TECHNIQUES FOR EVALUATING THE MECHANICAL CONDITIONS OF 4HI ROLLING MILL AIMING GUARANTEE OF ITS OPERATIONAL STABILITY[1]*

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Abstract

Gerdau Ouro Branco´s plate mill started the operation in 2016 with high level technology. In general, national and international plate markets are every day more rigorous about final product quality. Suppliers must be aware about dimensional accuracy, surface quality and flatness of the plates, independent of the quality standards. To guarantee the best service to this increasingly demanding and competitive market, it is extremely important to guarantee the original project conditions executing the right maintenance of the rolling mill main components. In order to maintain the product quality and avoid the production and maintenance cost increase, it is important to find ways to control the mill and the main process variables, through daily measurements of the equipment performance. This paper aims to present the influence of the main equipment variables that affect the mill operational stability and how to control and evaluate the mill performance.

Keywords: Plate Mill; 4HI Rolling Mill, Mill Stretch, Mill Hysteresis.

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1 INTRODUCTION

The Gerdau Plate Mill started his production in 2016, marking the entry of the company in the production of thick plates of high added value in Brazil.

The Plate Mill plant consists of two 220/265 t/h Walking Beam Furnace, one 4Hi Rolling Mill Stand, one Accelerated Cooling Machine - Mulpic® and two Hot Levelers. The finishing area consists of fully automated main line and is equipped with Double Side Shear and a Divide Shear, Inspection Area, Cold Leveler, UST machine and 4 Gas Cutting Machines [1]

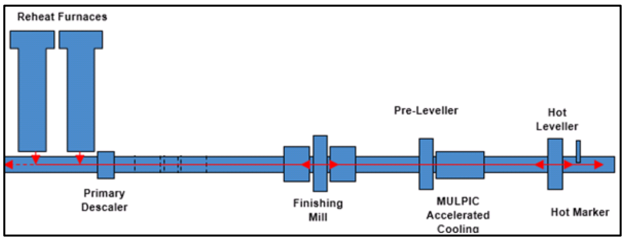


Figure 1: Layout of the Mill Area and main equipment.

In this project were employed the most modern technologies to ensure the final quality of the product: Complete automation of equipment with mathematical models of Process Control, HGC system, Work Roll Bending and Work Roll Shiftting with Smart Crown® [1]
It is of paramount importance for product quality and operational stability to ensure that these equipment and technologies operate at full capacity. This requires rigorous efforts and monitoring by the teams that operate and provide technical maintenance and process support. Conducting specific tests is fundamental for failure analysis, performance improvement and decision making to replace hydraulic and mechanical components.
In this paper will be detailed the execution of 3 important tests (hysteresis test, work roll crossing test and Bending & Shifting Test), its evaluation and relationship with instability/defects in the plate rolled.

2 MATERIAL AND METHODS

The operational stability of a Plate Mill is measured in a practical way in the performance of the results of quality, productivity and cost. Regarding the quality, the occurrence of big waves affecting the flatness of the plate and the occurrence of camber of the plate rolled are the main indicators.
The problems of flatness are directly related to the plate cross profile of the material (plate crown). The Figure 2 shows the main flatness problem.

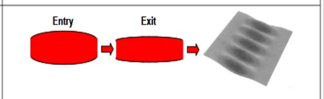
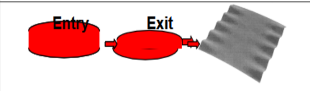
Crown	Waves Type	Representation
Low Crown	Center Waves	
High Crown	Edge Waves	

Figure 2: Main flatness problems.

To avoid the occurrence of big waves, the plate crown needs to be controlled.
The problems of Camber, figure 3, are related to side shifts of the material. When this movement occurs, the operator along with RAC - Roll Alignment Control tries to oppose this movement by tilting the work rolls in such a way as to close the gap on the side to which the material is moving.

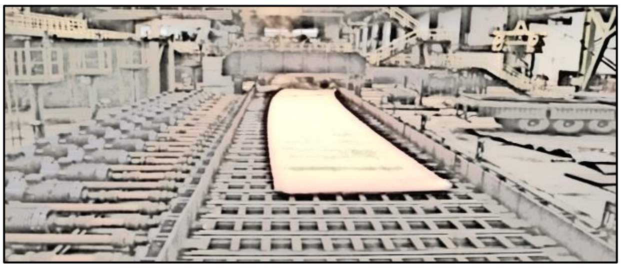


Figure 3: Typical case of camber occurrence on the plate.

When the correction is not done properly it generates instability in the process causing camber and edge waves. In not very rare cases, where there is no proper correction, the displacement force of the material is enough to cause bending of the material in the entry or exit side guards.

The material folded when passing through the work roll causes an excessive differential roll force in the mill stand and may rupture. The results are scrapping, line stoppages, damage to work rolls and damage to other stand mill components, as well as a long period of line downtime for scrap removal and the risks related to the safety of people for being a dangerous task.

For shape and flatness control, the following resources are used:

2.1 WRB - Work Roll Bending

The Work Roll Bending is used during the rolling passes to compensate the variations in the roll force, maintaining the relative plate crow. For the rolling process, this correction is more evident and more necessary at the edges of the material, depending on the differential roll force in this region due to lower temperature.

The mathematical model calculates the differential roll force and bending of the work roll and then anticipate for a necessary load of work Roll Bending to enable the corrections during the rolling pass [1].

The operator, depending on the direct visualization of the flatness result of the material after the rolling Pass, can also act manually in the Work Roll Bending, increasing the Bending force to correct edge waves and reducing Bending force to Correct center buckle.

The Work Roll Bending has 16 hydraulic cylinders, being 4 cylinders per Bending block with the following provisions: 2 uppers and 2 lowers.

Figure 4 illustrates the frontal and lateral view of the Bending block location in the stand mill.

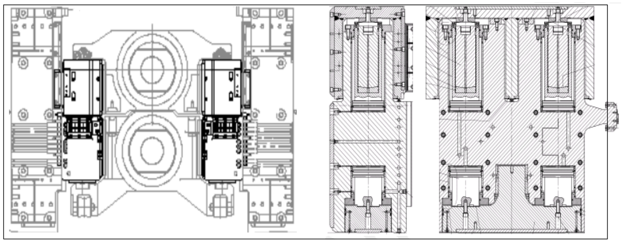


Figure 4: Frontal and lateral view of the Bending block location in the stand mill.

There are two ways in which WRB operates:

WRB positive: The hydraulic cylinders apply a force in the opposite bending of the work rolls during the pass, Figure 5.

WRB negative: The cylinders apply a force in the same direction of the bending of the work rolls during the pass, Figure 5.

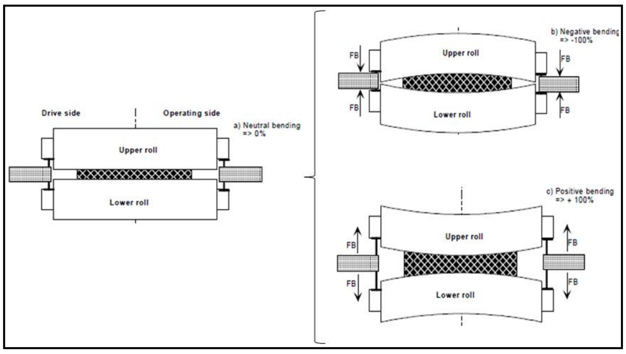


Figure 5: Bending actions to control the crown.

2.2 WRS - Work Roll Shifting

The Work Roll Shiftting with Smart Crown® is used to adjust the mechanical crowing of the working rolls before the start of each rolling pass. The position of the Shiftting is calculated by the mathematical model of the plate mill Setup as part of the reduction plan to achieve the intended crowing in the material without using the Work Roll Bending in its entirety. This allows the Work Roll Bending performance to be used only to maintain the relative plate crow between passes when the roll force variates from the predicted [1].

The Work Roll Shifting with Smart Crown® is also used to compensate for the wear of the work rolls, making it possible to extend the campaign in the mill.

Figure 6 shows a design with the Work Roll Bending and Work Roll Shiftting arrangement with Smart Crown®.

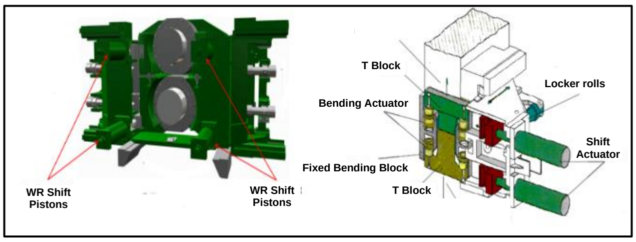


Figure 6: Work Roll Bending and Work Roll Shiftting arrangement with Smart Crown.

Figure 7 shows the basic principle of the work rolls profile for use in the Smart Crown®.

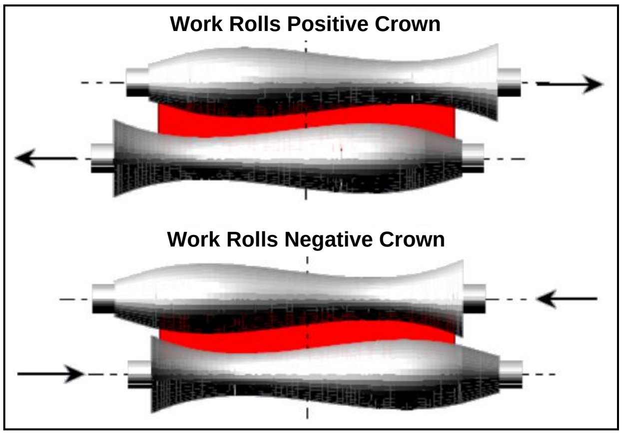


Figure 7: Basic principle of the work rolls profile for use in the Smart Crown.

There are two forms of WRS acting:
Positive WRS: The top Work roll moves to the drive side and the bottom Work roll moves to the operating side, tending to roll with the region with the largest diameter of the Work rolls consequent reduction of the plate crown;
Negative WRS: The top Work roll moves to the operation side and the bottom Work roll moves to the drive side, tending to roll with the lower region Diameter of the Work rolls with consequent increase of the plate crow;

2.3 HGC - Hydraulic Gauge Control

HGC capsules are located at the bottom of the stand mill between the lower back/sledge cylinder housing and the stand mill. There are two sets, one of which is positioned on the drive side of the plate mill and the other on the operating side. Actuators are hydraulically operated and act vertically for the application of roll force loads during the process [1].
HGC functions are:

- Engage the required roll force in the process;
- Make adjustment in the high of pass line;
- Correct positioning and tilt errors of screws down;
- To position the gap of the plate mill when the absolute reduction is less than 5 mm;
- To do automatic correction of material output thickness;
- To do the function of leveling Work rolls in accordance with the request of the operator;

Figure 8 shows a drawing with the positioning of the hydraulic capsules on the base of the stand mill.

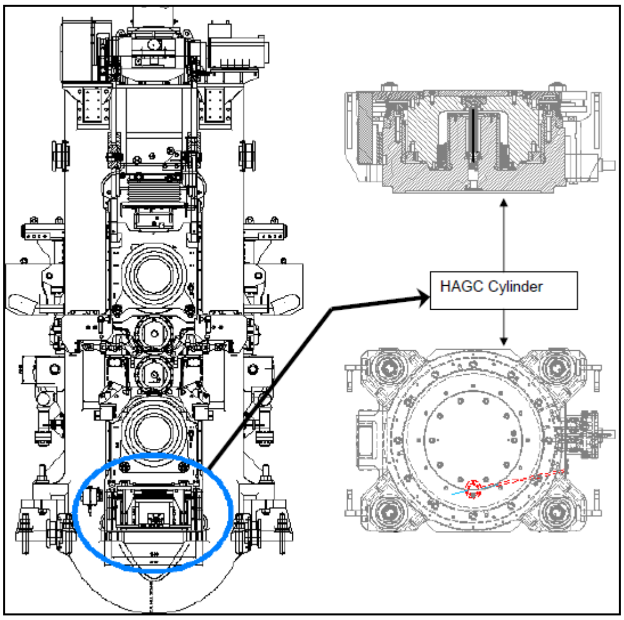


Figure 8: drawing with the positioning of the hydraulic capsules on the base of the stand mill

HGC functions are possible due to the hydraulic system relying on a dedicated unit controlled by servo valves with very small response times.

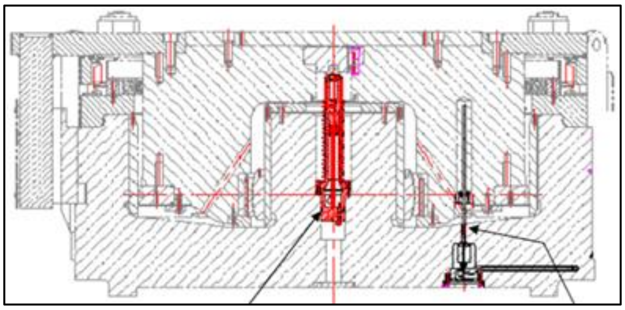


Figure 9: Positioning of the transducers in the hydraulic capsule.

The measurement of the course is done by using two position transducers. The transducer located in the center of the capsule is a relative position transducer and is responsible for the measurement of the course. The transducer located on the side is a transducer of absolute position and is able to measure the course and identify the slope of the capsules. The positioning of the transducers in the hydraulic capsule can be observed in Figure 9.

In order to avoid occurrence and camber, it is necessary to maintain the gap of the parallel Work rolls. This is done using the HGC capsules. The initial leveling is adjusted during the Gap calibration procedure, where the work rolls are kept in contact under the control of the HGC capsules that are adjusted to achieve the same roll force on both sides of the plate mill.

The roll force measurement is done by load cells located below the screws and by pressure transducers located in the hydraulic capsules.

3. Tests to check the mill mechanical conditions.

3.1 Work Roll crossover Test

The Backup Rolls and work Rolls tend to cross when there are clearances between liners and sliding bearings. This intersection can generate flatness and instability problems during roll passes.

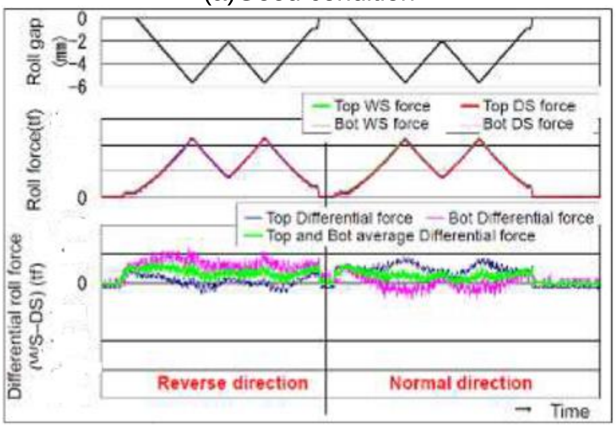
The objective is to evaluate the behavior of the forces between the sides of the stand mill, carrying and unloading the mill between forces below 1000 T and above the average rolling force under constant speed forward and then reverse due to the possibility of having significant differences on each side.

The frequency of this test is for each campaign/exchange of Backup Roll. The data are obtained after the calibration of the stand mill, where the forces of both sides of the mill and the position of the HGC are measured. The sampling cycle is approximately every 20 Ms.

The difference between the forces must be checked: (a) The top part measured by the load cell (b) bottom by the pressure transducers and (c) average of the upper and lower parts.

The Figure 10 illustrate examples of good and bad conditions of the behavior of these forces.

(a)Good condition



(b) Bad condition

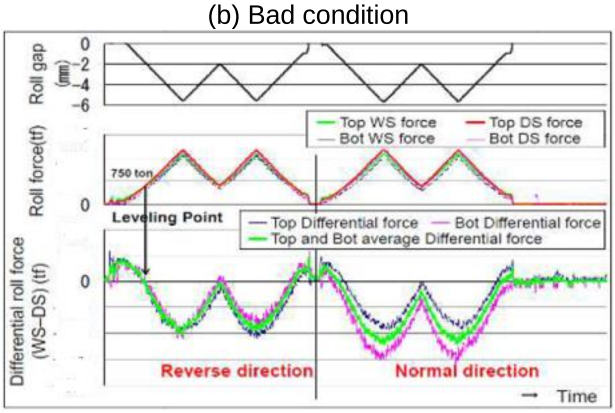


Figure 10: examples of good and bad conditions of the cross rolls.

In case of behavior similar to that shown in Figure 10b, a meticulous inspection should be performed on the mill seeking to find abnormalities such as:

- Clearances/wear of Liners
- Clearances Backup/Work rolls chocks
- Distortions in sled shims

3.2 Hysteresis test

The structure of the stand mill can be considered as a set of springs, each corresponding to a mechanical element of the stand from the base of the sledge, carcass, nut and positioning screws, housings and backup/Work rolls. Figure 11 illustrates the main components affecting the Stand mill modulus.

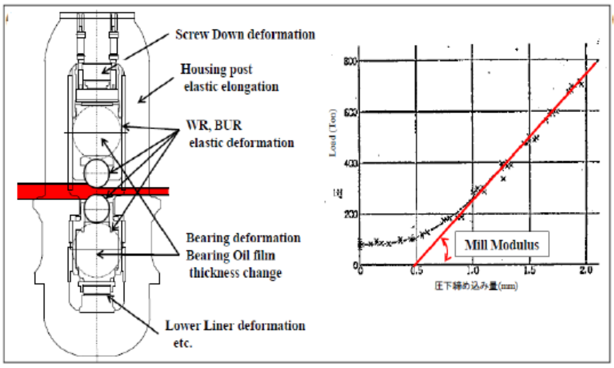


Figure 11: main components affecting the Stand mil modulus.

The measurement of hysteresis is performed to measure the modulus of elasticity of the stand mill and to verify its behavior independently by the sides of the plate mill.

The measured elasticity value is used by mathematical models in the basic equation of the "*gauge meter*" to calculate the gap needed to determine the thickness and flatness in the material as shown in Figure 9, where h = material thickness, S = GAP, P = Roll Force and M = plate mill stiffness [2].

Depending on the roll force, all the elements inside the stand will warp (lengthen) [2], as shown in Figure 12.

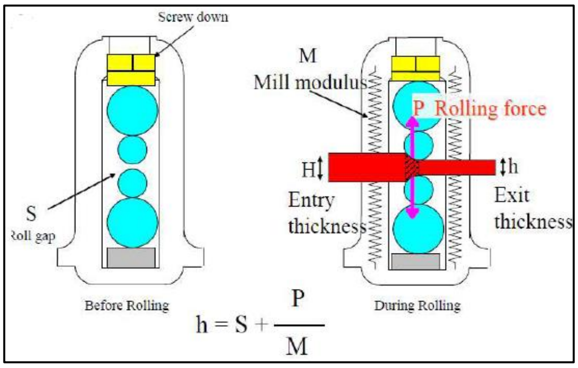


Figure 12: Example of the change in the mill modulus during a rolling.

This procedure should be performed periodically to track the wear of the mechanical components (clearances), improve the accuracy of the thickness and width of the materials, assist in the maintenance of the equipment and if necessary, repair the equipment and resume a safe condition.

The hysteresis test is usually performed after replacing the backup rolls and after making the plate mill reset. It is done automatically and with the Work rolls in contact using increasing roll force above the average rolling force at constant speed. The course of the hydraulic cylinder is measured. The result is a force x deformation curve. A characteristic hysteresis curve is represented in Figure 13.

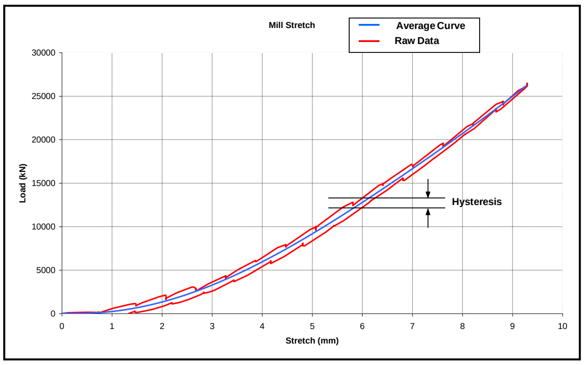


Figure 13: Example of a hysteresis curve.

In general rules the higher the modulus of stiffness and the lower the hysteresis, the more rigid the stand mill and the more uniform is the response of its stiffness to the applied roll Force [3]

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If there is any strange measurement it is necessary to check the mechanical conditions separately on the side of the stand mill.

3.3 Shifting & Bending Test

Its main objective is to relate the position of WRS and the force variation of WRB with the occurrences of camber.

The test consists of keeping the gap of the plate mill open at 50 mm approximately with the rolls rotating the constant velocity in a certain direction. At this moment we vary the strength of the WRB between the balancing force and the maximum available force for 3 different positions of the WRS.

The strength data of the load cells and pressure transducers of the hydraulic capsules are collected

This test is performed with the WRB compensation turned on and off to measure its influence.

4 RESULTS AND DISCUSSION

After the commissioning phase of the equipment, these tests were frequently carried out in order to correlate the operation stability and camber occurrences with the mechanical condition of the stand mill.

A history of the mill modulus per set of backup rolls was created where it was possible to parameterize a stable and non-stable operating condition, Figure 14 and 15. Figure 16 show an example of a history of hysteresis values along the backup rolls campaigns.

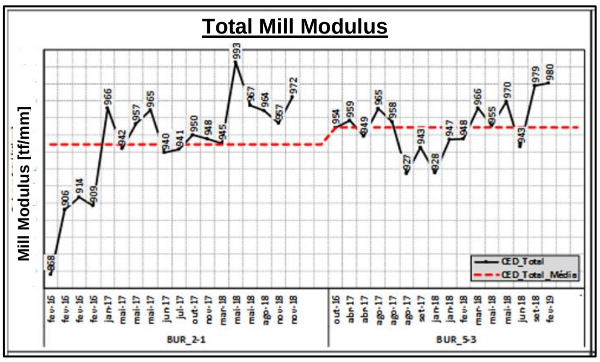

Figure 14: History of the total mill modulus along the backup rolls campaigns.

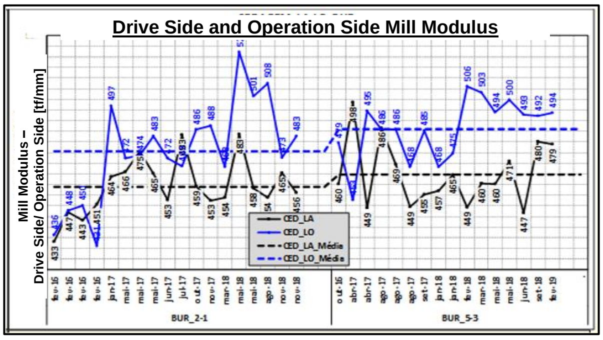

Figure 15: History of mill modulus of the operation side and drive side along the backup rolls campaigns.

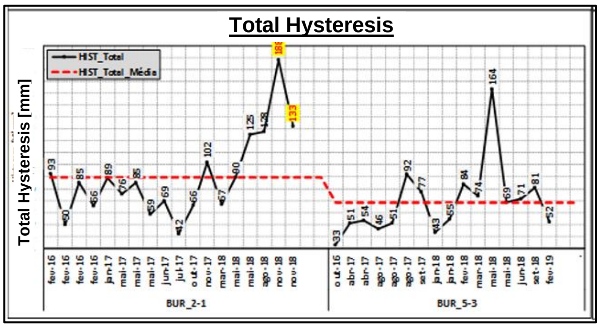

Figure 16: History of hysteresis values along the backup roll campaigns.

Table 1 show some reference values based on the history of the mill modulus and hysteresis correlated with occurrences of instability in the plate mill.

Table 1: Reference values for mill modulus and hysteresis.

Test	Position	Reference in %		
		Good	OK	Bad
Hysteresis	Total	< 10	10	> 10
	Drive Side			
	Operation Side			
Mill Modulus	Total	> 100	100	< 100
	Drive Side	> 45	50	< 45
	Operation Side			
	Operation - Drive Sides	< 3,5	3,5	> 3,5

Figure 17 is exemplified a case where adjustments were necessary in the housings of the backup rolls resulting in reduction of the differential and force relative to the crossing of rolls.

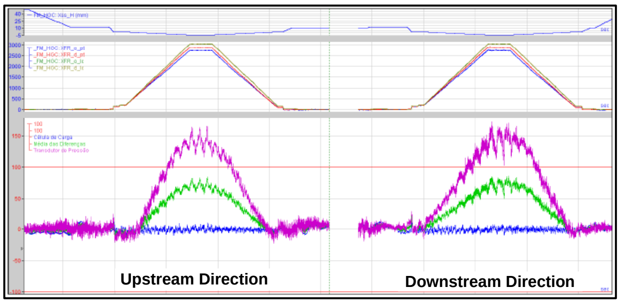

Figure 17: Crossover test with a non-expected performance.

To confirm what the crossovers test pointed out was measured the dimensional of the stand mill and the chocks that were in operation. Values were found above that specified by the project. Crossover test after maintaining the liners of Work roll chocks and housings, Figure 18.

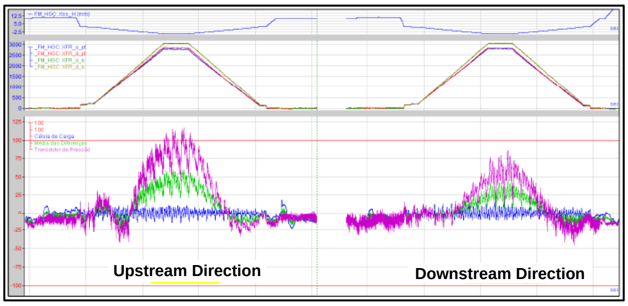

Figure 18: Crossover test with the expected result.

Figure 19 is exemplified another case where it was necessary to check the profile of the backup roll resulting in a significant reduction of the occurrence of camber. High strength differential.

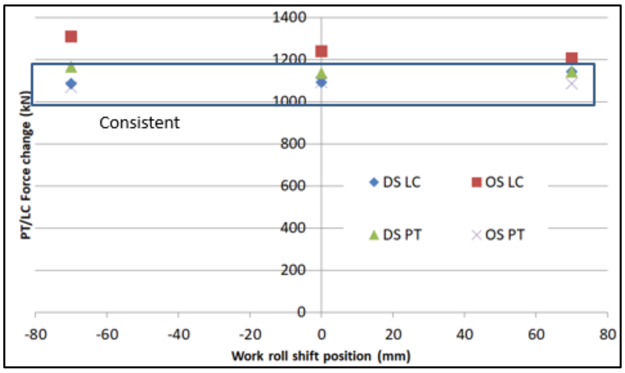

Figure 19: Example of high strength differential forces.

Roll Force differential after maintenance intervention and improvements in the WR and BUR profile, Figure 20.

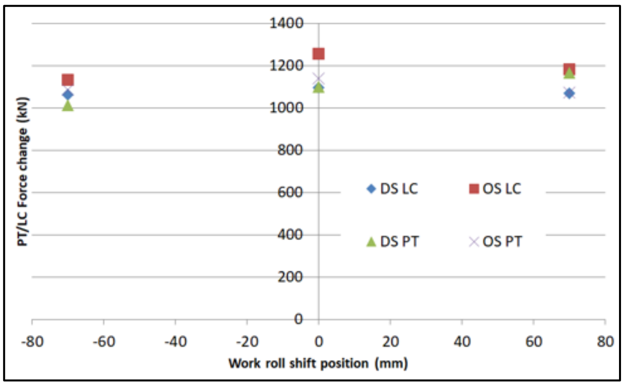

Figure 20: Example of low strength differential forces.

Reduction of the camber index since the start up can be seen in the Figure 21.

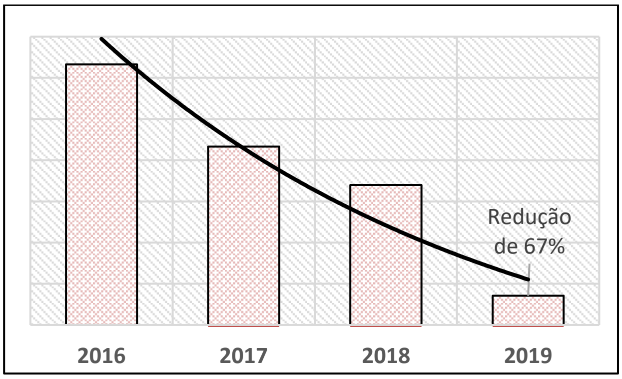

Figure 21: Camber defect reduction from 2016 to 2019.

4 CONCLUSION

The tests presented serve as a parameter to verify the "health" of vital points of the equipment aiming at operational stability.
The tests presented serve as decision-making for component replacement in order to maintain the design conditions of the machine.
The tests presented serve as a tool for analyzing the failure of chronic defects.

5 REFERENCES

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