IMPROVEMENTS IN THICKNESS CONTROL AT ARCELORMITTAL TUBARÃO*

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Abstract
Since the startup in 2002, the Hot Strip Mill at ArcelorMittal Tubarão has increased gradually the coil output as the customers demand new and more resistant dimensionally challenging (thinner and/or wider) steel grades. As a critical feature for customer applications, improvements have been carried out aiming a higher thickness performance and reduction of internal losses while still meeting the more restrict tolerances booked by the customers. This paper presents the recent thickness performance evolution since 2017 and the main actions deployed to improve it.
Keywords: Hot Rolled Coil; Thickness; Thickness Performance; Yield Losses.

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1 INTRODUCTION

1.1 ArcelorMittal Tubarão Hot Strip Mill

Since its startup on August 2002, ArcelorMittal Tubarão Hot Strip Mill (HSM) has gradually increased the coil output. [1].

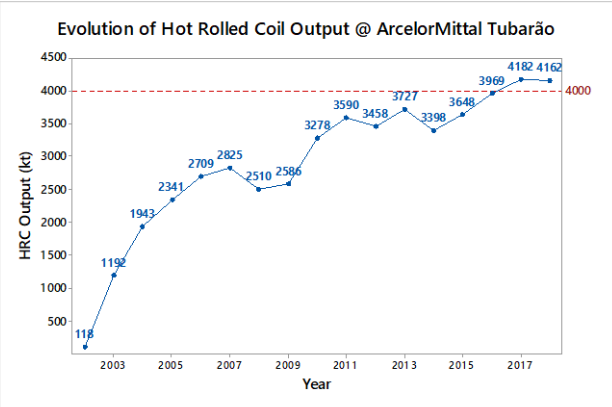

Figure 1. Evolution of HRC Output at ArcelorMittal Tubarão (2002 – 2018).

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

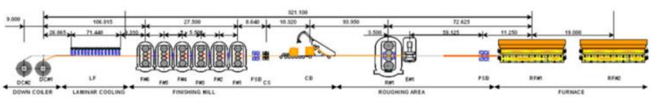

Figure 2. Current layout of the HSM at ArcelorMittal Tubarão.

The Hot Strip Mill complex also includes:

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

After the startup of the second Reheating Furnace (2009), the nominal capacity has increased from 2,8 Mt/year to 4,0 Mt/year (Figure 1)

The current hot rolled product portfolio contemplates a very broad range of steels, including Interstitial Free (IF) Steels, Ultra Low Carbon (ULC) Steels, Electrical Purposes Steels, Enameling Steels, Case Hardening Steels, High Carbon Low Alloy Steels, API Pipe Steels, High Strength Low Alloy (HSLA) Steels, Structural Weathering Steels, Dual Phase Steels and Complex Phase Steels. 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[2]

Considering its applications, products may be classified as[2]:

- General use
- Structural Parts
- Weather Resistant Structural Parts
- Pipes and Tubes
- Pressure Vessels
- Drawing / Deep Drawing
- Ship building
- Oil and Gas Pipelines
- Floor Plate
- Auto parts
- White Goods
- Single Face Enameled Parts

1.2 Yield losses related to Thickness Performance

In 2017, thickness losses accounted for one of the main reasons for yield loss, impacting quality, performance and route alteration for processing on the HPSM results.

The thickness performance behavior is shown on Figure 5, with the May/16 results impacted by rolling with the dummy F5 stand between April and June/16.

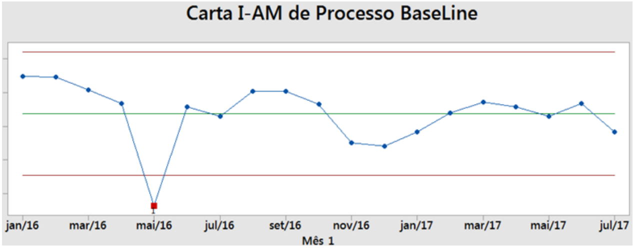

Figure 5. Control chart for thickness performance regarding process tolerances

Aiming to improve thickness performance, considering the process range, many improvements were implemented, briefly covered on the following sections

2 MATERIAL AND METHODS

2.1 Thickness Control at the HSM[1]

The target thickness on the HSM is initially set on Level 3 based on the order specifications (thickness and tolerances), following routes (Hot Pass Skin Mill, Pickling Line) and target crown; these data comprise – among others – the primary input data (PDI).

Compensations related to body deviations, bar-to-bar and/or lot-to-lot learnings are added to the previously calculated value by the Level 2 systems (mathematical model) being the result of this operation the setup thickness for the final product.

During rolling, Level 1 functionalities automatically adjusts the Finishing Mill work rolls gap based on the difference between predicted and real force (Automatic Gauge Control – AGC) and measured thickness at the exit of the F6 stand (AGC Monitor) in order to achieve target thickness. Figure 3 illustrates the HSM's thickness definition and control process.

The thickness profile is recorded by the Multifunction Gauge (MFG), processed and judged automatically by the Coil Classify system (Figure 4), as described below:

- *Prime*: Hot rolled coil approved with no deviations regarding client tolerances;
- *Recovery*: deviations are restricted to the extremities (head and/or tail end). And the coils must be sent to Finishing Lines for treatment
- *Hold*: deviations in the body and coil are automatically suspended, requiring further evaluation by Inspection Technician or Quality Specialist

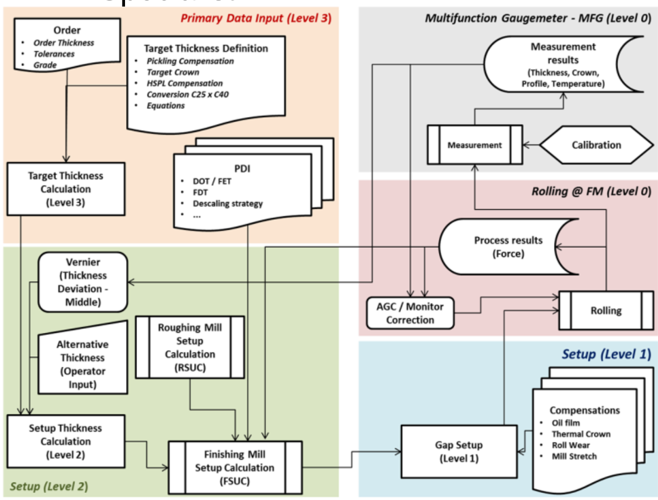

Figure 3. Process Map for definition and control of thickness on the HSM[1]

Bobina		ESP	LARG	TB	TA	COROA	CUNHA	CUN/COR	PL	ESPCW40
		Coil Classify								
G601092	BQ	P	P	P	H	P	P	P	P	P
G601093	BQ	P	P	P	P	P	P	P	P	P
G601143	BQ	P	P	P	P	P	P	P	P	P
G601069	BQ	P	P	H	P	P	P	P	P	P
G601070	BQ	P	P	P	P	P	P	P	P	P
G601061	BQ	P	P	P	P	P	P	P	P	P
G601033	BQ	P	P	P	P	P	P	P	P	P
G601034	BQ	P	P	P	P	P	P	R	P	P
G601032	BQ	P	P	P	P	P	P	P	P	P
G601012	BQ	P	P	P	P	P	P	P	R	P
G601010	BQ	P	P	P	P	P	P	P	P	P
G601009	BQ	P	P	P	P	P	P	P	P	P
G601031	BQ	P	P	P	P	P	P	P	P	P
G601029	BQ	P	P	P	P	P	P	P	P	P
G601030	BQ	P	P	P	P	P	P	P	P	P
G601027	BQ	P	P	P	P	P	P	P	P	P
G601025	BQ	P	P	P	P	P	P	P	P	P
G601026	BQ	P	P	P	P	P	P	P	P	P
G601028	BQ	P	P	P	P	P	P	P	P	P
G601024	BQ	P	P	P	P	P	P	P	P	P

Figure 4. Hot Coil automatic judgment (Coil Classify)

The profiles measured throughout the coil's total length are evaluated at the center (1/2 width) and near the edges (40 mm). When sent to the HPSM, the inspection technicians measure the coils, registering values on the system.

2.2 Classification of Thickness Deviations

The thickness deviations can be classified in 4 categories:

- Overthickness (XE): measured thickness at the center is above the client's upper tolerance
- Underthickness (FE): measured thickness at the center is below the client's lower tolerance.
- Underthickness by the edges (EF): measured thickness by the edges is below the client's lower tolerance
- Irregular thickness (EI): the thickness profile has periodic variations of high amplitude even though being inside the client's tolerances.

3 RESULTS AND DISCUSSION

3.1 Mechanical interventions on F6 stand

Roll gap adjustment considers the mill module, considering the stand and material elastic deformation ("stretch"), where[3,4]:

$$h = C_0 + \frac{P}{K_S} \qquad (1)$$

$$h = H - \frac{P}{K_M} \qquad (2)$$

h = Material thickness on stand exit
H = Material thickness on stand entry
C_0 = Stand's initial gap (unloaded)
P = Rolling Force
K_s = Stand's elasticity module = tan α
K_M = Material's elasticity module = tan β

The slope of the axis related to the mill stretch (green) corresponds to the stand's elasticity module, whose reduction implies on obtaining the balance point between the stand's straight (Equation 1) and the material's straight (Equation 2) on lower forces, resulting on a higher exit thickness than predicted.

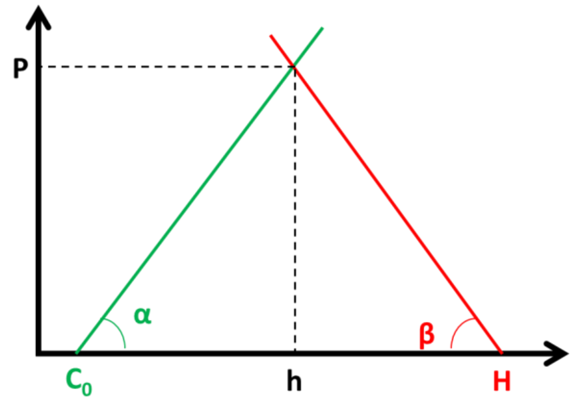

Figure 6. Schematic diagram for initial gap positioning

Along time line it may be observed that the F6 stand's elasticity module reduced due to equipment wear, with a divergence between the original values considered to adjust the initial gap and the real values measured on Mill Stretch tests. In reality, with the real value below the project value, there was a higher stand deformation when compared with the initially calculated value, causing thickness deviations resulting in values above the client's tolerances.

During the scheduled maintenance on May/2017, mechanical interventions were conducted on the F6 stand in order to normalize the elasticity module and recover the initial commissioning values (Figure 7):

- F6 stand's base machining;
- Sled and mechanical components replacement.

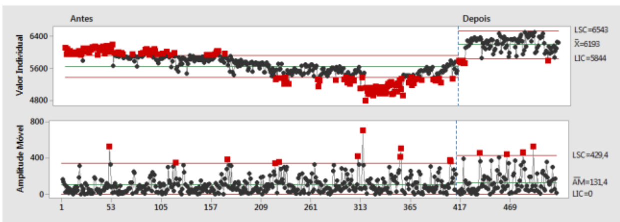

Figure 7. F6 Mill Module normalization after the interventions of the scheduled maintenance of May/2017

Additionally, standards and tools for monitoring Mill Stretch curves were reviewed, including more often tests.

3.2 Alteration of parameters for target thickness calculation

The FM setup thickness is calculated by Levels 2 and 3 based on order parameters (target thickness, tolerances) and process parameters (following routes, crowning, etc.).

To improve performance, modifications on setup thickness parameters were carried out, such as target crowning, body deviations and compensations due to following routes.

3.3 Target Finishing Temperature Modification

One critical item during threading is the compromise between stability by limiting bite speed and finishing temperature profile homogeneity along the coil's length. With the accelerations on the Finishing Mill, on some cases it is noted a considerable temperature elevation associated with a reduction on resistance, resulting on AGCs saturation and lower thickness process performance (Figure 8).

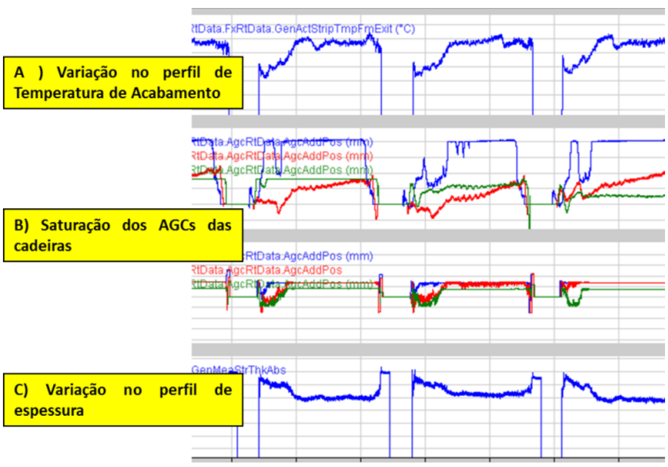

Figure 8. Effect of temperature variation on thickness temperature profile

Thus, the finishing temperature target values of some materials with lower performance were reviewed, with a reduction of approximately 50% on thickness deviation as a result of finishing temperature variation (Figure 9).

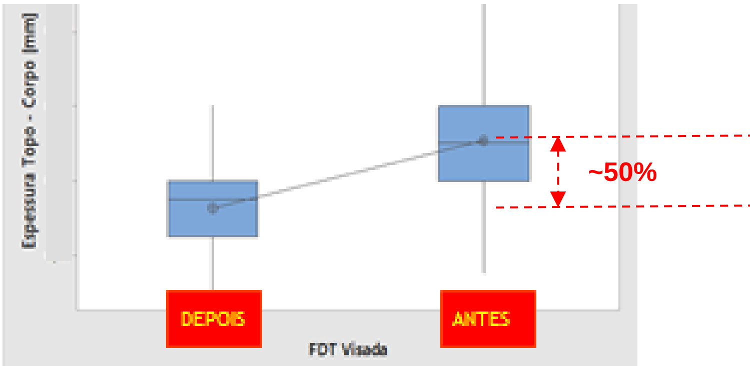

Figure 9. Reduction of thickness variation after target finishing temperature adequation

3.4 Optimization of AGC/Monitor correction parameters

In order to improve body thickness performance on the rolled material without compromising the stability during bite, thickness correction parameters were optimized (hydraulic capsules opening and closing speeds, integral correction limit and maximum correction limit per stand), with the result displayed on Figure 10.

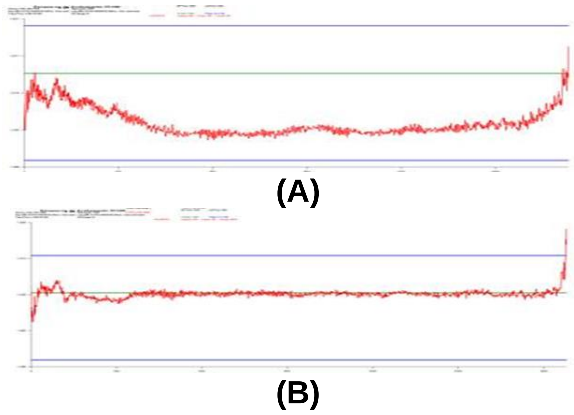

Figure 10. Effect of AGC/Monitor correction parameters optimization on thickness profile, showing profiles from before (A) and after (B) the modification

In Figure 10, one may observe a thickness drop along the body, some cases below the lower tolerance, because the parametrized AGC could not compensate the entire FDT variation along the coil. After the modification, the head end stability is preserved while avoiding thickness losses on body.

3.5 Revision of Deformation Resistance Classes

In April 2019, first trials were carried to reduce the number of both temperature and strain rate learning classes for deformation resistance calculations.

Such high number of classes, with an initial 10 x 10 matrix implies on high variability and huge differences in setups when speeds and/or temperatures varies. A classic example of this effect may be noticed when Coil Box is selected for a specific material which is usually processed bypassing Coil Box.

Trials reducing the number of classes (10 x 10 → 5 x 5 matrix) resulted in a higher process performance, with lower variability; Figure 11 presents a 17,63% increase in thickness performance and reduction in standard deviation from 18,61% to 5,63%.

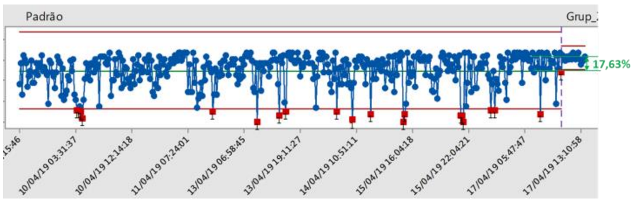

Figure 11. Head end performance for Low Carbon grades (Range = ± 0,025 mm).

3.6 Management / 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 12:

- Force and temperature performance;
- Number of iterations on calculation;
- Entry and finishing temperature homogeneity;
- Thickness defects occurrences and stratification by material / dimensions.

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

Figure 12. Examples of automatic reports showing preventive and reactive process indicators related to the thickness performance.

4 CONCLUSION

After deploying the actions, the overall thickness performance was increased by 7,60%, considering process tolerances (Figure 13).

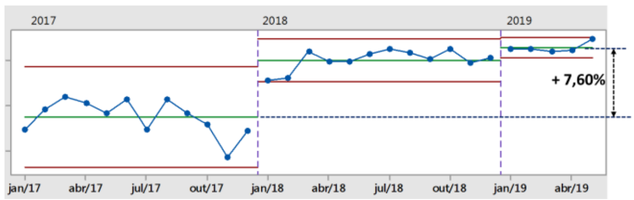

Figure 13. Monthly thickness performance considering process tolerances (2017 - 2019)

Also, it is important to notice the reduction of standard deviation of thickness performance in 2019, reflecting a more stable process (2017: 1,96% → 2019: 0,56%)

This implies on the reduction of internal yield losses related to thickness defects, which reduced by 53% (Figure 14).

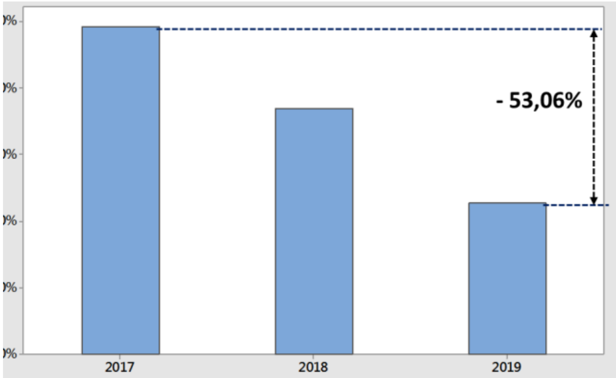

Figure 14. Yearly yield loss related to thickness deviations (2017 - 2019)

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