ENERGY EFFICIENCY INCREASING IN SLAB REHEATING FURNACE OF A STEEL PLANT*

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Abstract
The energy efficiency of reheating furnaces is a continuous challenge, as these equipment consume a representative portion of the total fuel of an integrated steel plant. Therefore, any investigation and implementation which brings improvement in this figure become an important issue for the mill competitiveness. In the case of production delays due to external factors (the condition addressed in this work), whether predicted or unforeseen, the slabs remain inside the furnace with high temperatures in order to avoid production delay during the production restart, elevating the specific consumption and scale formation. This work increased the energy efficiency of the two ArcelorMittal Tubarão's walking beam reheating furnaces, by reducing the consumption of mixed gas during production delays (either scheduled or not) lasting less than 3 hours. The objectives were achieved through improvements, among them, tuning of Level 2 automation system parameters, automatization of procedures and operational training. The work resulted in a 34.4% fuel gas consumption reduction during the delays.
Keywords: Energy Efficiency; Reheating Furnace; Production Delay.

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1 INTRODUCTION

ArcelorMittal Tubarão (AMT), founded in 1976 under the name of Companhia Siderúrgica Tubarão, as a state-controlled joint venture, started operations in November 1983 with a production of 3Mt/y of steel slabs [1].

In 2002, the Hot Rolled Strip Mill (HSM) was installed with nominal capacity of 2.0 Mt/y, focused on the domestic market, incorporating the most advanced technologies available in the market, among them the "digital furnace", new design of combustion control and slabs reheating [2].

In this design, the burners work in an optimal burning regime, allowing the maximum utilization of the applied energy, unlike conventional furnaces, where the burners have a lower efficiency when they operate at lower flow than projected.

It was also highlighted in that project, the Level 2 automation system (L2), designed to optimize product quality and uniformity as well as provide energy cost savings.

In 2009, the expansion of the AMT HSM was completed with the installation of the second reheating furnace (RF), which increased the production capacity to 4 million tons/year. It is currently operating at a rate of 4.2 Mt/year [3].

2 THERMAL EFFICIENCY OF REHEATING FURNACES

Thermal efficiency of heating equipment, such as RFs, is the ratio of heat delivered to a material and heat supplied to the heating equipment.

The purpose of the heating process is to introduce certain amount of thermal energy into product, raising it to a certain temperature to prepare it for additional processing or change its properties. To carry this out, the product is heated in a furnace [4]. The diagram in Figure 1 represents visually various outputs and losses so that specialists can focus on finding improvements in a prioritized manner.

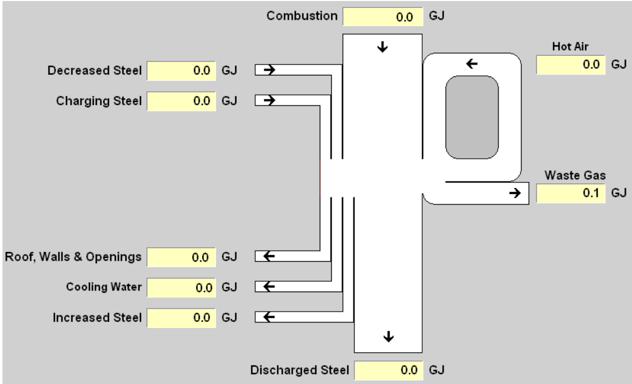

Figure 1. Sankey diagram for a heat balance.

In RFs, the thermal efficiency and uniform heating play an important role in the reduction of energy cost and minimization of metal defects. The purpose of a slab RF is to provide uniformly heated slabs at the discharge end of the furnace before they are rolled [5].

It is essential to improve the efficiency of furnace by saving energy and to get higher yields, less unwanted grain coarsening and more homogeneity in the products and to obtain better thermo-mechanical properties of the steel.

To achieve these requirements, it is essential to adopt modern heating control system/technology for the better management of energy in the present scenario for faster industrialization and less resources of energy as well as eco balance [6].

3 DELAY MANAGEMENT

The fuel consumption in a RF depends not only on the average discharge temperature, which itself depends on the size of the slabs as well as the quality of the steel but also on the production time, the schedule downtime and the delay time [4].

Thus, higher discharge temperature will increase fuel consumption, scale formation and reduce furnace efficiency. The usage of optimum thermal curves and delay strategy will ensure optimal discharge temperature resulting in reduction in fuel consumption and scale formation [6].

3.1 Level 2 Delay Strategies

The calculated set-points must be accommodated to any changing operating conditions. This is even more critical as the changes in production rate must preferably be anticipated to allow for the necessary response time due to the thermal inertia of the furnace.

Production delays (either scheduled or not) must also be handled to prevent against slab overheating, waste of energy and scale formation. To properly anticipate production variations, it is essential to know beforehand the individual rolling-times of slabs and delay duration.

The advantage of L2 to face production delays is their ability to optimize the ramping of furnace set point temperatures over time during scheduled and unscheduled delays on mill [7].

Since the unscheduled delays are unexpected, the end time is usually not known in advance. When such delays are encountered, the zone setpoints are reduced to force the burner to reduce the firing rate.

The delay setpoint is directly proportional to the length of the delay. Longer the delay duration, more the temperature setpoint is reduced [8]. So, the model can reduce the energy consumption and the observed reduction in scale build up during the delays lead to increase yield.

Schematically the set-point profile during a delay is represented on Figure 2.

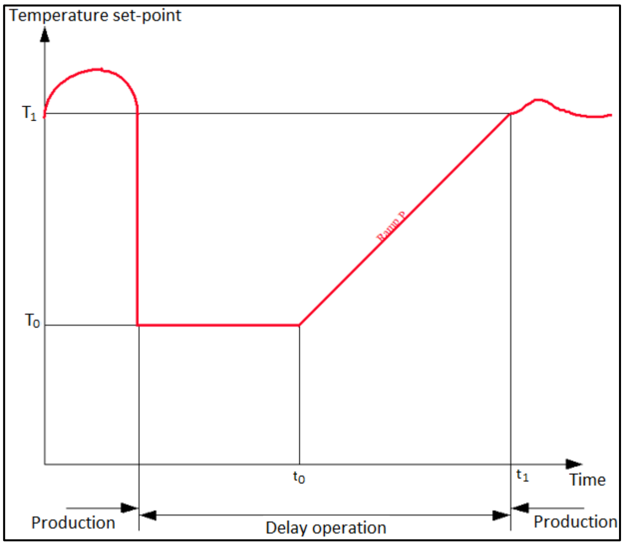

Figure 2. Set-point profile during a delay.

Where:
T_0 = Delay temperature;
T_1 = Temperature to be reached when production resumes;
t_0 = Time of heat-up restart;
t_1 = Time o production restart;
P = Heat-up ramp.

3.2 Scale Formation

The scale formation in RF represents a yield loss of steel. The yield loss in reheating operation varies from 1.50% to 2.50% by weight as well as energy losses [6].

The scale formation is strongly dependent on surface temperature of metal and residence time in furnace. It also depends on percentage of oxygen present in combustion product [6]. Temperature is the most important factor which, influences oxidation of metal.

Oxidation also causes burning and melting of the grain boundaries in the metal. This defect cannot be rectified. To prevent melting, overheating and burning, heating regime of the metal should be observed carefully especially during delays in the mill [6].

4 MATERIAL AND METHODS

This work used statistical tools to support changes in L2 software with purpose of increasing the energy efficiency of ArcelorMittal Tubarão (AMT) slab RFs by reducing the consumption of mixed gas during production delays (either scheduled or not) less than 3 hours.

The following basic performance requirements have been addressed:

- Minimizing scale formation;
- Avoiding slab overheating;
- Low energy consumption and minimal heat losses.

4.1 Furnaces' Key Attributes

AMT's RFs zones and burners are configured according to Figure 3 with the following key attributes:

- Manufacturer: Fives Stein (France);
- Type: Walking beam reheating furnace (3 sections staggered skids);
- Furnace inner length: 55.600 m (Distance between inner charging and discharging doors);
- Inside width: 12.100 m;
- Heating capacity: 400 T/h for 250 x 1250 x 11500 mm (reference slab).

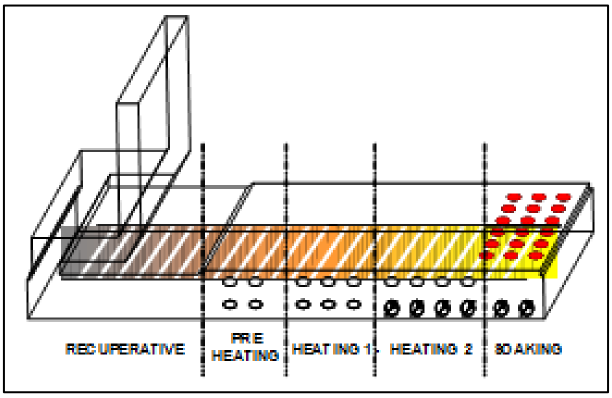

Figure 3. Furnaces zones and burners [4].

4.2 Slab Overheating

Figure 4 shows a overheating red alarm/popup in furnace number 2 during an unplanned delay indicating that the L2 delay strategy could be adjusted to increase thermal efficiency of both furnaces during the delays.

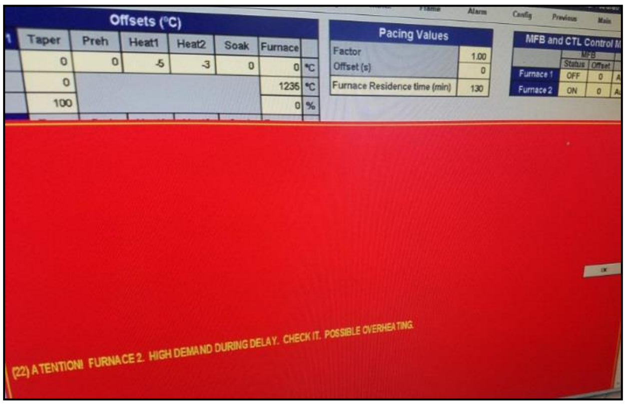

Figure 4. Overheating red alarm in furnace 2 – "Attention! Furnace 2. High Demand During Delay. Check It. Possible Overheating."

According to Figure 5, both furnaces did not show significant difference in gas flow rate during the delays. Based on this observation, it was considered that the analyzes and the results from one furnace could be extended to the other.

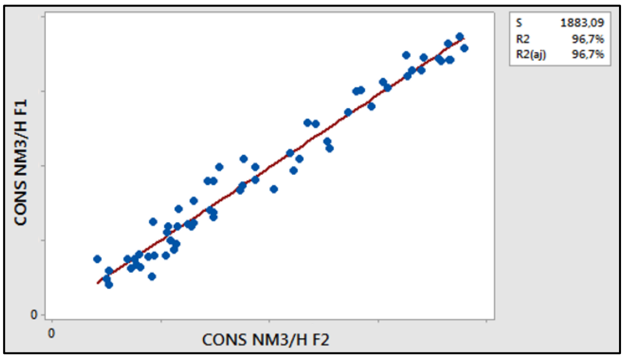

Figure 5. Furnaces consumption during the delays.

As can be seen in Figure 6, the slabs overheating during delays occurred in both furnaces at the time. The full bar-graph represents the difference between end of zone target and average product temperature (underheated in red and overheated in blue). In this example, the slab overheating reached 250 °C in heating zone 1.

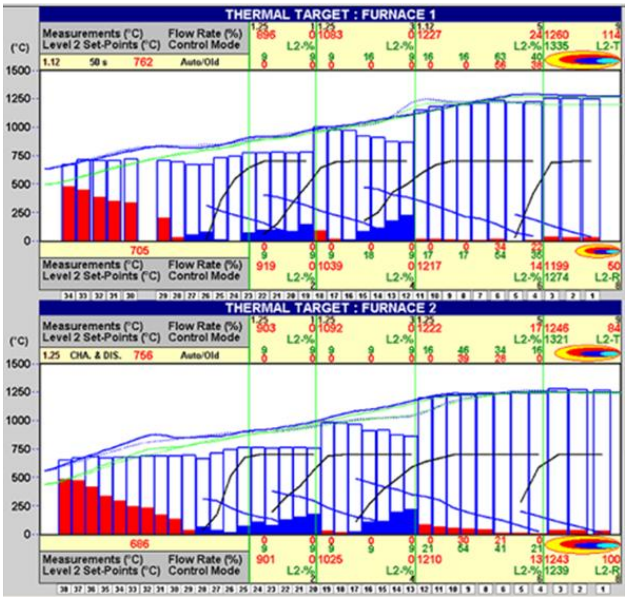

Figure 6. Slab overheating during delay.

It was also observed that the gas flow rate was related to the delay duration, the shorter the delay duration, the greater the consumption (see Figure 7). Physically this behavior can be explained by the large thermal inertia of the furnace which limits rapid changes in the temperature.

For this reason, as soon as an unexpected delay occurs, the operator must enter the probable duration of the delay. This type of delay is called "Immediate" Delay and depends solely on the operational input.
However, for various reasons (e.g. forgetting, inaccuracy of duration, lack of knowledge), this functionality was not being used in most cases, resulting in loss of efficiency of the furnaces.

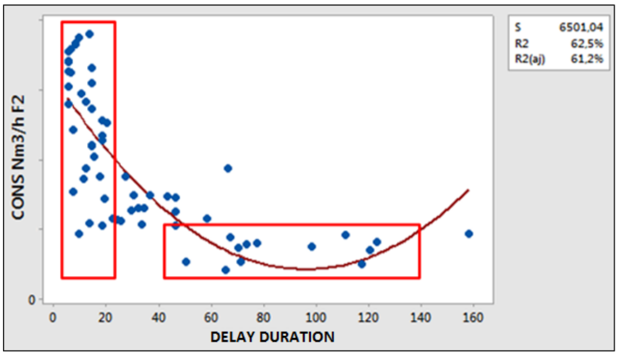

Figure 7. Delay duration and gas flow rate.

For that reason, several improvements were developed in the control systems. In this article we will highlight the ones associated with the L2 delay management module/strategy.

4.3 Noticed Delay

Another important type of delay existing in L2 is called "Noticed" Delay. When the application does not record any discharging during a given time, it itself declares the delay called "Noticed" delay. The operator cannot remove a notice delay because they are automatically removed after discharging a product.

Adjustments were made in the Noticed Delay parameters in order to avoid overheating and extend the delays in the return of production (end of delay).

4.4 Shift Function

During delays, there is a significant reduction in the heat demand required to maintain the slabs heating, which damage the oxygen excess control inside the furnace.

In addition, small values of heat demand are concentrated in powerful zones causing consumption steps that are harmful to the air and combustion gas pressure control.

In the left side of Figure 8, the furnace was operating in full demand. It can be noticed that the mean and the dispersion error are smaller than the central, when the furnace was operating at low demand.

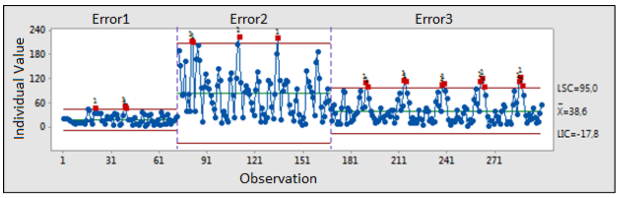

Figure 8. Combustion gas pressure control error.

Therefore, changes were made on L2 for auto-startup the shift function during Noticed Delay.

The shift function aims to improve the thermal distribution for lower demands since it consists of sending the opening command, according to demand, to only one side of the furnace at each cycle.

The cycle is related to the time to obtain 100% of the heat demand for a given zone. When smaller the cycle the more precise becomes the temperature control, but there is a trade-off between the capacity of the final equipment (shut-off valves) and the performance in obtaining the required demand and homogeneity. Figure 9 shows a schematic view for two consecutive cycles of a zone.

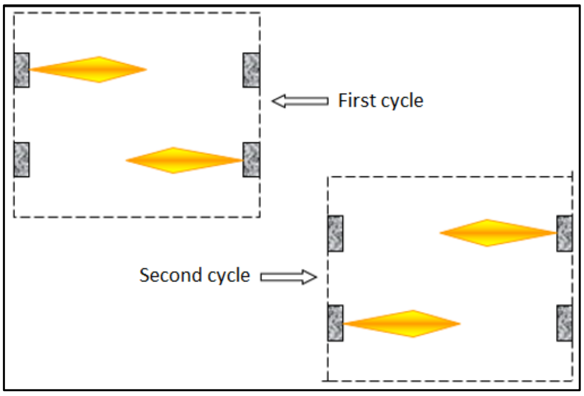

Figure 9. Shift Function.

5 RESULTS AND DISCUSSION

Figure 10 graphically compares the delays gas flow rate before and after the action plan conclusion. Data were collected in June 2018, when no action had been implemented, and October of the same year, when all actions were completed.

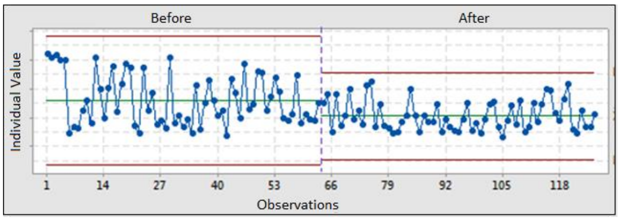

Figure 10. Initial and improved process.

It can be affirmed with a high degree of confidence that the median and variance of the improved process are smaller than the initial process. The work resulted in a 34.4% fuel gas consumption reduction during the delays as shown in Table 1.

Table 1. Main statistics indicators

	Reduction %
Average	34.4
Median	30.4
Std deviation	32.1

6 CONCLUSIONS

The objective of this work was achieved, since the company achieved the process improvement with cost reduction, which is a crucial factor in steel products market competitiveness that this segment is facing in the last years.

The results obtained showed the effectiveness of the use of data-driven approach/methodology in continuous improvement projects.

In addition, it also demonstrated the importance of tuning for better performance. A well-tuned furnace is more efficient and use less energy. In transient production, specifically during unscheduled delays, L2 could help deliver energy savings by being able to better manage the furnace temperatures.

With new tuning parameters, L2 could be more aggressive in controlling temperature reductions during the delay period, thus resulting in decreased energy consumption.

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