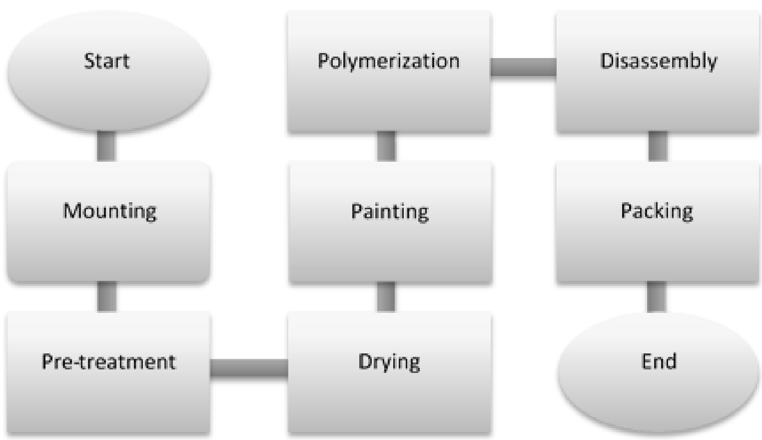
Table 3 – Flowchart of the Extrusion process.



Source: Authors (2020).

The extrusion process starts with brushing the billet to remove the oxide layer and dirt. Then the billet is placed in an oven for heating at 500ºC. After being heated, it is cut to the measure of 900 millimeters and placed in the compartment to be extruded. With each pull of approximately 60 meters, the profile is cut and then passes through the Set Up, which is an inspection of dimensional quality and finish. After the Set Up, the profile is sawn according to the order's need and segregated, removing short, twisted, crumpled bars or outside the quality standard. The bars are then placed in baskets and sent to the aging oven for heat treatment. After treatment, the profiles are cooled and sent to the packaging or to the painting sector, depending on your primary need.

Figure 4 - Flowchart of the Painting process.



Source: Authors (2020).

The painting process begins with the assembly of the profiles so that they can follow the pre-treatment. Pre-treatment consists of three stages: degreasing; washing; and conversion. In degreasing, the profiles are cleaned using an acidic product, removing dirt, dust, oils and other surface residues. Then the profiles go through the washing step, where they are rinsed to remove excess product from the previous step. When converting, the profiles receive the application of a product to guarantee the adherence of the paint. After pre-treatment, they pass through a drying oven with a temperature of 100ºC. After drying, they receive the paint, where the powder electrostatic paint is applied through special pistols in booths designed for this purpose. After painting, the profiles are sent to an oven with a temperature of approximately 190ºC for the polymerization of the paint to occur. Finally, the profiles are disassembled and packed.

Table 4 presents some of the non-conformities identified during data collection, in order to illustrate the completion of the spreadsheet.

Table 4 - Example of the completed non-conformity spreadsheet.

Item	Profile No.	Color	Qty.	Measure (mm)	Origin	Line	Date	Scrap Weight (kg)	Defect
JCI000	43	White painted	28	1195	Print	Engineering assembly line 10	02/10/2020	13.75	Dimensional
GDCORP	135	White painted	7	2432	Aluminum cutting	Special line assembly i	10/03/2019	21.48	Points
JCORRE	32	White painted	81	1095	Aluminum cutting	External pen. South i	09/25/2019	32.46	Dimensional
GDCORP	107	Painted black matte	3	1785	Mounting	Special line assembly i	06/12/2019	7.96	Points

Source: Research Data (2020).

As a large amount of data was collected during the months of April 2019 to April 2020, it became necessary to choose only a few of the several non-conformities identified to exemplify and explain the completion of the spreadsheet in order to better clarify the reader the process of collect.

In order to identify non-conformities arising more frequently, an analysis of the “defect” column of all collected spreadsheets was carried out. All defects were identified and quantified, transforming them into families and analyzing their frequencies. Table 5 illustrates the defects detected and their respective frequencies.

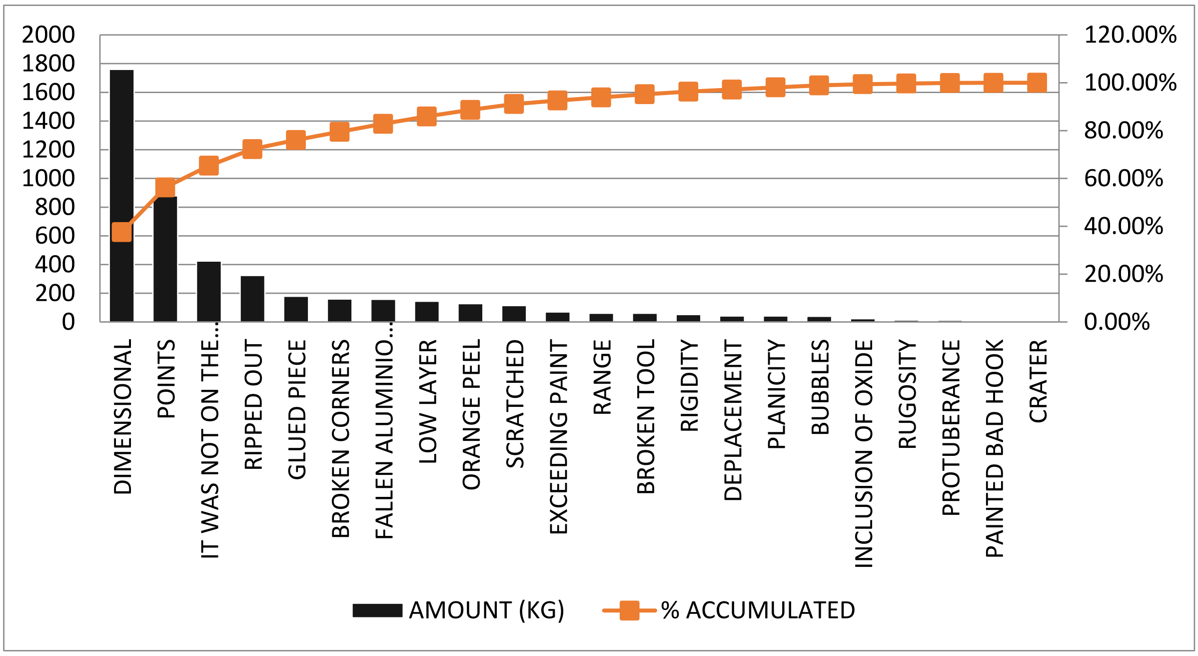
Table 5 - Defects identified in the Extrusion and Painting sectors.

Defect	Quantity (KG)	%	Accumulated%
Dimensional	1759.87	37.53%	37.53%
Points	878.68	18.74%	56.27%
It was not on the rack	424.95	9.06%	65.33%
Ripped out	324.16	6.91%	72.24%
Glued piece	179.11	3.82%	76.06%
Broken corners	160.27	3.42%	79.48%
Fallen aluminio profile	157.92	3.37%	82.85%
Low layer	144.02	3.07%	85.92%
Orange peel	128.28	2.74%	88.65%
Scratched	114.72	2.45%	91.10%
Exceeding paint	69.52	1.48%	92.58%
Range	60.99	1.30%	93.88%
Broken tool	60.98	1.30%	95.18%
Rigidity	51.79	1.10%	96.29%
Deplacement	41.51	0.89%	97.17%
Planicity	41.39	0.88%	98.05%
Bubbles	39.41	0.84%	98.90%
Inclusion of oxide	23.32	0.50%	99.39%
Rugosity	12.49	0.27%	99.66%
Protuberance	12.09	0.26%	99.92%
Painted bad hook	3.02	0.06%	99.98%
Crater	0.88	0.02%	100.00%
Total	4689.37	100.00%	

Source: Research Data (2020).

It can be seen in Table 5 that between April 2019 to April 2020, 4,689.37 kilograms of scrap from 22 different extrusion and paint defects were recorded. The generation of scrap can cause unnecessary costs with rework, delays in delivery, among other inconveniences. In Figure 5, it is possible to observe the Pareto Diagram elaborated from the data obtained in Table 5, in order to identify the main and most critical non-conformities.

Figure 5 - Pareto diagram of the identified non-conformities.



Source: Authors (2020).

With the analysis of the Pareto Diagram it was possible to identify that the “dimensional” defect is the most frequent, being responsible for 37.53% of the amount of scrap generated, followed by “points” with 18.74%, “it was not in the rack ”With 9.06%, and“ pullout ”with 6.91%. It is possible to observe that profiles with dimensional errors and with dots, are the two types of non-conformities with the highest number of occurrences, adding up to 56.27%, being responsible for more than half of the total scrap generated during the analyzed period.

Dimensional errors are mainly linked to the extrusion process, which can occur due to some failure from the profile matrix. After the profile is extruded and cut it passes through the *Set Up* , where its quality is inspected. In this process, negligence on the part of operators may occur, which causes profiles outside the quality standard to continue the production process.

The dots, on the other hand, are small relevant marks on the surface of the profile, which can occur directly on the paint layer or come from the profile itself. Therefore, this defect can be linked to both the extrusion process and the painting process. The cleaning of the billet and the profile before the extrusion and painting processes, respectively, can directly influence the occurrence of spots.

Non-conformities denominated as “not in the rack” occur due to a lack of communication between the production line and the inspection sector. The frame assembly line identifies the defect, but does not place the profiles in place, routing them directly to the scrap before the extrusion sector can inspect the defect. Therefore, it is not possible to identify the real error arising from these profiles.

The pullout defect is characterized by a discontinuity in the profile surface, in the same direction as the extrusion. This is due to the high temperature during the exit of the profile, problems with the extrusion tool, or an improper homogenization of the billet.

In order to identify the root causes of the nonconformities identified, a statistical analysis of the data was performed using the IBM *Statistical Package for the Social Sciences* (SPSS) version

21.0 software . With a very large amount of data, statistical analysis can lose accuracy. Therefore, for the purpose of obtaining more accurate results, the profiles that obtained more than 15 discards during the period from April 2019 to April 2020 were considered for analysis. In Table 1, the amount of scrap was compared generated with the different types of profiles analyzed.

Table 1. Comparison of the amount of scrap generated with the types of profiles, with more than fifteen annual discards, in a metallurgical company during 2019.

Profiles	n	Generated Scrap (kg/year)	Value - p[†]
		Average (Minimum – Maximum)	
E-5287 (8)	32	3,50 (1,78 – 5,42)	<0,001
E-7541 (12)	40	1,23 (0,67 – 6,11) [b]	
E-7874 (21)	17	2,28 (1,13 – 2,38) [b]	
E-8573 (32)	45	3,19 (0,94 – 9,04)	
E-9007 (39)	16	2,23 (1,11 – 6,95)	
E-9038 (43)	16	14,50 (2,07 – 29,56) [a]	
ES-065 (51)	20	1,97 (1,81 – 8,61)	
ES-097 (64)	23	1,41 (1,30 – 2,90)	
ES-396 (107)	17	6,49 (4,89 – 10,98) [c]	
ES-665 (129)	19	1,85 (0,14 – 3,70) [b]	
ES-675 (135)	18	5,92 (3,86 – 17,35) [c]	
ES-704 (141)	20	2,69 (1,79 – 4,68)	

[†]P value obtained after the application of the H test of Kruskal-Wallis.
[a,b,c] Different letters indicate statistically significant differences obtained after Dunn's post-hoc test.
Source: Research data (2020).

p value obtained after applying the Kruskal-Wallis H test.
[a, b, c] Different letters indicate statistically significant differences obtained after Dunn's post-hoc test.

Source: Research data (2020).

The statistical results showed that there is a relationship between the scrap generated and the type of profile, and this does not happen by chance. Thus, it can be said that some profiles generate a more significant amount of scrap than others. Profile number 43 was discarded 16 times during the study period, while profile number 12 was discarded 40 times, however according to the statistical results profile 43 is more likely to generate a more significant amount of scrap than profile 12. This indicates that when non-conformities related to profile 43 occur, the scrap from it will be greater than that of the rest of the profiles.

The profiles can be sold natural or painted. When painted, they can be of four different colors: white, bronze, gray or matte black. Table 2 shows the association between the types of defects found and the colors used in painting the profiles.

Table 2 - Association between the types of defects and the colors used in the painting.

Defects	Colors. n (%)				Value-p‡
	White n = 249	Bronze n = 15	Gray n = 8	Matte Black n = 11	
Pullout	11 (4,4)	0 (0,0)	0 (0,0)	0 (0,0)	<0,001
Scratched	1 (0,4)	0 (0,0)	0 (0,0)	0 (0,0)	
Bubbles	7 (2,8)	0 (0,0)	0 (0,0)	0 (0,0)	
Low Layer	14 (5,6)	0 (0,0)	0 (0,0)	0 (0,0)	
Broken Corner	6 (2,4)	0 (0,0)	0 (0,0)	0 (0,0)	
Orange peel	11 (4,4)	0 (0,0)	0 (0,0)	0 (0,0)	
Dimensional	58 (23,3) [b]	1 (6,7)	0 (0,0)	0 (0,0)	
Exceeding Paint	9 (3,6)	2 (13,3)	0 (0,0)	0 (0,0)	
Skew	32 (12,9)	2 (13,3)	0 (0,0)	2 (18,2) [b]	
Glued part	16 (6,4)	0 (0,0)	0 (0,0)	0 (0,0)	
Points	83 (33,3)	10 (66,7) [b]	8 (100,0) [b]	9 (81,8) [b]	
Protuberance	1 (0,4)	0 (0,0)	0 (0,0)	0 (0,0)	

‡ p value obtained after the application of the Linear by Linear Association test.

[b] Statistically significant values obtained after Residue Analysis.

Source: Research data (2020).

This association sought to find out if there is any relationship between the defect and the color of the paint used. After the application of the Linear Association by Linear test, it was observed that the p value presented a significant result, that is, there is a relationship between the paint and the defect. With the Residual Analysis, it was possible to obtain the statistically significant values, which are highlighted by the letter [b] . According to the statistical results, the "dimensional" defect is directly related to the use of white paint. This can be explained by the fact that the number of profiles produced in white is significantly greater than the rest of the colors, and the dimensional error also occurs more frequently. The "points" defect is significantly related to bronze, gray, and matte black profiles. In Table 3, we tried to find out if there is any association between the type of profile and the type of defect presented.

Table 3 - Investigation of the types of aluminum profiles and frames associated with defects in extrusion and painting.

Profile	Extrusion and painting defects, n(%)												Value- p‡
	Pullout n = 11	Scratched n = 1	Bubbles n = 7	Low Layer n = 14	Broken Corner n = 6	Orange peel n = 11	Dimensional n = 59	Exceeding Paint n = 11	Skew n = 36	Glued part n = 16	Points n = 110	Protuberance n = 1	
E-5287 (8)	1 (9,1)	0 (0,0)	4 (57,1) b	3 (21,4)	0 (0,0)	0 (0,0)	0 (0,0)	3 (27,3)	8 (22,2) b	2 (12,5)	11 (10,0)	0 (0,0)	0,041
E-7541 (12)	2 (18,2)	0 (0,0)	1 (14,3)	0 (0,0)	0 (0,0)	2 (18,2)	2 (3,4)	1 (9,1)	2 (5,6)	6 (37,5) b	24 (21,8) b	0 (0,0)	
E-7874 (21)	2 (18,2)	0 (0,0)	1 (14,3)	6 (42,9) b	0 (0,0)	0 (0,0)	1 (1,7)	0 (0,0)	6 (16,7) b	0 (0,0)	1 (0,9)	0 (0,0)	
E-8573 (32)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	32 (54,2) b	2 (18,2)	2 (5,6)	0 (0,0)	9 (8,2)	0 (0,0)	
E-9007 (39)	0 (0,0)	1 (100,0) b	0 (0,0)	2 (14,3)	0 (0,0)	3 (27,2) b	0 (0,0)	1 (2,8)	0 (0,0)	1 (6,3)	8 (7,3)	0 (0,0)	
E-9038 (43)	4 (36,4) b	0 (0,0)	0 (0,0)	0 (0,0)	6 (100,0) b	0 (0,0)	2 (3,4)	0 (0,0)	1 (2,8)	0 (0,0)	2 (1,8)	0 (0,0)	
ES-065 (51)	0 (0,0)	0 (0,0)	0 (0,0)	1 (7,1)	0 (0,0)	1 (9,1)	5 (8,5)	1 (2,8)	1 (2,8)	0 (0,0)	11 (10,0)	1 (100,0) b	
ES-097 (64)	1 (9,1)	0 (0,0)	1 (14,3)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	8 (22,2)	8 (22,2) b	7 (43,8) b	5 (4,5)	0 (0,0)	
ES-396 (107)	0 (0,0)	0 (0,0)	0 (0,0)	2 (14,3)	0 (0,0)	0 (0,0)	2 (3,4)	2 (18,2)	2 (5,6)	0 (0,0)	9 (8,2)	0 (0,0)	
ES-665 (129)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	2 (18,2)	15 (25,4) b	0 (0,0)	2 (5,6)	0 (0,0)	0 (0,0)	0 (0,0)	
ES-675 (135)	1 (9,1)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	3 (27,3)	0 (0,0)	0 (0,0)	3 (8,3)	0 (0,0)	11 (10,0)	0 (0,0)	
ES-704 (141)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	0 (0,0)	1 (2,8)	0 (0,0)	19 (19,3) b	0 (0,0)	

‡ p value obtained after the application of the Linear by Linear Association test.
b Statistically significant values obtained after Residue Analysis.

Source: Research data (2020).

In the results of the statistical analysis, it was observed that profile 43, which showed a greater tendency to generate scrap in Table 1, is directly related to the defect of 'pullout', and 'sharp corner', and this does not happen by chance. It is also possible to observe that profiles 32 and 129 are directly linked to the "dimensional" defect, and profiles 12 and 141, are related to the "points" defect.

After analyzing all the results from the Pareto Diagram and the statistical tests, a 5W2H action plan, illustrated in Table 6, was elaborated.

Table 6 - Action plan 5W2H.

What?	Who?	Where?	When?	Why?	How?	How much?
Identify tools (dies) that have flaws or wear	Tooling	Extrusion	Immediate	Because the dimensional and pullout errors are directly linked to the profile tool	Evaluating the tools of the profiles that presented the greatest amount of scrap	No additional costs
Perform maintenance or replaceme	Tooling	Extrusion	Aug to Oct. 2020	To avoid the generation of scrap due to defects related	Performing maintenance or replacing tools that have faults	R$ 5,000.00 per tool

nt of faulty arrays				to the lack of maintenance of the profile tool	that may cause defects in the profiles	
Trainings	Leaders and charge	Extrusion and Painting	Annually	To contribute to the increase in productivity and the good individual performance of employees	Conducting training with operators on the proper use of machines and equipment, reinforcing the procedures of each activity	No additional costs
Meeting with employees	Leaders and charge	Extrusion	Immediate	To make employees aware of the importance of quality inspection in reducing rework	Holding a meeting with the employees of the Set Up process, explaining the importance of identifying failed products before continuing the production process	No additional costs
Cleaning of the entire production area	General Services	Extrusion and Painting	Immediate	To avoid contamination of the profiles by means of dirt particles	Regularly cleaning machines and the production environment	No additional costs

Source: Authors (2020).

The action plan presents suggestions for improvements that can be easily made by the company in order to prevent and reduce the occurrence of the main defects identified in this study.

4. Conclusion

The bibliographic research carried out and the study carried out in the company highlighted in this article, showed that quality management is essential in the search for improvement and optimization of the production process. The detailed analysis of productive data and the application of quality tools can positively interfere in the identification of non-conformities and in the definition of methods that seek to solve problems.

The study carried out proved to be satisfactory, since the objectives of the article were achieved, being able to effectively identify and classify, with the use of quality tools, the non-conformities occurring in the extrusion and painting processes of aluminum profiles.

The use of the IBM *Statistical Package for the Social Sciences* (SPSS) software proved to be fundamental in identifying the root causes of the main non-conformities, showing that there is a direct relationship between the types of profiles produced, their colors, the type of defect and the amount of scrap generated.

With the results obtained through the use of quality tools and statistical analyzes carried out, it was also possible to develop a viable action plan for the solution of the main problems identified within the studied processes.

It was concluded that, when used correctly, quality tools can help in a practical and efficient way in the identification and solution of problems within a given production process. The tools are easy to apply and enable better management of the process, contributing to the decision of the best path to be followed to obtain continuous improvement.

It is suggested for future work to implement and monitor the improvements proposed in this article. In addition, the results obtained through statistical analysis associating the types of profiles with the types of defects can be analyzed and studied in greater depth, and serve as the basis for a new study focused strictly on a specific profile.

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