INCREASE HOT CHARGE - AUTOMATION REALOCATION SLABS *

José Fabiano Martins Assunção[1]
Nayara Coutinho[2]
José Fagundes[3]
Henrique Carneiro Pinto[4]
Leonardo Araújo Peruch[5]
Marco Túlio Costa[6]

Abstract

The objective of this project was to increase the hot charge by reducing reheating energy consumption and raising the productivity of ArceloMittal Tubarão's hot strip mill by changing the HSM's schedule process with optimization of the relocation process of slabs after HSM's chance with focus on slab temperature in reheating time. The project began with the revision of metallurgical rules for the relocation of materials, definition of criteria temperature setting (hot / cold), definition of restrictions of the process and review of modus operandi scheduling process. With the implementation of the process / system it is expected to achieve a 10% increase in the hot charge index in slabs reheating furnaces and increase productivity of the ArcelorMittal Tubarão hot strip mill
Keywords: Optimization; Hot Charge; Slab Yard; Hot Strip Mill

[1] *Engenheiro Metalúrgico, Especialista em Desenho Integrado de Processos, Gerência de Desenho Integrado de Processos, ArcelorMittal Tubarão, Vitória, ES, Brasil.*
[2] *Engenheira Produção, Especialista em Desenho Integrado de Processos, Gerência de Desenho Integrado de Processos, ArcelorMittal Tubarão, Vitória, ES, Brasil.*
[3] *Engenheiro Metalúrgico, M.Sc., Especialista de Desenvolvimento de Processo e Modelamento, Gerência de Área de Confiabilidade de Produção de Bobinas, ArcelorMittal Tubarão, Vitória, ES, Brasil.*
[4] *Engenheiro Mecânico Especialista em Eng. Mecatrônica, Consultor de Sistemas, PSI Metals Brasil LTDA, Rio de Janeiro, RJ, Brasil.*
[5] *Mestre em Ciências da Computação, Gerência de Área de Sistemas de informação, ArcelorMittal Tubarão, Vitória, ES, Brasil.*
[6] *Sistemas de informação, Especialista de programação de produção, Gerência de Área programação da produção, ArcelorMittal Tubarão, Vitória, ES, Brasil.*

1 INTRODUCTION

Continuous improvement, innovation and process optimization aligned with industry 4.0 are drivers for development projects in the area of integrated process design of ArcelorMittal Tubarão. According to Slack and Lewis [1] "Companies believe that the way they manage their operations is that they distinguish them and put them above their competitors." The improvement of production processes is essential to increase the productivity of the man, the productive units and to maintain operational stability. For Gaither and Frazier [2] the essence of operations strategies is the formation of positioning strategies (customized or standardized products, production focused on the product or in the process, and stocks based on production for stock or production On request).

In order to elevate the hot charge index, reduce the gas consumption in the reheating furnace and increase the productivity of the Hot Strip Mill (HSM) of ArcelorMittal Tubarão, a working group was created coordinated by the Integrated design management of Processes, for the study of solutions in the search for the increase of hot charge index in the rolling process. In the macro strategic plan, we have a sequence of projects aligned with this objective, being this work an action of this plan.

The project began in 2018 with the revision of metallurgical rules of material relocation, definition of the criteria of definition of slabs temperature (hot/cold), groupings of material in sequence/chance, impacts on the process/Level 2/Level 3 of the relocation of slabs very close to its effective charging, change evaluation (MTS-Minimal Tecnical Solution) of the process reallocation of slabs (slab temperature, handling slabs) prioritizing the exchange of slabs in sequence by hot slabs available in slabyard HMS's with optimization handling.

Currently, the project is in the IT construction phase of the new business rules, with implementation forecast in September 2019, with great expectation in the potential increase of hot charge index and increased productivity of the Hot Strip Mill of ArcelorMittal Tubarão.

1.2 General concepts of planning, scheduling and production control

It is up to the planning and control of production (PP) the management of interests between sales and production, determining the volumes to be sold and produced, delivery deadlines, production priorities and inventory levels, always aiming at low costs, High yields and operating index of productive areas with the assurance of meeting the commitments made with customers regarding volumes and delivery times, this all with low inventory levels.

For Slack [3] "The purpose of planning and control is to ensure that production processes are effective and efficiently and that they produce products and services as required by consumers".

Production planning and control is basically divided into three segments, which can be long-term, medium-term and short-term planning.

According to Davis, Aquilano and Chase [4], long-term planning should contain the overall objectives of the Organization and its goals for the next 2 to 10 years and takes into account the company's capacity, as well as the economic and political scenario.

The medium-term planning can be subdivided according to the following items:

- <u>Aggregate production planning</u>: monthly production Planning for the main products or productive areas, in order to minimize production costs, inventory levels and meet demand.

- Master Production Planning (PMP): PMP depends on the product, market and resource plan and generates for the operation the quantity and data of the individual final products. It is performed for a period of 6 to 8 weeks.

-Short-term planning: accomplished through detailed programming of when each operation should be performed at each work center and how long it will take to be processed, and ultimately control of production activities, which is the daily refinement of Programming, as it involves the programming and control of day-to-day activities on the factory floor.

1.3 Scheduling Process

According to Arnold [5], "Sequencing is a short-term planning technique for real jobs to be operated at each work center based on capacity and priorities. Priorities, in this case, is the sequence in which work should be operated in a work center. "

Production sequencing refers to the production programming activities closest to the operation, it is at this stage of programming that changes are made due to operational problems, last-minute priorities or any other Occurrences that have not been previously planned and must follow some rules in order to maximize the results, and in most cases it is impossible to meet all the objectives at the same time, even because, several of these rules, are technical rules and of operational and equipment and/or quality constraints and therefore, in most cases, cannot be unfulfilled. In Figure 1, we have a schematic representation of the process.

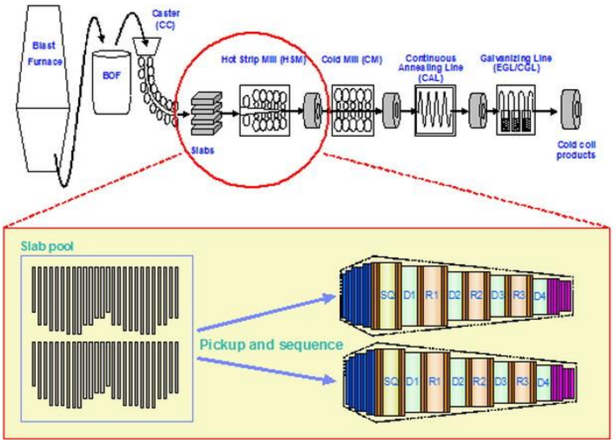

Figure 1. Schematic representation of the process

1.4 The process of charging slabs

The slabs charging process [6] includes the removal of the steel slabs from a continuous casting machine and loading them into a slabs reheating furnace. The temperature at which the steel slabs will be introduced into the reheating furnace is called ' furnace charging temperature ' and the temperature at which they will be removed from the reheating furnace is called ' Output temperature ' or ' Discharge Temperature (DOT) '. The output temperature varies according to material/chemical and dimensional characteristics of the slabs and the final product. It can also be called ' processing temperature ' because it is the temperature required for a slabs to be processed in the rolling process. The furnace charging temperature, together with the output temperature and slabs thickness, determine the processing time of each slabs in a reheating furnace, called ' Residence Time '. It is the residence time that determines the speed of displacement of a steel slabs inside a reheating furnace. There are different furnace charging temperature processes that will be detailed below.

The ' traditional ' furnace charging process is the ' cold furnace charging ' of the steel slabs in a reheating furnace. In this process, the steel slabs newly run from the

steelmaking do not go directly to the reheating furnace, they are driven to a storage yard of slabs where they are temporarily stocked before they are processed in the reheating furnace, and with this their temperatures fall so that there is no beneficial use of its heat energy. As it is a process between a steelmaking and a reheating furnace, this process is known and named in the bibliography continuous casting-cold charge rolling. It is said that the furnace charging process is continuous casting-cold charge rolling when the charging furnace temperature of the slabs in the reheating furnace is less than 400 º C, but it is very frequent that this temperature is at room temperature.
Below will be described the other hanging processes:

- 'Hot Charge ' (CC-HCR-Continuous casting -hot charge rolling), where the steel slabs come out of the steelmaking and go to ' termal tanks' in the slabyard or to any other thermal insulation and, only after a time, they are furnance charging in the reheating furnance. It is often said that through this method of furnace charging the slabs enter ' warm ' in the reheating furnace. Generally the loading temperatures are between 400 º C and 800 º C;
- ' Direct hot charge ' (CC-DHCR-Continuous casting – Direct hot charge rolling), where the steel slabs come out of the steelmaking and go straight to the reheating furnace without passing through the slabyard. Generally the charging temperatures are between 700 º C and 1000 º C;
- 'Direct hot rolling' (CC-HDR-Continuous casting-hot direct rolling), where the slabs go directly to the HSM, without first passing through the reheating furnace. For this process to be possible, the slabs should leave the MLC with temperatures above 1100 º C.

It is important to emphasize that the more direct the connection between a steelmaking and the rolling area, the lower the energy consumption due to the use of the heat energy of the steel slabs itself, however, the more difficult will be the synchronism (programming and the sequencing) between the equipments involved, ' may ' cause the subtilization of some of them, because the criteria of programming and sequencing, for example, of a steelmaking and a HSM are very diferente, i.e, very difficult to achieve a continuous flow of production.

In our working process, there are no ' thermal tanks ' in the slabyard or any other thermal insulation and only after some time, they are furnance charging in the reheating furnace. The company has already had in the past ' thermal tanks ' but have been deactivated.

1.5 Contextualization

ArcelorMittal Tubarão has 3 continuous casting machines, all of which can supply the Slabs HSM's, but only continuous casting machines No. 1 and 2 have a direct connection (via roller table) with the HSM. The slabs produced for the HSM in the continuous casting machine No. 3 are compulsorily diverted to the conditioning area for later being sent to the HSM.

The HSM in turn has a single slabyard of finished boards, and the stock of slabs available for rolling process (slabs available for the formation of sequence/chance) is 100% addressed in the HSM, that is, even if there are finished slabs ready to be rolling but not addressed in the slabyard HSM's, they cannot be scheduling to the HSM before they are moved to this slabyard. Below, in Figure 2, a general layout of the HSM slabyard.

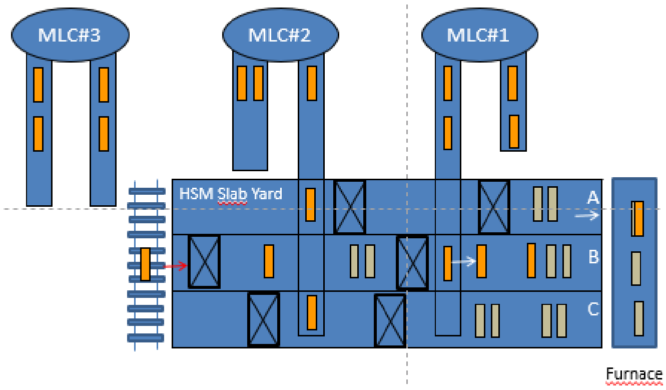

Figure 2. Layout HSM slabyard

Currently, 100% of the production of slabs in the AMT is make to order, and each application consists of specific slabs (already allocated to the orders), according to the characteristics of these requests. Thus, in the HSM's sequencing , the orders are scheduling with the slabs previously allocated to them (the allocation comes from the continuous casting machines). Often in the HSM slabyard it is necessary to have a large number of bridge moves to get to the slabs scheduling for rolling.

The Project slabs of relocation was implemented in 2015 in the company with focus reduction of slabs reduction of crane movement for formation / adjustment piles in the HSM Slabyard for later furnace charging. According to Francisqueto [7], currently the project presents gains in the order of 20% in reducing the movement of plates in the courtyard.

In 2018, the relocation of plates was developed and implemented focusing on the prioritization of hot slabs, in line with increased hot charge, reduction of gas consumption in the furnace reheating slabs and increase production of HSM.

In the current configuration of the HSM's slabyard, ways of expanding the increase in hot charge, reducing gas consumption in the slabs reheating furnaces and increasing the production of HSM are being studied.

In this context, the current project aims to evaluate optimization in the process of relocation of slabs after the release of chance/sequence of the HSM in time closest to the furnace charging, since between the sequencing of the material and its effective furnace charging we have a fairly high delta time (H) leading to a significant loss of slabs temperature.

2 MATERIAL AND METHODS

The first stage of the project was related to the determination of metallurgical rules for the slabs relocation, adjustments of existing standards. Subsequently, the rules and assumptions for optimizing the sequence were defined, prioritizing the inclusion of hot material with few impacts on the relocation process of existing slabs, that is, maintaining the basic rules of the relocation process, as per example, evaluation of possible combinations of replacing a slabs in the lamination sequence by another slabs available in the slabyard, seeking to reduce crane movement slabs in the stacks of the HSM slabyard, do not change customer service balance among others.

2.2 – Process and optimization system

The main rules designed for the slabs relocation system to prioritize the furnace charging materials considered hot were:

- Evaluation of minimum grouping of hot slabs in the rolling sequence.
- Avoid replacing hot plates with cold slabs (see Figure 3).
- Replacing hot slabs by hot slabs to reduce movement in the slabyard, one of the basic functions of the system (see Figure 4).
- There isn´t hot temperature differentiation for a warmer temperature, both of which will have the same weight for the system.

Rolling Sequence - stacks on HSM - Slab Temperature

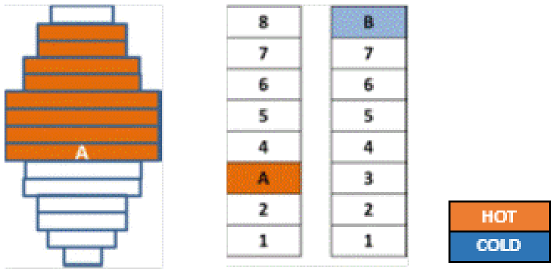

Figure 3 – Exchange not allowed, although slab B is at the top of the stack with possible combination for order A

Rolling Sequence - stacks on HSM - Slab Temperature

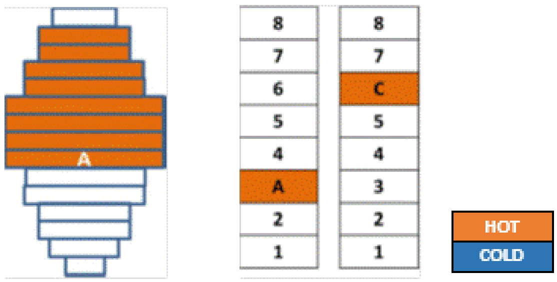

Figure 4 – Exchange allowed. The C slab (hot) located at the sixth position of the stack is also possible combination for the order A, reducing 2 unpillings.

- If there is no minimum grouping of x slabs, other rules will be applied, such as:
    - Case 1: If a order (regardless of temperature) has combinations with a hot slab and another cold and the two slabs have the same stack position or difference of y unpilling, the temperature of the slab should be priority in relation to the amount of Movements (see Figure 5).
    - Case 2: If a order (regardless of temperature) has combinations with other N slabs, the slab that causes the smallest amount of slabs moviments should be chosen.

Rolling Sequence - stacks on HSM - Slab Temperature

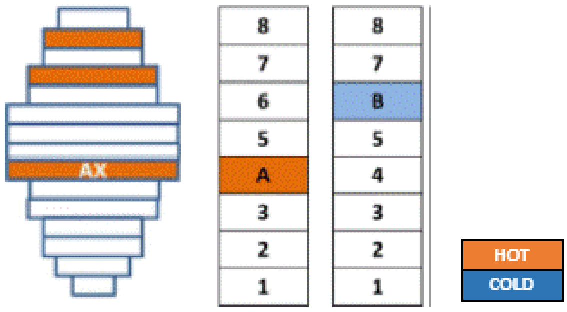

Figure 5 – The AX order has combinations with the A (hot) and B (cold) slabs, the A slab has 4 unpillings and the B has 2 of unpilling, so the plate A has priority in the relocation over the plate B, aiming the hot slabs

- Thermal Jump Restrictions (DOT): This rule evaluates the temperature jump when there is mixture of hot material with cold material and vice versa, verifying thermal equilibrium in the furnace.

Currently the relocation process occurs immediately after the process of preparing the rolling chance/sequence. As there is a sequenced front of slabs, the slabs of the new sequence will be waiting a considerable time until its effective furnace charging. Hence the new process of periodic relocation arises as a constant monitoring of opportunities for the exchange of cold slabs (and/or slabs that have lost temperature) of the chance/sequence by hotter slabs in the HSM slabyard or by newly arrived steelmaking slabs in time near furnace charging .

In this process, the system will evaluate all sequences / slabs that have been instructed and the new hot slabs that have come from the Steelworks periodically.

Slabs that are in the safety zone will not be evaluated for safety reasons..

Figure 6 shows an example of how the system will work, evaluating opportunities for cold slabs exchange of sequence 2 by hot slabs available in the slabyard. After evaluation/optimization, analysing rules chemical composition, metallurgical rules, movement of cranes/stacks, temperature slabs among others, there will be automatically exchange slabs between sequence 2 with the slabyard. At the end of this realocation process, the system may terminate the evaluation process and/or initiate the evaluation and exchange of the slabs for the next sequence to be furnace charging, which in the case would be sequence 3 to sequence n + 1. Note that the slabs belonging to sequence 0 and 1 will not be evaluated because they have slabs in the safey zone.

Example:

Figure 6 – In the example above, only sequences 2 and 3 can be reallocated. Sequences 0 and 1 because they have slabs in the safety zone will not be relocated, due to the proximity furnace charging.

3 RESULTS AND DISCUSSION

The results will be known from the implementation of the project in September/19. The expectation is that it exceeds 10% increase in the current hot charge index.

4 CONCLUSION

The expectation that the implementation of the project generates gains in the increase of hot charge index with the respective reduction of gas consumption in the furnace reheating slabs and increased productivity of the hot strip mill.

REFERENCES

1 Slack, N.; Lewis, M. Estratégia de Operações. Porto Alegre: Bookman, 2009, p.27.

2 Gaither, N.; Frazier, G. Administração da produção e operações. São Paulo: Cengage Learning, 2001, p.39.

3 Slack, N et al. Administração da Produção. São Paulo, Atlas; 2002, p.314.

4 Davis, Mark M.; Aquilano, Nicholas J.; Chase, Richard B. Fundamentals of Operations Management, 4ª Edição, MacGraw-Hill, New York, 2003.

5 Arnold, J. R. Tony. Administração de Materiais: uma introdução. São Paulo, Atlas, 1999

6 Portal PUC RIO, Sistema Maxwell. [Acesso em 5 de Maio de 2018.]; 22-23. Disponível em: < https://www.maxwell.vrac.puc-rio.br/3762/3762_3.pdf>

7 Francisqueto, Jovanir; Nascimento, Vanessa GS; Merelles, Welington B; Pinto, Henrique C; Mohallem, James Albert SS, *et al*. Otimização do Pátio do LTQ – Realocação Placas. In: Associação Brasileira de Metalurgia, Materiais e Mineração. Anais do 52º Seminário de Laminação, Processos e Produtos Laminados e Revestidos; 2015; Vitória, Brasil. Rio de Janeiro: ABM; 2015. p.178-185.