Quality Management Directing The Way To Defect Reduction And Production Improvement

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Abstract

With growing competition for markets in the various production sectors, both in Brazil are looking for improvements in the world, as well as improvements that can improve their productivity and reduce production costs and quality services. For this, among other strategic actions, continuous improvement can be sought as a means to remain competitive. In this context, the present work case, developed as a work study, has as its central objective the reduction of refuges generated by deficiencies in the production process in a metallurgical company that manufactures ductile iron pipes, among other products. From the application of the method and quality tools used, it was possible to identify the main causes of scrap, favoring its reduction through process improvements. With the identification and analysis of problems related to the training of manpower, lack of compliance with material specifications, inadequate or unfulfilled methods of production and making adjustments to machines used in production processes, it was possible to reduce the occurrence of defects in cast iron pipes, when compared to the amount of scrap counted before and after the changes implemented. The results achieved showed significant gains for the company by reducing the amount of scrap and rework generated during the production process. The reduction in the occurrence of defects favored a reduction of costs, contributing for the company to become more competitive.

Keywords
MASP, Metallurgy, Quality, Scrap, Production cost.

1. Introduction
In the metallurgy sector, organizations seek ways to survive and remain competitive as a result of the current fierce competition for consumer markets. Under these conditions, companies in the sector have been seeking to produce with increasing cost reduction as a strategy to make their products more accessible by reducing prices to consumers (Brimacombe, 1989; Delange et al. 2005; Garbacz-Klempka et al. 2017).

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One of the ways to reduce production costs is to avoid or reduce waste and solid waste that negatively impact the environment (Araujo et al. 2021). In metallurgy, one of the most frequent wastes, known as scrap, is associated with material discarded due to process problems or inadequate quality of the manufactured products. Scrap in metallurgy can generate production losses that impact company costs, especially when the quality of products does not meet customer needs because they do not comply with consumer requirements (Li et al. 2020; Petrov et al. 2016; Vekovshinina et al. 2018).

In this context, the identification and analysis of production problems that cause scrap, as well as the verification of the criticality of these problems, can contribute to the proposition of solutions or reduction of losses associated with the quantity and/or extent of scrapped products and, as a consequence, the reduction of production costs for companies in the sector (Komárek et al., 2008; Sales et al. 2022; Tsakiridis et al. 2008).

In a metallurgical industry, object of the present study, considering the production line of one of its industrial units, there are goals established for the reduction of production costs, as well as the increase of the quality of its products commercialized by the company in the Brazilian market Based on cost reduction targets, initiatives were carried out in the company as a means of achieving the outlined objectives. One of these initiatives sought to identify and analyze occurrences related to the generation of scrap from defective products or products with poor quality in the company. Such occurrences have generated additional production costs, reducing the company's competitiveness in relation to its competitors. Among the possible production problems that generate scrap, the appearance of slag and other metallic and non-metallic inclusions in the product was identified in one of the company's products (ductile cast iron metal tube). This problem, generated in production and classified in the company as an "A30" defect, depending on the extent and quantity of inclusions presented in these elements, often led to the failure of tubes when submitted to the company's quality control processes.

As a result, the tubes produced with this type of defect were unusable for commercialization by the company due to the economic or technical infeasibility of possible reworks. In this process, the tubes discarded for commercialization were scrapped and the material reused at the beginning of the production chain only as scrap to correct the chemical properties of the next tubes to be manufactured. In order to reduce losses, the company sought to reduce the waste of component materials of the manufactured ductile iron pipe (A30 defect), characterized by metallic and non-metallic inclusions contained in the pipe body. Under these conditions, the manufactured tube became more fragile and often did not pass the hydrostatic tests performed as one of the product's quality controls. Product scrap and loss of added value are sources of significant additional production costs for the company. In this way, the company began to seek a reduction in the level and quantity of defects so that fewer tubes were scrapped. Thus, less material and added value would be lost and, consequently, less production costs the company would have, making the product more reliable and the company more competitive. The main objective of this work is to analyze and improve the organization's process through adjustments in its production process in order to reduce the occurrence of the type of defect classified as "A30" (leaking scrap by inclusion in the metallic structure of the slag tube and other metallic and non-metallic inclusions inside) and, as a consequence, the elimination or reduction of additional production costs.

In order to reach the general objective described above, the following specific objectives were established: The present work was carried out in a large metallurgical company, considering its number of employees, which, among other industrial units, has one of its facilities located in the southeastern region of Brazil. The company currently produces ductile cast iron pipes, fittings, valves and plugs, to be used in civil construction, industries in different sectors, mining and sanitation. As these are varied products, the company's production takes place alternately, that is, depending on demand and according to the production mix. The company has, in its factory, different production lines due to the differentiation of each stage of the manufacturing process, such as centrifugation, modeling and casting. The production process begins with the arrival of iron ore in the blast furnace. This is transformed into pig iron and sent to an electric furnace in order to correct the chemical and physical properties of the metal produced and ensure that they are within specifications.

2. Literature Review

Currently, the dissemination and application of computational methods and algorithms to solve or reduce production problems is a common practice in companies or institutions of the most diverse economic segments. In the manufacturing scenario, there are different ways or methods of identifying and treating quality problems or non-conformities in products, processes and systems. However, it is significant that a portion of these is based on the use of the PDCA cycle, or variants thereof, as a means of controlling and promoting continuous improvement (Yan Chen & Li, 2019; Nsafon et al. 2020; Sampaio et al. 2022; Silva et al. 2021).

Control is essential for the objective of the PDCA to be achieved. This objective is characterized by the presence of reliability in the results and the effectiveness of the company's processes. PDCA is a simple and effective method for controlling and improving processes of any kind. For its execution to be the best possible, the organization's employees, involved in the processes, must have mastery of the method (Yihong Chen et al., 2020; Liu et al., 2019; Sunadi et al. 2020).

The nature of the PDCA cycle is based on the outputs of a process that serve as inputs for the subsequent process, thus creating a flow of information for decision making on analyzes regarding the quality of the processes. PDCA is a system that aims at continuous improvement and has the purpose of achieving a goal or achieving increasingly better performance scenarios. of business systems". The method is applied in specific order, starting with P (Plan): plan; D (Do): do or execute; C (Chek): check or verify and A (Action): in the sense of acting correctly. Within each of the steps described above, a series of actions must be taken to analyze the problem. The PDCA cycle, applied to the study and analysis of problem solving, uses in each of its stages a set of tools that, once applied correctly and in the proper sequence, can help achieve the objectives of the method. Known as quality tools, these favor the identification and prioritization of the most relevant problems to be tackled first, as well as the analysis of possible causes, their correlation with other elements and their control (Kong et al. 2021; Sari et al. 2019; Suriadi et al., 2019). Table 1 describes the quality tools most used in each of the PDCA stages.

Table 1. Recommended Quality Tools in the PDCA Steps. Source: Adapted from Kong et al. (2021), Sari et al. (2019) and Suriadi et al. (2019).

Quality tools	P	D	C	A
Data Collection	X	X	X	
Flowchart	X			X
Pareto Diagram	X			X
Ishikawa Diagram	X	X		
Correlation Graph	X			
Histogram	X	X		
Control Charts	X	X	X	

The PDCA method, originally created in the 1930s by the American Walter Shewhart as a cycle of only three stages, was disseminated in Japan by William Edwards Deming, an American statistician and university professor, around 1950. Recognizing the relevance of the method and its applicability, the Japanese adapted the Shewhart cycle to a four-step cycle and created the PDCA which, in Japan, was called the Deming cycle. However, with a concern for the development of learning among supervisors, engineers and workers, the Japanese created a script for the documentation and presentation of the history of the work to improve the application of the PDCA, called the QC-Story method (Koskela et al. 2019; Montgomery & Borror 2017; Waychal et al. 2011).

3. Methods

The company, the object of this study, is a large multinational in the metallurgical industrial sector known for producing ductile iron pipes, among other products, for the Brazilian and international markets. The study was developed when the company, under pressure from market conditions, was seeking opportunities to reduce costs and improve the quality of its products by improving its production processes. The ductile iron pipe was the product chosen for the development of this work because it is the main item commercialized by the company, responsible for most of its revenues, as well as representing the highest production costs among other types of products manufactured in one of its industrial units. The production process of the pipes begins with the arrival of the iron ore, which needs to be within the specifications stipulated by the company in order to adequately meet the needs of the production process. The iron ore is then directed to the blast furnace, with the objective of reducing the oxides contained in its minerals, using charcoal as a reducing element.

After the iron ore is submitted to temperatures above 1000°C, pig iron is obtained as a result. It is composed of specific percentages of carbon, silicon, phosphorus and manganese, as well as impurities called slag. The presence of certain levels of slag in the metal structure (molten iron), as well as inadequate percentages of chemical elements present in the process, can alter the mechanical and chemical properties of the manufactured products. Subsequently, the pig iron or just pig iron is sent to the electric furnace, where the metal temperature and the physical-chemical properties must meet the specifications of the centrifugal machines that will manufacture the cast iron pipes. Therefore, when there is some divergence between the specifications and the material, it must be corrected in the electric furnace, maintaining the percentages of carbon, silicon, phosphorus and manganese required by the centrifugal machine, where this raw material is transformed in the first stage of the product. In the machine, the pig iron is centrifuged, forming the tube that passes through a visual inspection and is sent to the annealing furnace.

The annealing furnace plays a key role in the manufacturing process of ductile iron pipes because it is where the heat treatment takes place, where internal stresses are reduced, wear resistance is increased, ductility is improved, among other desired benefits. After this stage, the pipe goes to the hydrostatic test in which the resistance is verified and if there is any leakage in the pipe. This process happens by filling the pipe with pressurized liquid. Following the manufacturing process, the pipe is sent to the finishing sector, where it is sanded and painted, getting its internal and external coating, and sent to the yard, waiting to be sent to the customer. In order to conduct a study that could bring satisfactory benefits to the company, it was sought, initially, to know and prioritize the most relevant defects of the product. To this end, data was collected over a period of six months of the company's production. The data was obtained through shift changeover forms filled out by the area supervisors.

This form, filled out at the end of each work shift, contains the description and the quantity of defects found in the product during that period. The form is composed by its index, date in which the defect was identified, work shift, supervisor's name, defect type (each defect has a specific name), defect location (in which area of the product the defect was found), amount of defect found, description of what was found and what may have occurred and immediate action taken. Using an Excel spreadsheet, the data obtained in the defined interval was stratified, according to defect classification, with the objective of prioritizing, through a Pareto Diagram, the defects that had the highest occurrence in the process and, consequently, should be studied.

It is already known from the previous step that the problem consists in the generation of a significant amount of scrap during the manufacturing of ductile iron pipes by the company. In the Problem Observation stage, historical production data was stratified in order to understand the types of defects involved in the generation of scrap, as well as the most affected locations or regions of the product, the production processes involved, and also the work shift where the problem occurred the most. All this analysis could indicate a safer way to solve the problem. The team involved in the project visited the field and made an observation at the workstations to identify if the employees involved in the processes were performing their activities according to the standards and training carried out by the company. In addition, in order to deepen the information needed for the problem analysis, interviews were conducted with employees involved in the production processes, in order to better understand how each production step worked and the possible failures throughout the process. This allowed a more comprehensive view of the production process and the proposal of solutions not previously visualized.

For the interviews, we selected, as far as possible, more experienced employees, with more time in the company and directly involved in the processes. These interviews were carried out by means of recordings and the following questions were applied in a common manner: How are the operations in your work area carried out?; What is your experience in this function?; Do you use the standardized instructions to consult possible doubts on how the activities should be carried out and how the work environment should be?; What is your view on the production problems that generate so many scrap in this company product (ductile iron pipe)?; How do you report or report the quality problems in the product from the production process carried out by you or received (to be carried out)?; and What would you indicate to minimize or solve this scrap problem?

From the observation stage, having gathered more detailed and comprehensive information about the product and its production process, we reach the phase in which it would already be possible to start analyzing what could be causing the defect and, consequently, the scrap parts. For this, the application of the 5 Whys tool is a useful step to avoid spending unnecessary resources and additional time on partial or superficial causes that do not solve or eliminate the problem in its root cause. So for each cause identified, the question was "why does this problem occur? Until it was discovered what was really causing the problem.

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To facilitate the analysis and broaden the visualization of the possible causes of the problem, the Ishikawa Diagram was used, with the stratification of categories, to assign each related cause an "M" corresponding to: Method, Machine, Material, Labor, Measurement and Environment; as seen in the Bibliographic Review of the present work.
Once the true causes of the problem are established, it is possible to draw up an Action Plan aimed at reducing or eliminating these causes. For this, the 5W2H tool is commonly used, facilitating the detailing of the Action Plan and thus avoiding misunderstandings or lack of understanding by those involved or responsible for the development or execution of activities or processes. This reduces the loss of time and the lack of understanding of what will be done, when it will be done, and who will be responsible, increasing productivity in solving the problem. The Action Plan, prepared with the help of Excel software, was built as countermeasures to the causes identified for the problem, with the sequence of questions and information. At this stage, the defined actions were monitored on a weekly basis, along with the scheduling of meetings to share the results of the actions, difficulties and other relevant information.

4. Results and Discussion

Considering the types of scrap or defects that can affect the same product, we initially sought to identify the one or those that most impacted the company's financial results and its relationship with its customers. Thus, through an analysis using the Pareto Diagram, the problem classified as A30 was identified as the second most relevant, and the one that would be chosen because there was already another ongoing project to solve the main problem in the company classified as A29. Defect A30 was responsible for 40% of the scrap in the whole plant, and the imposed objective was to reduce this percentage as much as possible. This would reduce the percentage of factory scrap and, as a consequence, reduce production costs. After identifying and defining the problem, in this case defect A30, we started to observe its characteristics with a still generalist vision.

As a starting point, for the observation and analysis of the problem, a form was filled out to classify and characterize the product according to its production conformity or nonconformity. The form, a company document, contained information about traceability, the type of defect, the date and time of the problem detection, among other useful information. Once the form had been filled out, it was passed to the supervisor in charge of the area who, after checking the information contained in it, directed it to be entered into the company's computerized system, thus favoring its proper monitoring by the employees involved in the processes.

This information contributed to clarify doubts about how and where the defect was occurring, as well as help in understanding how the solution to the problem could be achieved. In addition, the interviews with employees clarified the team's vision, helping to understand the process more deeply. From the observation, data analysis, and interviews, it became evident the constancy and relevance of defect A30, as well as the phase in which it occurred more frequently, causing the scrap of the manufactured tubes and a considerable loss to the company. With this information and more clarity about the defect, we proceeded to the analysis of the causes of the problem.

The result obtained was used for a parameterization relating the causes of the problem with each of the M's of the Ishikawa Diagram. This allowed the understanding of where each cause fit in relation to the 6M's categories, facilitating the definition and prevention/correction actions. After the analysis of the causes of the problem in the previous step, where the relation between cause and effect was understood in detail, it was possible to develop an action plan aiming at a solution or reduction of the scrap problem classified as A30. For this, the 5W1H tool was used, the action plan sought to detail what would be done, why, how, where, when, and the responsibility of the pilot of each action. This was important so that all areas had complete information about what would be done to solve or minimize the problem. In the execution stage of the action plan, we sought the fulfillment of all the planned actions, as well as the follow-up of the results, so that the difficulties encountered could be addressed and, in the end, all the actions carried out. The follow-up was done using the Excel tool, as illustrated in Figure 1.

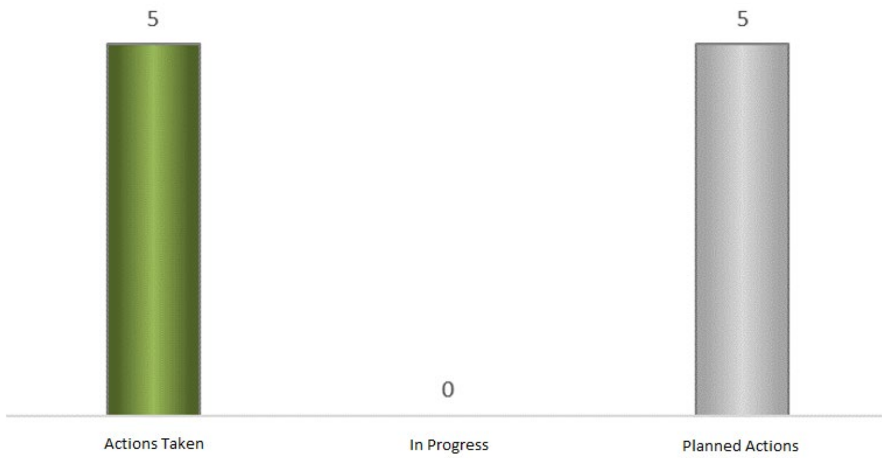

Figure 1. Stages of the PDCA Cycle

After monitoring the results and adjustments to the process, through training of the personnel involved, an improvement in the reduction of A30 scrap was observed. On week 20, the machine ran only one day and for only 5 hours (55% of the programmed hours), due to an equipment shutdown for alignment of the tap changer. On this occasion 220 tubes were produced and 100 tubes were scrapped by A30, which represented 0.45% of production. If the machine had run fully, as scheduled, the expected production would have been 210.6 tons, and the scrap rate would have been 0.25%, below the initial 0.40%.

5. Conclusion

With the objective of contributing to make the company more competitive, it was sought, with the development of this work, the reduction of the scrap index called A30, in ductile iron pipe produced by a metallurgical industry, after analysis and identification that it was the most relevant defect to be studied at that moment. The quantitative survey of the defects in the produced pipes identified the anomalies in the period of three months of production. Since the types and quantities of defects found were numerous, we sought to establish the analysis of the most common ones. Thus, of the six defects identified in the produced tubes, defect A30 represented a total of 40% of those defects that caused scrap.

To obtain the solution or reduction of the problem identified with the help of the Pareto Diagram, it was sought to observe and understand the way the process was being performed, as well as if the company's standards were being followed, generating potential causes that, using the 5 Whys tool associated with the Ishikawa Diagram, it was possible to reach the root causes. The identified causes were grouped into 6 categories (Labor, Material, Method, Machine, Measurement, and Environment) in the Ishikawa Diagram as a way to facilitate the analysis and its understanding. In function of the results obtained, it was observed that the most incident causes of the identified defect were caused by Method (33%) and Labor (25%) problems.

Thus, based on the results of this study, the company was able to elaborate countermeasures to try to nullify the causes of the problems, as well as establish plans and goals and apply training to understand how the company's standards should be interpreted to guarantee that they are followed, with the objective of reducing the scrap rate resulting from defect A30, which before the beginning of the work was 40% of all problems or defects incident on the product. After the implementation of the MASP project, the scrap rate dropped from 40% to 28%, representing a reduction of 30% of the scrap caused by defect A30. This 12% saving in scrap ratifies an average saving of 3 thousand tons of cast iron per month, representing an annualized gain of more than 100 thousand Reais.

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