DEVELOPMENT OF NEW STEEL GRADES AT ARCELORMITTAL TUBARÃO: AN OPERATIONAL PERSPECTIVE*

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Abstract
Driven by market trends, increasing environmental accountability, government regulations and fostered by the Company's strategic plan, ArcelorMittal Tubarão has developed new steel products to deliver better solutions to fit each customer's needs. This often translates in higher strength, more complex and dimensionally challenging (thinner and wider) steels to attend a broad array of goals, such as reduction of vehicles fuel consumption and carbon emissions, increase in fatigue performance of heat treated parts, higher load capacity per net weight in vessels or wagons and lower supplying lead time as ArcelorMittal Tubarão establishes itself as a domestic option for so far imported grades. Based on the annual Product Development Plan, a structured workflow involves technical discussions from an operational point of view about safety issues, metallurgical project, steel grade family definitions, offline simulations prior to field trials, deformation resistance and process parameters adjustments and scheduling strategy. As a result of the increasing synergy between the areas, the share of new materials developed in recent years has been sustainably increased up to 15% in 2018, adding value to the final product without impact on hot rolled coil output and with a low cobble index.
Keywords: Hot rolled coils; Product development, New materials

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1 INTRODUCTION

1.1 ArcelorMittal Tubarão Hot Strip Mill

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

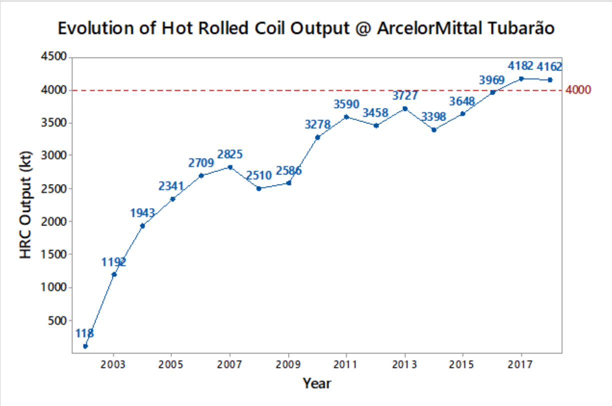

Figure 1. Evolution of HRC Output at ArcelorMittal Tubarão (2002 – 2018).

Accordingly to its current layout, 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) (Figure 2)
- Laminar Flow
- 2 Hydraulic Downcoilers

Figure 2. General view of the Finishing Mill 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

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 Product Development Plan

Between 2012 and 2014, as new and more challenging grades were tried out, cobble rate (Figure 3) and yield losses (Figure 4) related to mill instabilities during development phases increased approximately 275% and 240%, respectively.

On the other hand, during the same period the new grades share on HSM portfolio doubled (Figure 5).

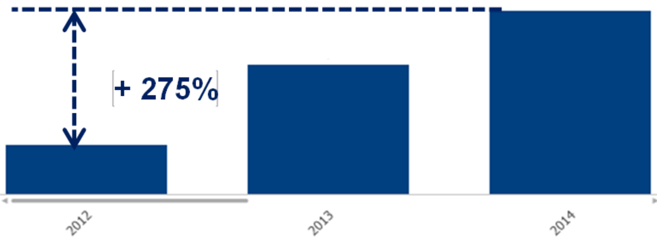

Figure 3. Cobble rate of grades under development (2012 – 2014) showing an increasing trend.

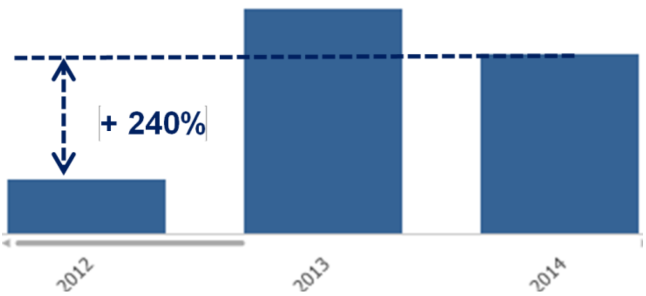

Figure 4. Yield loss related to instabilities during new grades development.

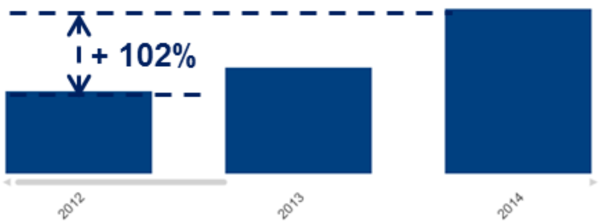

Figure 5. New grades share evolution – Weight % (2012 – 2014)

Therefore, driven by market trends[3,4,5], increasing environmental accountability and governmental regulations, it was clear the need to review operational procedures and internal organization to reduce instabilities during new product development not only due to yield related costs, but also to reduce mill stops due to cobbles generation that could jeopardize the compliance with production plan.

2 MATERIAL AND METHODS

From 2015 on, a new set of internal procedures were defined in order to improve trials planning and forecast inadequate mill setups and more favorable rolling conditions.

2.1 Internal organization of Process Control team

While Metallurgy team was already organized by steel application cells, both Product Development and Quality Control teams, the new trials were conducted by few specialists from the Process Control Team. As the number of new trials increased, the original centralizing structure created a bottleneck in the Process Control Team with few specialists being responsible for evaluating, planning and carrying out field trials.

The logical solution was to replicate a similar "Steel Application Cell Structure", including all staff members from Process Control Team with one senior specialist as coordinator and support for all cells (Figure 6).

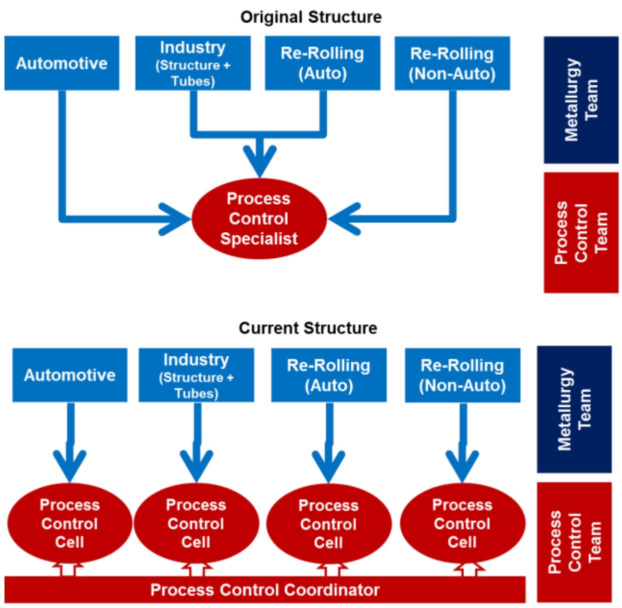

Figure 6. New cellular organization of Process Control team regarding product development

Some advantages of the new structure are listed below:

- Speeds up product development.

- Tightens the relationship between areas.
- Provides uniform knowledge about the processes to all team members.
- Develops a wider sense of ownership among all team members.

2.2 Evaluation and Follow Up of Product Development Plan

After gathering new product demands from Marketing Department, Customers Assistance and R&D, the items are recorded in a document and submitted to all areas (Steelshop, R&D, Metallurgy, Hot Strip Mill, Finishing Lines, Cold Rolling / Pickling Lines) to evaluate:

- Safety issues related to materials (i.e. debris projection of brittle/high carbon steels, spring effect, etc) .
- Capability (dimensions vs. mechanical properties, surface requirements).
- Technological gaps.
- Deadlines.

The agreed dimensions and grades are then scheduled throughout the year and periodic meetings are carried out to follow up its overall performance.

2.3 Offline Simulation of Rolling Conditions

In 2015, the Automation (Level 2) team provided an offline simulation tool with the exact human machine interface displayed at the Operator's screen at HSM pulpit, containing the same model used by Level 2 to calculate the mill setup (Figure 7).

Figure 7. Finishing Mill Off-line simulation screen

Now, each specialist can evaluate and/or simulate in advance:

- The better family in the model to classify the new steel grade
- Load distribution / reductions
- Deformation resistance adjustments
- Definition of process temperature
- Optimum condition of cooling systems

Another important feature of this tool is to foresee and to define countermeasures to setup errors due to non-convergence of mathematic model, anomalous load distribution, risk of cobbles, among others.

2.4 Technical Discussions among involved teams (Metallurgy, Process Control, Operation, Automation / Level 2, Scheduling, R&D)

Based on the offline simulations, another round of technical discussions may be required to improve success probability of trials.

These rounds are necessary to:

- Present all safety risks and to define the best strategy (rolling after administrative hours, system limits to cooling flow, higher interval between strips, etc)
- Evaluate an alternative Metallurgical project (chemical compositions, process temperature, draft / reduction schedules, etc)
- Define scheduling strategy (position in the lineup, thickness and width steps, steel grades before and after the trial, etc)

2.5 Trial documentation

After all the previous steps, an Internal Experiment Plan is written and validated by all areas, including all recommendations and the specialists responsible for the trials. Usually, a more conservative approach is taken for critical grades first trials when no learning data is available for the new product. This includes higher discharging temperatures, slow automatic gauge control (AGC), descaling restriction at the finishing mill, among others.

2.6 Mill Conditions checklist

By the week of the trial, conditions of the Hot Strip Mill must be evaluated to assure better results. Among the checked items are reheating issues (heterogeneous profile, soaking, temperature compliance), mill stretch conditions (stiffness, differential stretch Operator x Drive side), CVC clearances, roll gap lubrication condition, leakages, *et cetera*.

2.7 Result Evaluation / Standard Review

The specialist responsible for the trial must evaluate the results and review – if necessary – the procedures to assure a stable rolling and compliance with the quality requirements. At this point it is also pointed out if the item (grade x dimension) should be released to mass production or new trials are required.

2.8 Routine Management

To improve equipment and process reliability, autonomous groups divided by area (Furnaces, Roughing Mill, Finishing Mill, Down Coilers / Conveyors), with specialists from Process Control, Operations, Maintenance and Quality were created to gather in a weekly basis to discuss equipment conditions and define action priorities.

New KPIs based on automatic reports (Power BI, QlikView) were created to follow trends and proactively act in case of disturbances. Specific problem solving meetings may take place in case of a specific issues that must be addressed.

3 RESULTS AND DISCUSSION

As foreseen, the share of new and critical materials increased 192% from 2014 to 2019, bringing a more profitable but challenging mix (Figure 8).

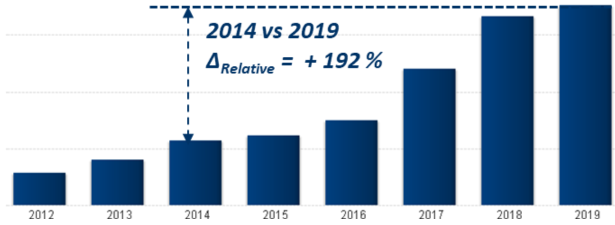

Figure 8. New and critical grades share evolution (2012 – 2019).

Nevertheless, comparing 2014 and 2019, both cobble rate (Figure 9) and yield related to cobbles with new grades (Figure 10) decreased 72,8% and 84,9%, respectively.

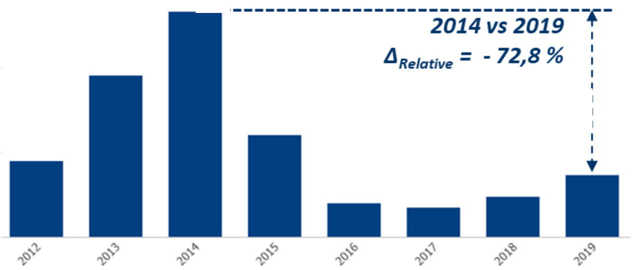

Figure 9. Cobble rate for new grades (2012 – 2019).

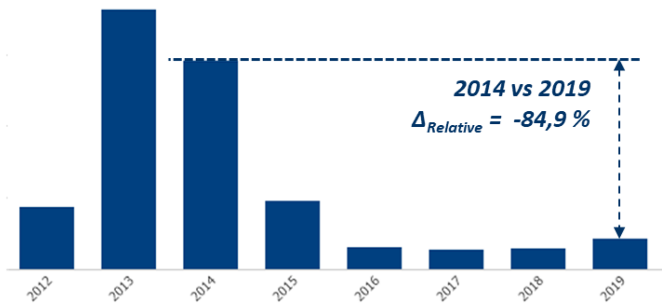

Figure 10. Yield loss related to cobbles with new grades development (2012 – 2019).

4 CONCLUSION

Market trends, increasing environmental accountability, government regulations and Company's strategic plan have driven ArcelorMittal Tubarão to develop new steel products to deliver better solutions to fit each customer's needs. This often translates in higher strength, more complex and dimensionally challenging (thinner and wider) materials.

To cope with this new scenario, it was necessary to review the operational perspective of product development by adopting a more flexible and lean philosophy, seizing the knowledge of all specialists from HSM Process Control Team.

A new cellular structure was defined as a key point to speed up the product development and tighten the relationship between the areas. When combined to an offline simulation tool provided by Automation team, this also allowed a deeper evaluation of each development prior to field testing, anticipating failures and increasing success rate.

As a result, even with a more challenging product mix throughout the years, cobble rate and yield losses reduced by almost 73% and 85%, respectively.

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