# REDUCTION OF THE UNPRODUCTIVE TIMES IN THE TANDEM COLD MILL BY OPTIMIZING THE SIDE TRIMMER ADJUSTMENT AND USING THE AUTOMATIC SURFACE INSPECTION SYSTEM*

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**Abstract**

ArcelorMittal's pickling and cold rolling line has been demanded to increase production since the installation of equipments in 2015. In addition to the improvement in productivity related to these new equipment, one of them the automatic surface inspection system (SIAS), work has also been developed in other equipment seeking improvement of production indicators. The present article exposes the actions and gains that were achieved with actions on two equipments in the same section as the Side Trimmer. The first one deals with the optimization of time gains with sequencing adjustments without financial contribution, using only internal labor seeking reduction of unproductive times by adjustments of the side trimmer in the cold strip mill. The second item discussed demonstrates the actions and the gains generated due to the availability of new resources (installation of SIAS equipment), the optimization of these resources seeking a focus on the reduction of ruptures in the tandem cold mill, configuring the same in the aid of the identification of critical defects and also in the automatic speed reduction action of the tandem cold mill in defects considered serious. In both cases the intention was to improve production, seeking to improve the results of the section and the line.

**Keywords:** Bottleneck; preparation of side trimmer for lateral cutting; setup in continuous processes, automatic surface inspection system.

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## 1 INTRODUCTION

The ArcelorMittal Vega Strip and Cold Rolling line, built in 2003 with a capacity of 880,000 tonnes of flat steel per year, comes
receiving constant investments to increase its productive capacity. In 2010 the installed capacity was raised to 1,440,000 tons annually with the installation of the drum shear and second tension reel at the output of the tandem cold mill. As early as March 2015 the fourth acid pickling tank was installed, raising its capacity to 1,600,000 tons per year. However, some additional work was planned in specific equipment, seeking additional results, it was identified that side trimmer equipment figure 2 had a significant impact on the tandem cold mill unproductive time due to adjustments made in the side trimmer, in this way could contribute with the results of the line providing greater productive times (available time).
Another identified item was the unproductive times caused by ruptures in tandem cold mill, due to visible defects on the surface of the strip [1].
To achieve this goal, two work groups were assigned to work with a focus on reducing unproductive time, seeking actions on these two equipment (side trimmer and SIAS). The groups had as attributions the mapping of actions, quantification of their effect on the key indicator and conduction of actions necessary to reach the established goal. This project was born from a need to expand PLTCM production.

## 2 MATERIAL AND METHODS

In order to allow the quantification of the gains of each mapped initiative and the correct management of resources to prioritize the actions ones with the highest results, it was necessary to create priorities and thus define the following KPIs.
Selected KPIs:

- • Unproductive time due adjustments of side trimmer (h);
- • Unproductive time due to rupture (unproductive time (h) / Kton).

PLTCM line specific data:

- • Speed in the pickling process (maximum speed of 200mpm);
- • Side trimmer speed (maximum speed of 230mpm);
- • tandem cold mill inlet speed (limited to 210mpm);

In survey, we identified two key points chosen for the work.

1. Side trimmer: Side trimmer is an equipment with the purpose of adjusting the width of the pickled hot coil to the route request, as well as guarantee trimmed edge quality (free of critical defects). Then with each new order width, the equipment requires the soldering stop (union between the current and the next coil) for various adjustments including new positioning for cutting at the requested new width. These actions of adjustements demand time of stopped section, if realized in high frequency or in high times, affect the next process (tandem cold mill) causing the reduction of the speed of processing.
   The unproductive times caused by side trimmer adjustment have an average impact of 6.45 hours per month due to deceleration of cold strip mill (TCMSlodown / month), this is the sum total of the adjustments without occurrence of side trimmer failure.
2. SIAS: Rupture in the rolling mill has a direct impact in production, due to the instant stoppage of the tandem cold mill, this evaluation was transformed from unproductive hours to unproductive hour rate per thousand tons produced, seeking a KPi more aligned to the demand of utilization of the rolling mill to cold.

In this case the average unproductive rate identified was 0.0402 h / Kton due to ruptures that could be identified by surface inspection systems.

Based on these two impactors, the groups created several actions in the search for reduction as detailed below.

2.1Reduce side trimmer cycle time;
2.2 Reduce unproductive time per strip rupturing in tandem cold mill with Installation and optimization of SIAS use.

**2.1 Reduce side trimmer cycle time.**

The work investigated in the side trimmer evaluated possible shortcomings related to the loss of time during the sequencing of adjustment during the processing of the materials (adjustments detailed in the topics (2.1.1, 2.1.2, 2.1.3 and 2.1.4).
In evaluating these adjustments, we identified waiting time gaps that could be adjusted and optimized, reducing the total equipment cycle time in some equipment setting conditions.

Types of sequences that occur in the side trimmer:

- 2.1.1 - Side trimmer entry in line: Equipment initially in the garage (off line) and the next soldering comes into operation. This was one of the sequences worked and will be detailed in the article.
- 2.1.2 - Side trimmer in operation (cutting): Next coil also with preset of cut, but with preset other than GAP, Overlap or width. That is a more frequent and normal condition for the equipment, however it will not be an item addressed in this article.
- 2.1.3 - Side trimmer output of line: Side trimmer trimming on the current coil, but at the next weld the equipment will be redirected to the garage (off line). This sequence was also worked during the period, aiding in the gains that will later be shown.
- 2.1.4 - Side trimmer still out of operation: Sequence not covered in this article as it only involves the notch sequence.

Note: the distribution of quantity of exchanges by type of adjustment (2.1.1, 2.1.2, 2.1.3 and 2.1.4) showed us that we would work in 20% of total exchanges, 10% Side trimmer entry to cut, and more 10% of side trimmer going out of operation, as shown in figure 1.

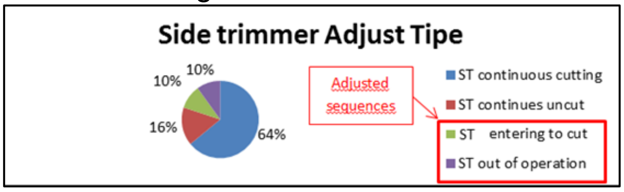


Figure 1: Percentage Distribution for side trimmer adjustment of type.

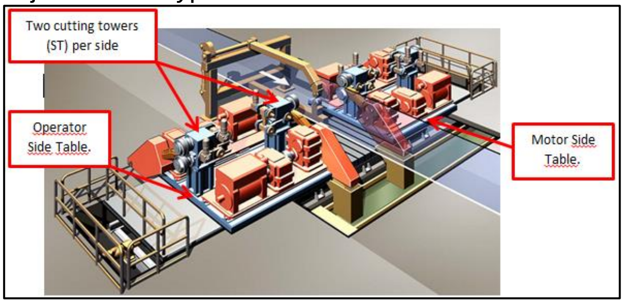


Figure 2: Similar layout of side trimmer with 2 table, 1 for side each, and 2 turrets for each table.

Figure 2 shows a layout similar to that installed in AM Vega, composed of two independent support tables (bases) one each side, one. In each table there are two cutting towers (side trimmer), mounted in opposing positions ones to each other, in a need of exchange of circular knives (inversion), there is a rotation of 180 ° of table, for entry of opposite tower in operation.

2.1.1 Reduce side trimmer input cycle time in operation.
In this case, the side trimmer is the maximum distance from the center line of the line, specifically the 2650mm opening (distance between the towers of the side trimmer on each side) and with the fully

open GAP and OVERLAP settings, equipment.

Original side trimmer input sequencing for entry in operation - 2.1.1:

1. Off-line equipment, weld approaching the side trimmer section;
2. Reduction of welding approach velocity;
3. Weld stop on the notch;
4. ASC-10 Achievement of notch;
5. ASC-11 Weld transfer to the side trimmer;
6. ASC-12 Adjust of width, GAP and OVERLAP (simultaneous);
7. NRSTS - Normal running (start section).

After evaluation of the sequences, the team identified points for improvement by looking for parallel moves including new independent sequence sequencing steps as indicated by the new sequencing indicated below.

**Changed side trimmer input sequencing in operation - item 2.1.1:**

1 Side trimmer off-line, weld approaching the side trimmer section;
   a. ASC-12 anticipated adjustment (item included). At this time the weld is approximately 100 meters away from the side trimmer and approaching, the ASC12 sequence is started already looking for the final values of GAP and Overlap of the next coil to be trimmed, and in parallel adjusts the width as close as possible. This width is preset to 400mm more in relation to the larger width strip ( current coil and the next coil to be trimmed).

2 Reduction of welding approach velocity;

3 Weld stop on the notch;

4 ASC-10 Achievement of notch;

5 ASC-11 Weld transfer to the side trimmer;

6 ASC-12 Width adjustment, GAP and OVERLAP (complementary adjustment, time gain item);
   a. At this point the side trimmer is already set with the desired GAP and Overlap values, only the final width adjustment is missing, which is much closer than in the original condition, considerably reducing the total adjustment time according to the actual example shown in Figures 3 and 4 .NRSTS – Normal running.

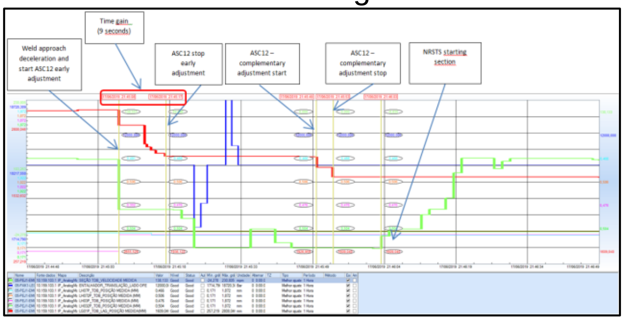


Figure 3: Side trim chart showing the anticipation of the ASC12 sequence generating a total 9 second cycle time reduction for this event.

Table 1. table of colors and signs represented in the previous figure

| | |
|---|---|
| Green (thick line) | Side trimmer speed (mpm) |
| Red (thick line) | Width position of side trimmer (mm) |
| dark blue (thick line) | Notch position (mm) |
| Pink | Side trimmer GAP position (mm) |
| Orange | Side trimmer Overlap position (mm) |

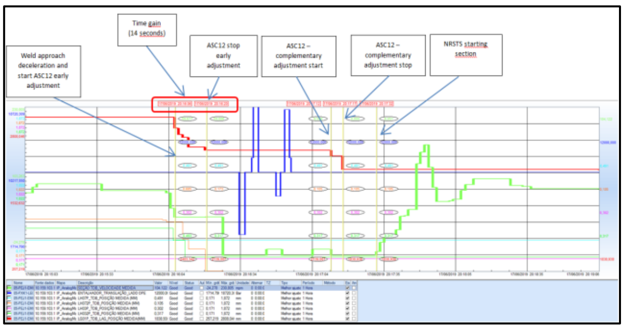


Figure 4: Side trim chart showing the movimentation and anticipation of the ASC12 sequence leading to a reduction of the total cycle time of 14 seconds for this event.

Table 2. table of colors and signs represented in the previous figure

| | |
|---|---|
| Green (thick line) | Side trimmer speed (mpm) |
| Red (thick line) | Width position of side trimmer (mm) |
| dark blue (thick line) | Notch position (mm) |
| Pink | Side trimmer GAP position (mm) |
| Orange | Side trimmer Overlap position (mm) |

This pre-tuning activity reduced the average cycle time for a side-line input in 6.5 seconds.

**2.1.3 Reduce side trimmer adjustment cycle time at operating output:**
**In this case, the side trimmer is in cut and the next weld will be removed from operation.**

Original sequencing for Side trimmer output - item 2.1.3:

1. Equipment cutting edges of the coil current, weld of the next coil approaching the section but without the trimming schedule;
2. Reduction of velocity of section due weld approach;
3. Weld stop on the notch;
4. ASC-10 Achievement of notch;
5. ASC-11 Weld transfer to the side trimmer;
6. ASC-12 Adjust width, GAP and OVERLAP (simultaneous);
7. NRSTS – Normal running.

In the quest for the time cycle gain, we have observed too many waiting times of the sequences, due to the need for sequence completion confirmation of all positions of the side trimmer (GAP, OVERLAP and width) in the original programming. In this way we perform sequence breaks for starting of the section with adjustment sequence still in operation.

**Changed Side trimmer output sequences - item 2.1.3:**

1. Equipment cutting the edges of current coil, the weld of the next coil in approach of section, but without cutting schedule;
2. Reduction of weld approach velocity;
3. Weld stop in notch;
4. ASC-10 Achievement of notch;
5. ASC-11 Weld transfer to side trimmer;
6. ASC-12 Adjust width, GAP and OVERLAP;
7. NRSTS – Normal running (Including sequence adjustment).
   a. In the original condition the NRSTS sequence only started after complete completion of the ASC-12 sequence, then we changed the condition for automatic start of the section following the condition below:
   b. if the opening width of the side trimmer is greater than 400mm than the current coil width, if the response is positive, the NRSTS sequence is automatically thrown.

Note: the ASC-12 sequence continues to run in parallel until it reaches the positioning targets even with the moving section.

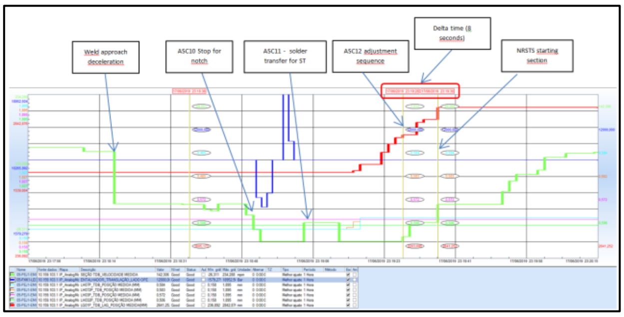


Figure 5: Side trim chart showing the anticipation of the NRSTS start generating a total 8-second cycle time reduction for this event.

Table 3. table of colors and signs represented in the previous figure

| | |
|---|---|
| Green (thick line) | Side trimmer speed (mpm) |
| Red (thick line) | Width position of side trimmer (mm) |
| dark blue (thick line) | Notch position (mm) |
| Pink | Side trimmer GAP position (mm) |
| Orange | Side trimmer Overlap position (mm) |

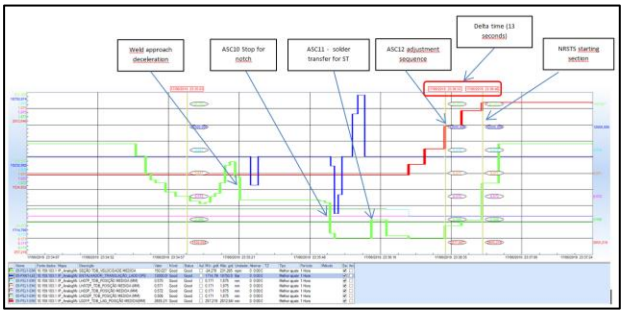


Figure 6: Side trimmer move chart for the anticipation of the NRSTS start generating a total time reduction of 13 seconds for this event.

* Technical contribution to the 11th International Rolling Conference, part of the ABM Week 2019, October 1st-3rd, 2019, São Paulo, SP, Brazil.

Table 4. table of colors and signs represented in the previous figure

| | |
|---|---|
| Green (thick line) | Side trimmer speed (mpm) |
| Red (thick line) | Width position of side trimmer (mm) |
| dark blue (thick line) | Notch position (mm) |
| Pink | Side trimmer GAP position (mm) |
| Orange | Side trimmer Overlap position (mm) |

This action early departure activity reduces the average cycle time for the side trimmer line output condition in 6.3 seconds average.

The added gains due adjust of sequence in side trimmer section inlet and outlet sequences resulted in a significant reduction of the unproductive times, as shown in figure 7.

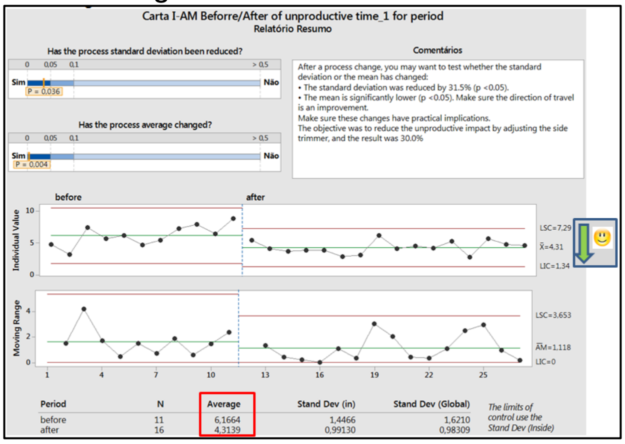


Figure 7: Chart before after, showing the reduction of unproductive times by adjustment of the side trimmer without occurrence of failures.

We have little variation of adjustments to the side trimmer in and out over the months, as can be seen in figure 8, this result in stability of the gains over time.

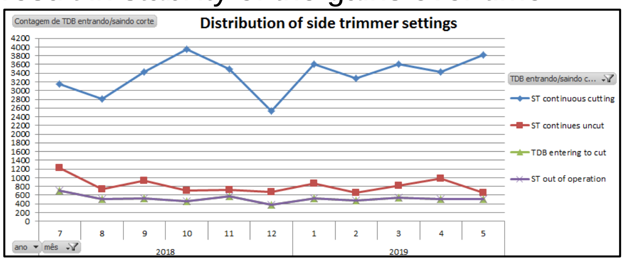


**Figure 8:** distribution chart by type of adjustment of the side trimmer.

## 3 RESULTS AND DISCUSSION

**These side trimmer jobs reduced the cycle time to the in-line side trimmer condition by 6 seconds and the line side trimmer output, on average 6 seconds per cycle, resulting in an average total reduction of 1.85 hours month unproductive times released as flawless side trimmer due adjustment.**

### 2.2 Reduce unproductive time due to strip rupture in tandem cold mill due to surface defects with installation and optimization of SIAS (project 2).

Previous condition, defect inspection was performed only visually by trained operators, based on integral visualization of the guaranteed face (superior), and that of the unsecured (bottom) face being performed on a punctually (sampling ) in inspections with the stopped section following the interval of one inspection every five reels.
The application of SIAS aims at the automatic inspection of both faces in 100% of the coils.
The work developed in the SIAS sought to reduce the losses in the process due to ruptures by visible defects in the surface of the material, with this objective, action groups were created in the pursuit of actions, in order to maximize the results. The main actions were separated into three phases:

- **2.2.1 –** Installation and learning of SIAS: After installation of the equipment, there was a period of collection and selection of images, for the development of a standard image bank. This phase is continuously evolving according to the database feed. At this moment the return of the equipment was still barely visible.
- **2.2.2 –** Operational training: Phase aimed at the operational learning of the tool, which sought understanding and early indication of defects critical to the cold rolling process.
- 2.2.3 – Automatic actuation at the speed of the tandem cold mill: A phase that aims to make a direct actuation of the speed of the

tandem cold mill process, after SIAS identify critical defects (defects cataloged by the quality team and validate with operation team) to avoid ruptures.

The phases (2.2.1 and 2.2.2) were started in parallel immediately after the installation of the equipment, involving a multidisciplinary team with technical monitoring in the first months after the installation, the team is working alongside the line operators in order to guarantee results after the installation.
The phase 2.2.3 of automatic actuation in the speed of the tandem cold mill, for defects detected by the SIAS and classified as critical, It was a complex operation and although it is implemented, it demands actuation and continuous improvement in the assertiveness.
The action was subdivided into two groups with different demands.
Group 1:
Focus on the classification of critical defects, segregating by type of defect, intensity, transpassive (identified on both sides of the material), etc.

1. Collection and storage of representative images;
2. Selection of images for the SIAS database;
3. Segregation of defects considered critical for the following process according to the examples of the figures of items 9 and 10;

Critical message sending (intensity 5) to the specific SIAS output port, according to figure 11;

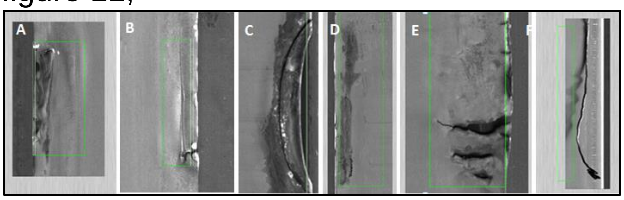


**Figure 9:** Images of critical edge defects (A kneaded handling, B edge crack (ripped), C Bent edge, D scab, E scab, E attached edge).


**Figure 10:** Images of critical surface defects (A transport abrasion, B scab, C Cross bending, D Strong scratch).

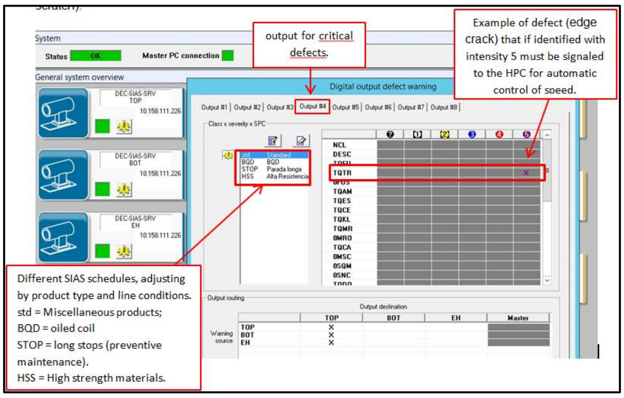


**Figure 11:** SIAS programming screen, indicating defect sending with intensity 5 in output # 4 and programming types by product type and line conditions.

Group 2:
Focus on obtaining the critical defect signal issued by the SIAS and handling it for use in the speed control system in the tandem cold mill according to the sequence given below.
Sequence of detection and automatic actuation of the tandem cold mill.

1. SIAS detects defects and compares with the database, categorizing it according to the established schedule (intensity / defect);Um ou mais defects identified in the coil control chart are classified as critical and at risk of rupture;
2. 2. If the defect is critical there are two parallel actions for this condition;
   a. Alarm sending on the SIAS screens of the tandem cold mill pulpit and the pickling inspection for visual evaluation of the defect by the operators, as shown in figure 12;
   b. In parallel, another signal is sent to a SIAS auxiliary port (output # 4) already sent to the HPC (central controller);

3. The signal sent at "b" and picked up by relay that sends the signal to the HPC (central controller) figure 13;
4. HPC treats the signal and stores it in a buffer, thus preventing subscription of defects (there may be more than one defect in the same coil);
5. The signals are automatically tracked and as they approach the tandem cold mill input the HPC reduces the speed of the tandem cold mill to a standard speed determined by software programming;
    a. At this point after the tandem cold mill deceleration, the tandem cold mill operator can re-accelerate the speed if it judges as not critical, being at his discretion.

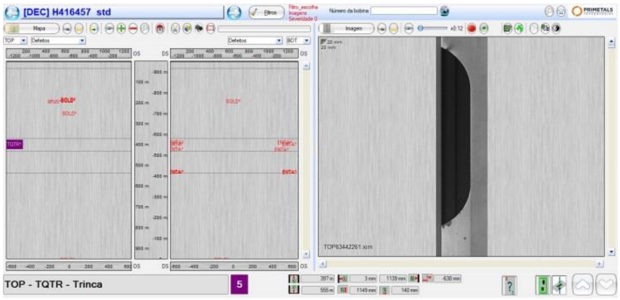


**Figure 12:** Control chart of defects of the SIAS, indicating a considered and informed defect (notch) as critical for the operators on the right of the screen and the tracked of the defect on the left of the screen.

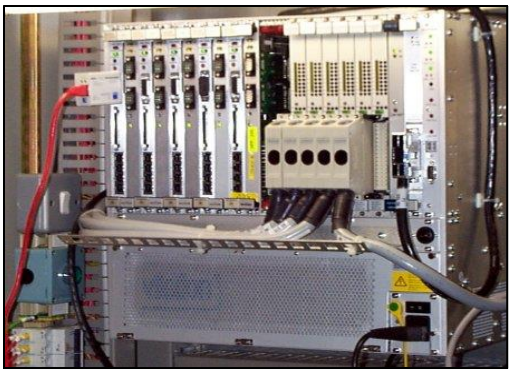

**Figure 13.** Layout HPCi and P80i (Alstom).

## 3 RESULTS AND DISCUSSION (SIAS)

These combined works in SIAS for identification, demonstration and actuation (manual and / or automatic) reduced the time of unproductive ruptures caused by surface defects detectable by SIAS in 25.82%, as indicated in figure 14.

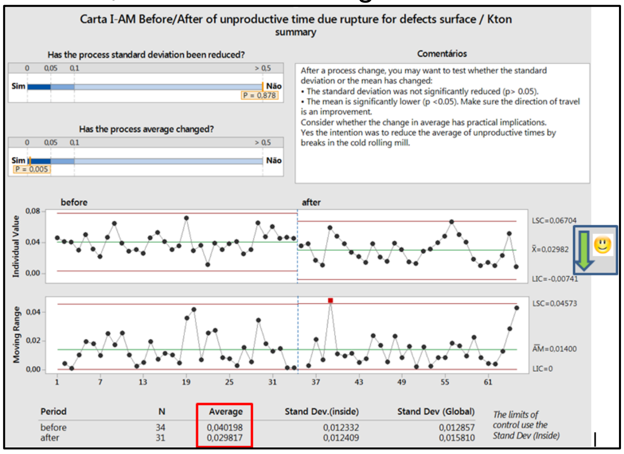


**Figure 14:** Chart chart before, after, show the reduction of unproductive time rates for ruptures detectable by SIAS (unproductive time hrs / Kton).

## 4 CONCLUSION

With the integrated work of specialized internal teams involved in the two projects addressed in this article, adding to this the availability of resources (SIAS), ArcelorMittal Vega has been able to increase the productivity of the pickling and rolling line by improving the operational condition of the equipment and the own operating resources and conditions, thus achieving significant results as detailed in the article.

The factory has been able to produce without decreasing quality and safety since the implementation of new systems, leading to early and final acceptance of the operation, safety, maintenance and quality teams.

## REFERENCES

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2 Manual SIAS MU-030203-06-EN XLine® Inspection Station_ptbr