

Increased Reliability and Anode Quality by Using Statistical Process Control Tool at Paste Plant

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Abstract

Statistical Process Control is a well-known quality tool within the modern industry and commonly applied in the production processes of aluminum manufacturing plants. This paper presents the tool used for the maintenance strategy, in order to provide information to detect the main unplanned breakdown and bottlenecks of the green anode plant, aiming to guarantee reliable data for root cause analysis, aiding in the overcome of a very unstable condition. The methodology applied is very useful to identify nonstandard behavior and treat it by using root cause analysis as 5 why and Ishikawa diagram. Unplanned breakdowns at Paste Plant have a direct impact on the control of the process parameters and consequently on the paste and anode quality, the reduction of the interferent stops increase the number of preventive maintenance for the critical equipment to guarantee better results in the anodes properties, mainly green anode density. This paper aims to present the positive results that can be achieved using statistical process control tools as well as the good synergy between the operation, maintenance and process teams.

Keywords: Statistical process control, pareto, unplanned breakdown, anode quality, root cause analysis.

1. Introduction

Statistical Process Control (SPC) was a quantitative quality tool developed by Walter A. Shewart to improve the process of any plant. Today SPC is a tool which every company need to have and uses on its routines to have an advantage on today's competitive market.

Statistical process control arises to aid in the engineering area to help make decisions under uncertainty. This happen because our world has so much variables, creating random variations in our engineering decisions. Furthermore, statistics helps us to make good decisions and avoid mistakes. Thus, when we talk about quality, to predict and remove failures, the use of statistical tools is very critical, because most deficiencies arise as the result of random variation [1].

According to the Handbook of Quality Engineer, a process is composed of a certain repetitive sequence of events that can lead to a tangible or intangible result. Due to its repetitive nature the process can be mapped and controlled through the SPC methodology, which uses statistical tools, to assist in the localization, resolution and prescription of problems [2].

Every process has variability and its sources can be classified in special and common events. The cause of common variability is inherent to the process by its characteristics, and that it is not controlled by the operators, for instance the variations of the environment, the plant and raw

materials. Special causes of variations include unusual events, which when detected, are usually removed or adjusted.

A critical point of process management is the separation of common and special causes. Like when an operator has to do corrections in the process due to common causes, the result is much larger variations than if no action had been taken. This is called super-adjustment or super-control. However, when an operator does not treat a special cause, there is a large variation in the process. This is named as a sub adjustment or sub control. For these reasons, control worksheets are vitally important to help operators recognize the presence of special causes to take appropriate action.

Other critical point about SPC is that you can have all historic events about your process, and make critical analysis, measure performance, improvements, variations and correlate with the plant maintenance. It is the base in data collected by the operator or an automated system, to build control charts, which is easy to read and to interpret. By using the SPC, the engineer can start to see behaviors on the process, also take the necessary actions before the problem arises or start a critical failure analysis on the process. Data processing, root causes analysis, and all other activities supported by statistical process control can help to promote a synergy between areas (operation, maintenance, quality and process) with the focus on continuous process improvement. [2].

2. Methodology

As a maintenance strategy, the SPC was used to measure and analyze the behavior of the equipment in the Anode Plant. One of the main reason to use SPC is that it helps to identify nonstandard behavior of the equipment (trends, problems) and treat it. The SPC methodology is based on a control chart that allows the machine to talk to us as it is shown in the Figure 1.

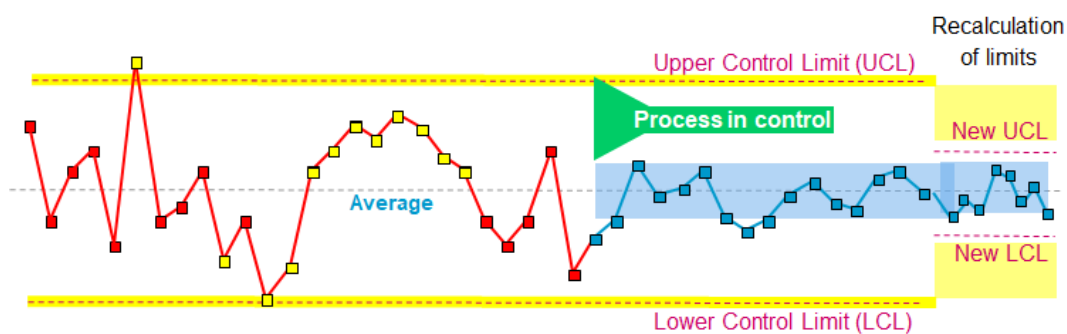


Figure 1. SPC control chart

As a control chart, the SPC has the Upper Control Limit (UCL) or under Lower Control Limit (LCL) that are the limit acceptable for the process [3]. Each point over the limit must have a Root Cause Analysis to figure out what happened. Three points closed to the limit or eight consecutive points over or below the average must have a root cause analyses as well.

When the process has eight consecutive points close to the average, it means that the process is getting stable and it is possible to observe a process change. Each process change must have a new UCL and LCL until the maintenance process achieve the target [4].

The SPC methodology is based on five steps: define the standard of the data base, measure the data, analyze it, improve process, check and control to keep it on control [5].

2.1. Define the Standard of the Database

The first step of the methodology is to define the standard of information that is needed to measure and analyze production stoppages. Anode’s Plant has a panel operator dedicated in the control room and he had information about the stops of production. Looking for standardization, it was created a shift report with all the information needed to manage the plant and to use in SPC methodology as it is possible to see in Figure 2.

Stop Time Control System									
Date	Hour	Level 1 (Maintenance / Operational)	Level 2 (Planned/ Unplanned)	Level 3 (Equipment)	Level 4 (Subset)	Level 5 (Mechanical / electrical)	Loss Time [min]	Comments	Week
02.dec	22:09	Maintenance	Unplanned	Ball Mill	Motor	Electrical	1431	Motor k-13 (burned)	49
03.dec	22:00	Maintenance	Unplanned	Conveyors	Power Circuit	Electrical	29	Overload k-3.	49
03.dec	00:57	Maintenance	Unplanned	Vibrocompactor	Control System	Mechanical	38	Incorrect deviation of the L-34 tar valve.	49

Figure 2. Example of database

Basically, information about the date and hour of the stoppage were collected; if it was a maintenance, operation or process problem as well as a planned or unplanned stop. The next information is related to the equipment, subset and type of the problem. The duration of the problem is reported, and it is one of the most important information because the SPC depends on the duration of the stop. Finally, the report informs if the plant had a stop of production, what was the shift in which it happened and some additional comments.

2.2. Measuring the Data Reported

All the planned and unplanned stops in the area must be reported. Even 5 or 10 minutes will be important in the final result and people that are responsible to report it have to know that. All the data reported were measured and treated, grouping the information according to the Figure 3.

Week	Weekly breakdown %	Average of eight weeks	UCL	LCL	R - Range	\bar{R}_m - Average of seven ranges	Target
9	4,6 %	4,75%	13,00%	-3,49%		3,1%	5,00%
10	7,4 %	4,75%	13,00%	-3,49%	2,8%	3,1%	5,00%
11	9,5 %	4,75%	13,00%	-3,49%	2,1%	3,1%	5,00%
12	3,8 %	4,75%	13,00%	-3,49%	5,7%	3,1%	5,00%
13	2,8 %	4,75%	13,00%	-3,49%	1,0%	3,1%	5,00%
14	6,9 %	4,75%	13,00%	-3,49%	4,1%	3,10%	5,00%
15	2,1 %	2,13%	7,02%	-2,75%	4,9%	1,8%	4,00%
16	0,9 %	2,13%	7,02%	-2,75%	1,1%	1,8%	4,00%
17	3,2 %	2,13%	7,02%	-2,75%	2,3%	1,8%	4,00%
18	4,2 %	2,13%	7,02%	-2,75%	1,0%	1,8%	4,00%
19	0,9 %	2,13%	7,02%	-2,75%	3,3%	1,8%	4,00%
20	2,7 %	2,13%	7,02%	-2,75%	1,8%	1,8%	4,00%
21	2,2 %	2,13%	7,02%	-2,75%	1,9%	1,8%	4,00%
22	0,8 %	2,13%	7,02%	-2,75%	1,4%	1,8%	4,00%
23	2,7 %	2,13%	7,02%	-2,75%	1,8%	1,8%	4,00%
24	2,0 %	2,13%	7,02%	-2,75%	0,6%	1,8%	4,00%
25	4,8 %	2,13%	7,02%	-2,75%	2,7%	1,8%	4,00%
26	6,1 %	2,13%	7,02%	-2,75%	1,4%	1,8%	4,00%
27	14,3 %	2,13%	7,02%	-2,75%	8,2%	1,8%	4,00%

Figure 3. Standard of database for SPC

The week are based on the date of the problem. The Weekly breakdown % is the sum of all the stop production in a week that is related to unplanned breakdowns caused by the maintenance. The Average of eight weeks was calculated based on the eight first results, based on SPC methodology. Then, the SPC will have the R – Range and \bar{R}_m according to equation (1) and (2):

ek) (1)

$$\bar{R}_m = \text{Average of seven } R \tag{2}$$

The \bar{R}_m is the average of seven ranges because the first range happened in the second week and it is related to the eight first weeks.

Finally, it is possible to calculate the upper control limit (UCL) and lower control limit (LCL), based on the equation (3) and (4), respectively:

$$UCL = \bar{X} + E_2 \bar{R}_m \tag{3}$$

$$LCL = \bar{X} - E_2 \bar{R}_m \tag{4}$$

\bar{X} Average of eight weeks

\bar{R}_m Average of seven ranges

E_2 It is a constant based on the limits calculation. For sample equal to two and mobile range and X individual chart, it is 2,66 [3].

2.3. Analyzing the Database

Based on the results of Figure 3, it is possible to create the SPC chart, shown in the Figure 4.

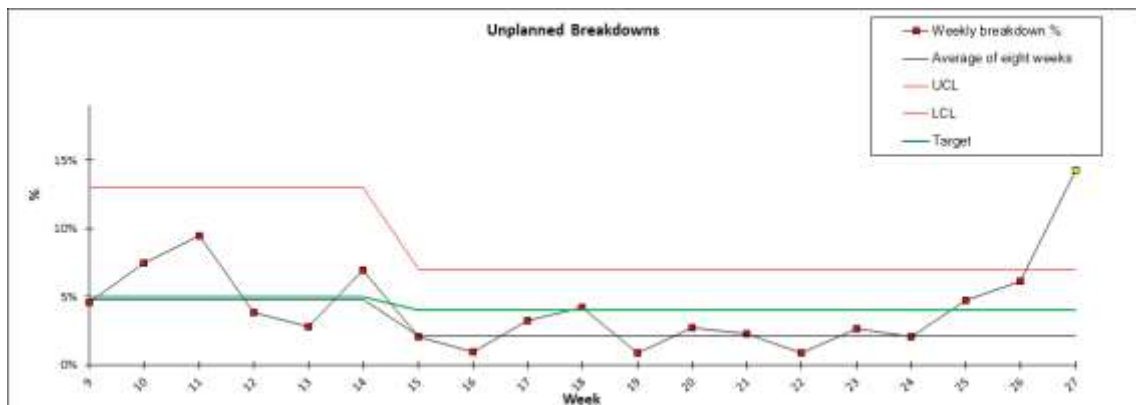


Figure 4. Unplanned breakdown SPC

In Figure 4 there is a recalculation of limits in the week 15. This week is the first of eight weeks that the stop of production was below average. It shows that the percentage of unplanned breakdowns has decreased, and the process is getting stable. For this reason, it is necessary to recalculate the control limits looking for improvements until it reaches the target.

In the other hand, in the week 27, it had a point outside the control limit and it was necessary to do a root cause analyze to figure out what happened in that week. In the Anode Plant, we also work with Pareto's to analyze what is the equipment that has the most unplanned breakdowns as it is possible to see in the Figure 5.

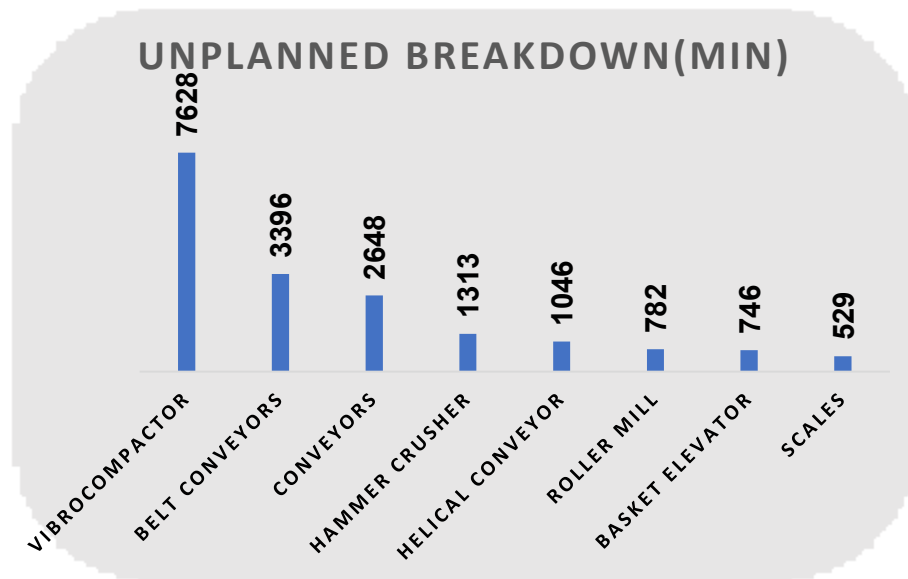


Figure 5. Unplanned breakdown Pareto

Pareto analysis as used to show what was the most critical equipment and after that, we created another Pareto to show what is the subset of this equipment that has more impact in the unplanned breakdowns. The subset that have more unplanned breakdown is the first one to work in order to achieve the necessary improvements.

2.4. Improvements in the Equipment

The result of the Pareto analysis will indicate the necessary improvement that need to be done on each equipment. The improvements could be a procedure review, a new training for employees, a new way to measure the equipment or, sometimes, the necessity to change the equipment. Most of the energy must be concentrate in the equipment that has more unplanned breakdowns.

2.5. Check and Control the Improvements

The last step of the methodology is to check and control all the improvements that were made in the plant and equipment. The SPC should be used to show if the process is getting stable and the Pareto will show which equipment is the most critical. The combination of these results will allow the machine to show what its main problems are and how to prioritize them. Audits in the area are recommended to confirm that the maintenance process is stabilizing.

3. Results

In a short term it is possible to see the reduction of unplanned stoppages in Paste Plant, since this project had focus on continuous improvement. First with the reestablishment of equipments basic conditions, adjustment of preventive maintenance program and low cost operational improvements.

The improvements were developed by maintenance and process critical groups and always focusing on the main bottlenecks identified in the Pareto Charts. Among all improvements implemented, we can highlight the suitability and protection of the control system from the vibrocompactor machine, adjustment of process parameter, development of control charts to follow and treat deviation related to fractions of raw material used in the anode production and the replacement of scales controllers in order to reduce the process variation.

The Figure 6 shows the progress of the maintenance unplanned stops results from Jan/2017 to Feb/2018. The impact represents a reduction of 65% in the unplanned time.



Figure 6. Graphic of Maintenance Unplanned Stops

The stop time reduction has also a fundamental contribution to the reduction of the number of start and stop of production. That is one of the main reasons of scrap generation (pieces and paste out of acceptable quality parameters).

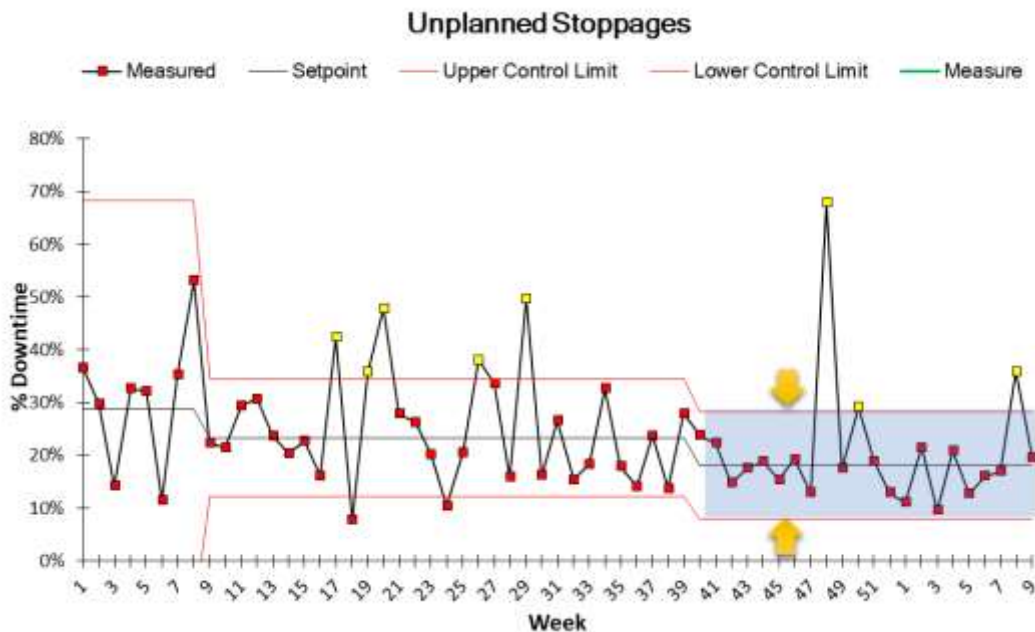


Figure 7. Statistical Process Control Applied to Maintenance

A better plant performance can also be observed in the Figure 7, the Statistical Process Control Chart utilized as base of the continuous improvement in this work. The results show a reduction of 40% in the equipment's performance variation, bringing more stable and predictable behavior to the plant and consequently to the paste plant process.

In a medium term, the best performance reflexes brought impacts in the maintenance cost control. As can be seen in the Figure 8, the cost was under control in the last 4 months of this monitoring.



Figure 8. Graphic of Maintenance Cost

It is important to mention the indirect benefits of this work. To have a systematic way of work creates a routine for the team and define rules and responsibilities for each. This provides a better work environment and engagement of the team. People are the key to have a step change in any industry process and in Paste Plant wasn't different. Advances in commitment, housekeeping and maintenance leading indicators came easily since we had clear team goals based on facts and figures.

For the process, continuous improvement is a fundamental aspect for the good work performance and its learning must be used in the change management [10]. This, served as the basis and mindset for a sustainable construction of the main objective of this work: stability and quality in the green anode production. Both can be seen through the Figure 9, graphic of green anodes inventory, which had a huge recovery capacity along 2017 and achieved a new record of inventory in the last 4 years of operation, and Figure 10, the green anode density, which has as a target 1.650 g/cm³.

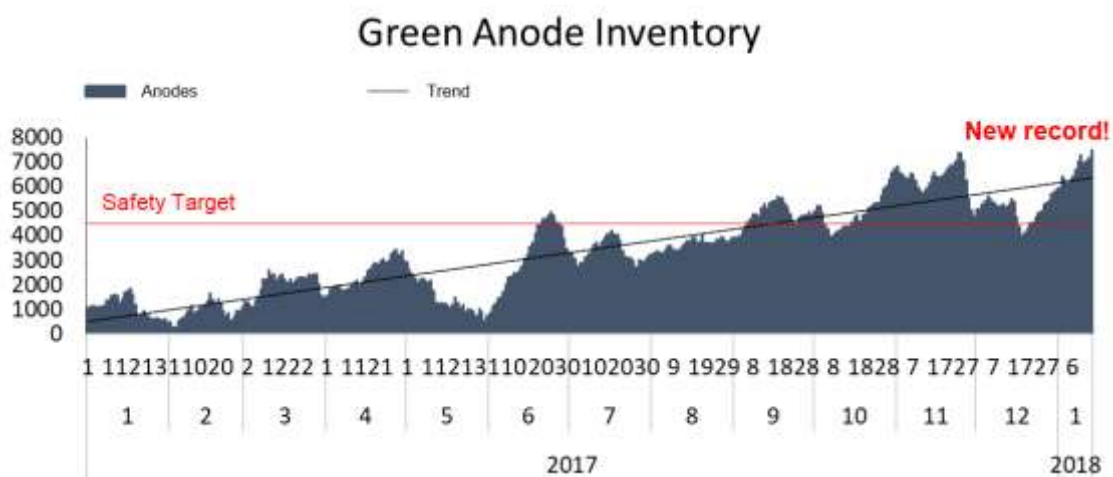


Figure 9. Graphic of Green Anode Inventory

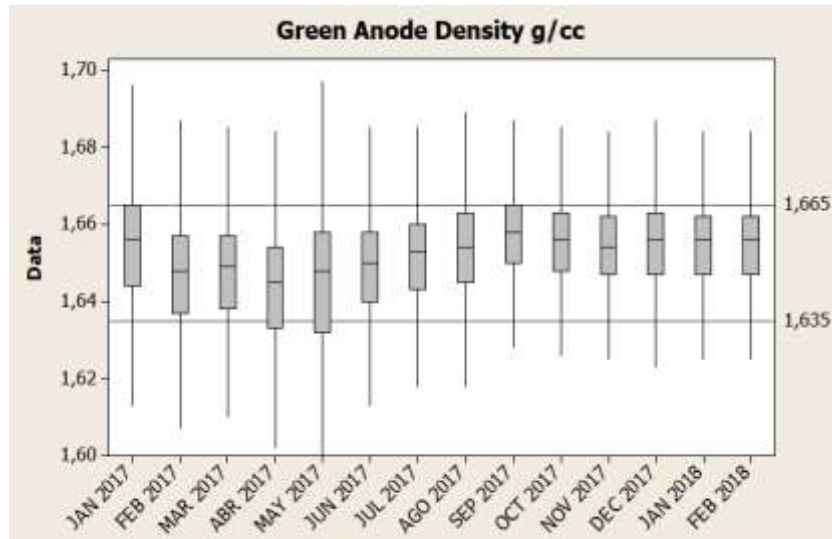


Figure 10. Graphic of Green Anode Density

The new situation made it possible, gradually, to carry out the planned activities needed to maintain the factory, once the number of green anode inventory sustain the overhaul and big maintenance stops as stablish in the plan of production. The firefighting cycle slowly became a progressive and productive cycle with positive feedbacks from the pot lines.

4. Conclusion

The systematic work had a positive impact in all disciplines involved in the anode manufacturing at Paste Plant. The application of this methodology allows us to identify the bottlenecks that most impact the process and lead our efforts to solve the problem, after all this work we could see the positive results begin to appear. It is important to emphasize that it is necessary that the entire plant is united to implement the SPC, gaining the control of the process after its phase of implantation and stabilization, resulting in a greater production, with products within the specification delimited by the control of the process.

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