IMPROVEMENT IN ROLLED IN SCALE INDEX ON HIGH PRODUCTIVE MILLS *

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Abstract

The increase in customer demand for steels with higher surface requirements, associated with the need to increase ArcelorMittal Tubarão's HSM productivity, it was necessary the development of controls and actions to reduce scale losses within the scenario of high productivity. This article describes the path followed by the hot strip mill team in order to reduce the occurrence and severity of scales.

Keywords: Hot rolled coils; Rolled in scale, Productivity

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1 INTRODUCTION

1.1 The Hot Strip Mill at ArcelorMittal Tubarão

Since its startup on August 2002, the Hot Strip Mill has gradually increased the coil output. After the installation of the second Reheating Furnace (2009), the nominal capacity moved from 2,8 Mt/year to 4,0 Mt/year (Figure 1).

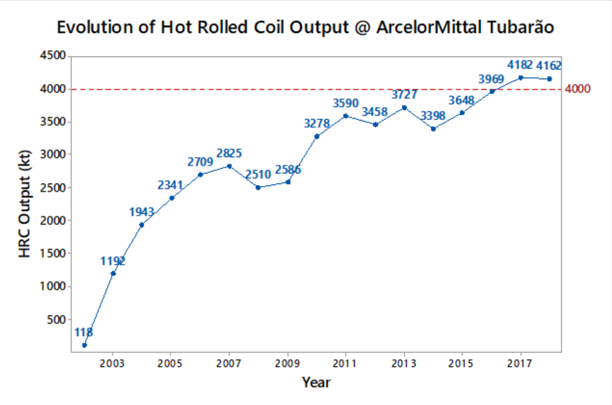

Figure 1. Evolution of HRC Output at ArcelorMittal Tubarão (2002 – 2018).

Accordingly to its current layout (Figure 2), the Hot Strip Mill comprises:

- 2 *Walking Beam Reheating Furnaces* (400 t/hour each)
- 1 Vertical Edger (2 x 1500 kW = 3000 kW)
- 1 4-High Reversible Roughing Mill (2 x 7500 kW = 15000 kW)
- 1 Coil Box
- 6 x 4-High Stand Tandem Finishing Mill (6 x 8000 kW = 48000 kW)
- Laminar Flow
- 2 Hydraulic Downcoilers

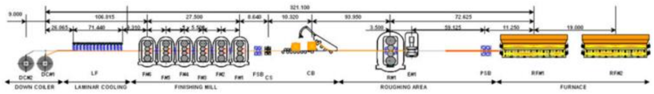

Figure 2. Current layout of the HSM at ArcelorMittal Tubarão

The Hot Strip Mill complex also includes:

- 1 Hot Skin Pass Line
- Coil Division Line
- 1 Sampling Line
- 1 Roll Shop
- 1 Water Treatment Plant

The product portfolio includes IF and Ultra Low Carbon Steels, APIs, HSLA, Dual / Complex Phase grades and the recent Advanced High Strength Steels (*AHSS*). Thicknesses may vary from 1,5 to 19,0 mm and widths from 700 up to 1880 mm, with a maxim weight of 40 metric tons per coil[1]

Considering its applications, products may be classified as[1]:

- Commercial quality grades
- Structural quality grades
- Structural grades with enhanced formability
- Tubes
- Propane Tanks and Pressure Vessels
- Drawing
- Structural quality grades resistant to atmospheric corrosion
- Ship building
- Oil and gas pipelines
- Floor plate

1.2 Yield losses related to Rolled in scale

Between 2015 and 2017 ArcelorMittal Tubarão's hot strip mill productivity increased 14%, achieving values on the level of high productivity mills (figure 3).

Also, on this time period, there was a significant increase on production of high strength and surface criticality steels (figure 4).

On this context, the processing conditions migrated to a higher work roll stress region, causing a higher level of yield losses due to scale defects (figure 5).

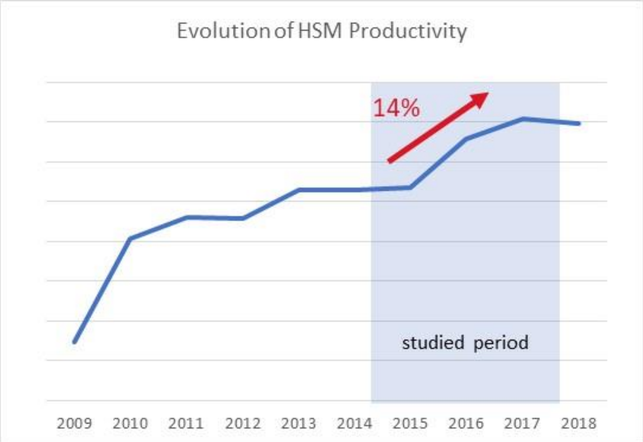

Figure 3. Evolution of ArcelorMittal Tubarão HSM productivity (2009 – 2018)

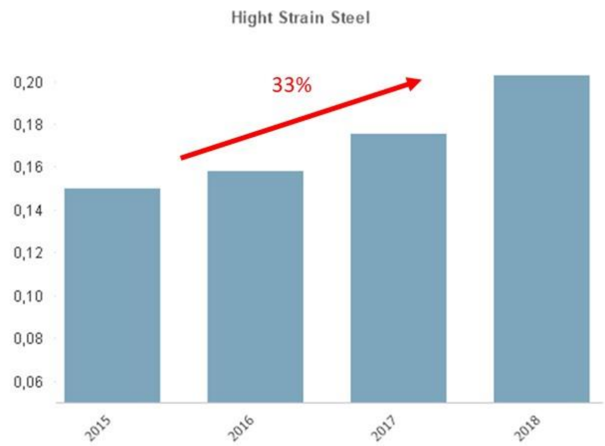

Figure 4. Evolução do mix de materiais de elevada resistência (2015-2018).

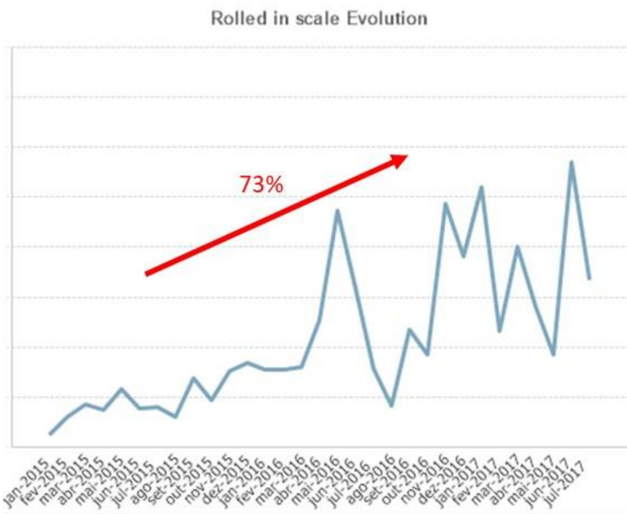

Figure 5. Yield loss related to rolling in scale during the studied period (2015-2017).

Based on the high level of yield losses and the challenging market environment for high surface, complexity and demand, a work group was assembled aiming to return the yield values to its best historical values, while maintaining the high productivity index.

2 MATERIALS AND METHODS

2.1 Classification of scale defects

The scale defect is classified according to its origin on the process of hot strip rolling. At ArcelorMittal Tubarão the defect is defined as:

2.1.1 Primary scale: Very typical scale defect, mostly formed before the finishing mill, due to scale from the furnace or roughing mill which has not been completely removed (figure 6).

Figure 6. Typical primary scale defect.

2.1.2 Salt and Pepper: This defect is caused by the rolling-in of secondary scale in the finishing mill.
Higher risk for thinner strips (<= 2.0 mm) when both, the temperatures and forces are higher (figure 7).

Figure 7. Typical salt and pepper scale defect.

2.1.3 Peeled Roll Scale: Very superficial loss of work roll surface caused by thermal or mechanical reasons.

Mainly originated in the first stands of finishing mill due to heavy wear of the rolls. It is worse on long programs with a lot of consecutive thin materials (figure 8).

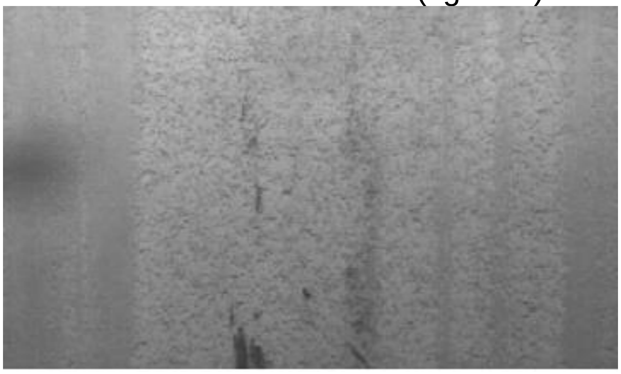

Figure 8. Typical peeled roll scale defect.

2.2 Evolution of scale defect by type on ArcelorMittal Tubarão:

Evaluating per defect type it is clear that the main cause for the increase on losses is the peeled roll scale (figure 9). Therefore, the formation mechanisms for this defect were studied in-depth.

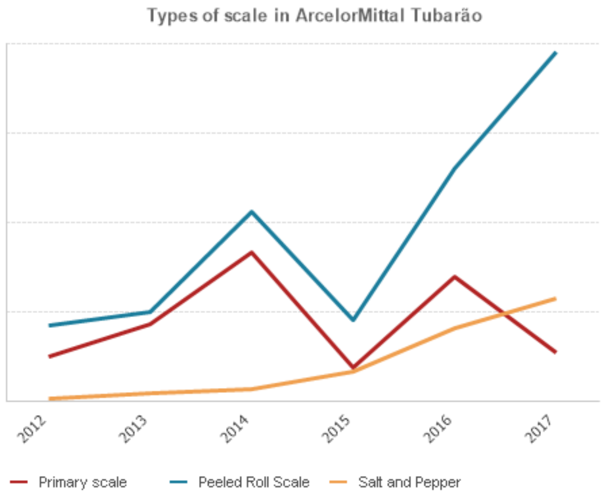

Figure 9. Scale evolution (by type of defect).

2.3 Evaluation of work roll surface aspects after change.

At the same time it was observed a substantial increase of work roll degradation, highlighted by the elevated roughness realized on work roll changes.

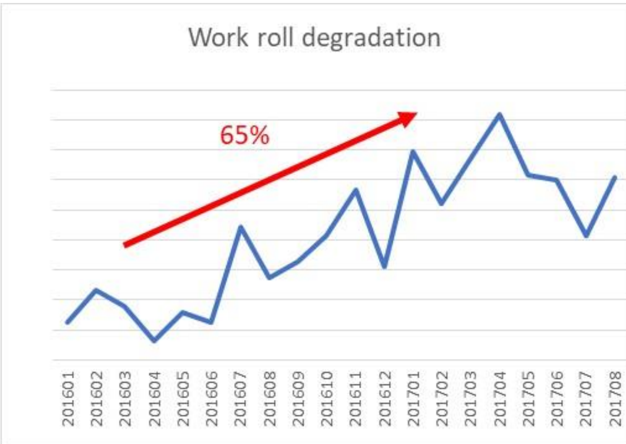

Figure 10. Work roll degradation index after roll change.

3 RESULTS AND DISCUSSION

The degradation of rolls occurs due to stress suffered during the contact with the strip during rolling. The main factor for roll degradation and occurrence of scale defects are explained on figure 11.

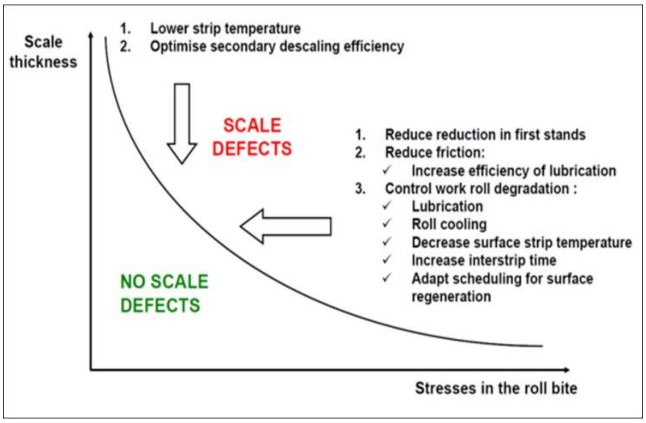

Figure 11. Main factors to avoid rolled in scale defect.

3.1 Roll degradation control

Seeing that the defect is predominantly caused by roll degradation, the focus of the work was to improve conditions to reduce the stress suffered by the rolls during rolling and to allow surface recovery during the rolling campaign.

3.2 Lubrication

Lubrication consists in creating a lubricant layer at the contact patch between the roll and the strip. The lubricant constitutes an easily sheared film that will accommodate the velocity gradient between the surfaces. For hot rolling, the most common lubricant is oil. Several materials and process parameters are influencing the friction behavior of the roll bite and lubrication efficiency: temperature, speed, reduction, hardness, surface roughness, lubricant properties, etc.

Lubrication can decrease friction and limit energy loss. Lubrication also acts on roll wear (Figure 12 from Mase 1979) and mechanical failures.

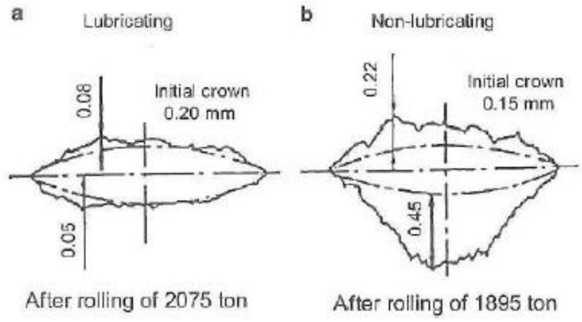

Figure 12 - An example of surface profiles of rolls after rolling with and without lubricant [5]

The typical behavior of friction along one campaign can be described as follow (Figure 13). With a new roll (not yet thermally oxidized), friction first quickly decreases. This behavior happens whether the system has lubrication or not: part of it comes from the favorable oxide formation on the rolls at the beginning of the campaign and from the decrease of roll roughness. Then, friction re-increases due to the roll surface degradation before it gets to a final stabilizing phase.

Obviously, depending on process parameters (including lubrication) and materials to be rolled, the friction can evolve differently in some particular cases.

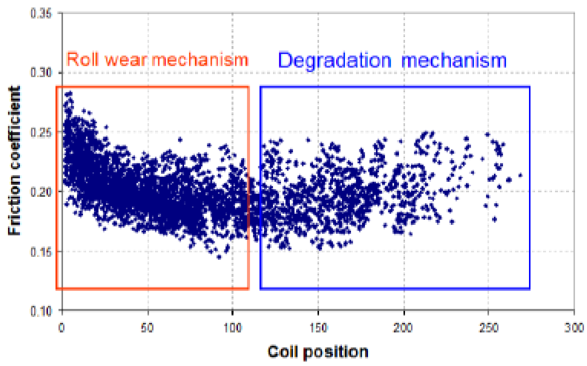

Figure 13 – Typical behavior of friction along campaigns (evaluated with Orowan model)

To improve roll lubrication performance actions were developed to ensure the reliability of the lubrication system and to optimize the concentration for material and application type.

The application of lubrication is made by pulverizing the emulsion of water on the roll surface before the contact with the strip, as exemplified on figure 14.

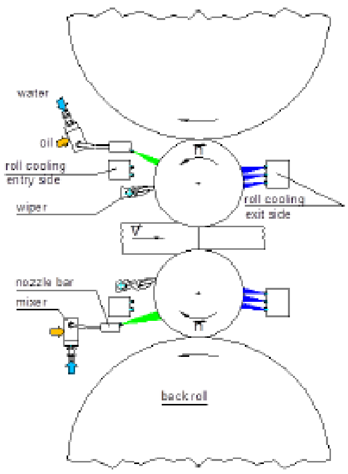

Figure 14 – Lubrication arrangement in the finishing mill stand

The main control items for the performance are the system obstruction and the existence of leaks on the circuit. To evaluate the conditions of this critical items, control charts (figure 15) and a daily quality inspection system for spray and emulsion were created (figure 16).

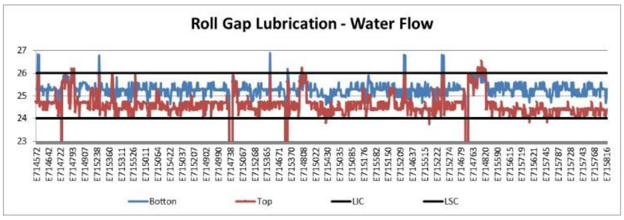

Figure 15 – Control chart of roll gap lubrication water flow

Figure 16 – Emulsion Test

In observance with abnormalities on the control points, equipment interventions were done in order to ensure a proper functioning of the system.

3.3 Decrease surface strip temperature

The surface temperature of the strip plays a significant role in the thickness of the oxide layer formed and in the thermal cycles that the work rolls are subjected, speeding up its degradation, so that:

1. Scale hardness decreases with temperature
2. Scale adherence decreases with its thickness
3. Scale thickness is strongly dependent on temperature (figure 17)

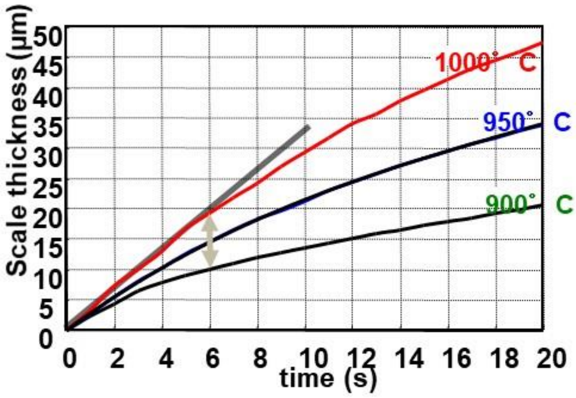

Figure 17 – Scale thickness by temperature for a low carbon steel.

The temperature cycles are the cause of thermal fatigue: the work roll in contact with the hot strip presents a high thermal gradient. This gradient is reversed during cooling and causes the thermal cracks to start and propagate.

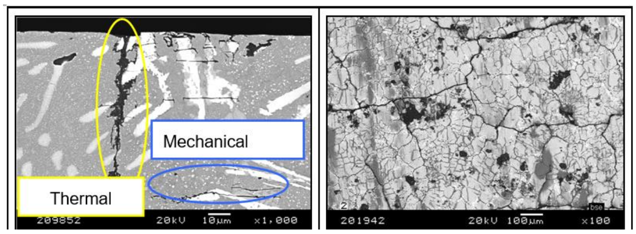

Figure 18 – Termal and mechanical cracks under the work roll surface

If thermal cracks develop themselves too much, surface oxides leave the roll surface and remove roll material (banding). This phenomenon increases the roughness and accelerates the degradation circumferentially.

As the temperature on the work roll surface increases, its hardness decreases, as can be seen on figure 19.

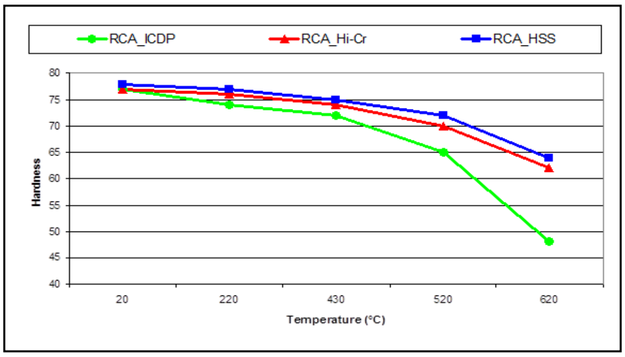

Figure 19 – Surface hardness by the temperature in work rolls

The skin cooling is very important in this context as it reduces the surface temperature of the strip before contact with the work rolls in the roll bite (figure 20).

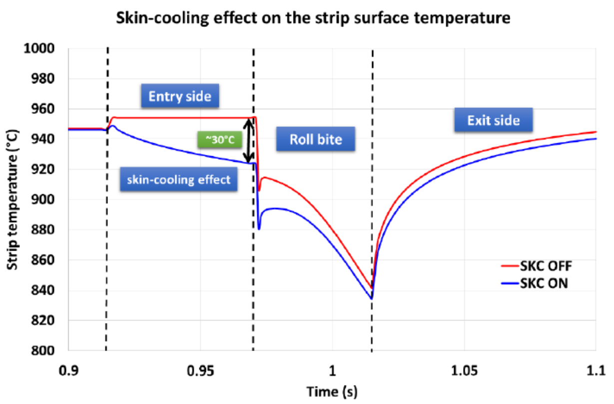

Figure 20 – Effect of skin-cooling on the strip temperature

In order to achieve the required temperature reduction of the strip surface, controls were established to ensure temperatures within suitable limits before the entry of the finishing mill. Example: automatic speed reduction if the temperature is higher than specified.

Another point was to ensure the use of skin cooling throughout the length of the rolled strip to avoid temperature peaks that cause momentary loss of the rolls surface resistance and thereby the release of the material oxide layer.

3.4 Management and Routine

Besides the process modifications mentioned above, specific automatic reports were developed with the acquisition of specific software to create queries on the process database, as exemplified on Figure 21:

1. Roughness of work rolls;
2. Finishing mill temperature accuracy;
3. Roll gap lubrication oil consumption;

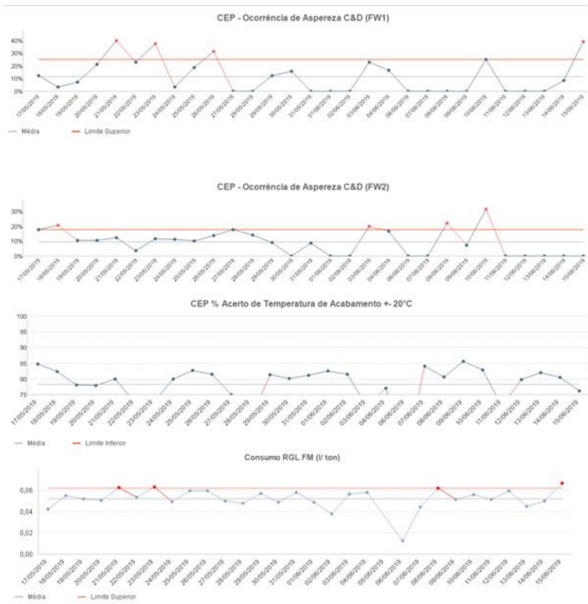

Figure 21 – Examples of automatic reports showing preventive and reactive process indicators related to the thickness performance.

Operation standards for reactions in case of quality deviations were also reviewed.

4 CONCLUSIONS

After the actions implemented as described above, a reduction of the occurrences and losses was achieved, the quality result being much better than the previous months, even with the increase of productivity of the hot strip mill at the same period, as can be seen in figure 22.

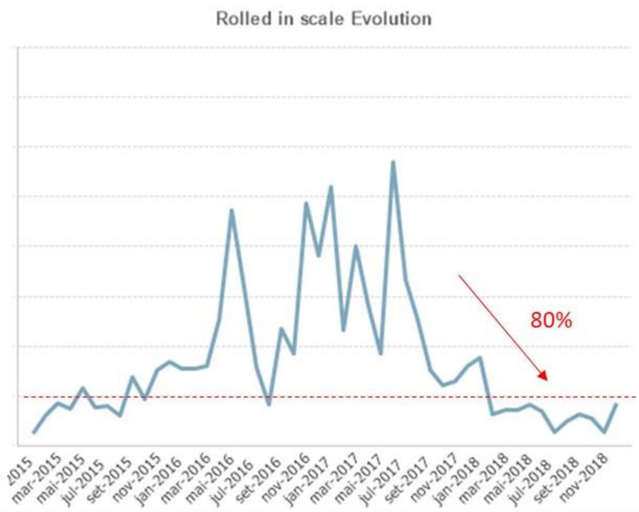

Figure 22 – Yield loss related to rolling in scale during the studied period (2015-2018).

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