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GSMPM – BLOW CHARGE MODEL IMPLEMENTATION AT ARCELORMITTAL TUBARÃO*

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Abstract
This paper presents the results obtained on the exchange of an original old blow charge model for a new up-to-date state of art global model, employing optimization techniques and process modelling, and, the results obtained in terms of fluxes consumption reduction and the introduction of user friendly tools and practices.
Keywords: Optimization; Process control; Project management; Process models.

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1 INTRODUCTION

Oxygen steelmaking process represents about 70% of world steel production. Since its advent, its controls continue to be a challenge due to the very aggressive environment inside the reactor, which makes the application of continuous measurement sensors almost impossible. Therefore, monitoring is very limited, leading to numerical modeling based on fundamentals and statistics as a preferred method of control. Blow charge calculation model, also named as static model was the first one. Aimed at predicting what should be added to oxygen reactor, this model uses some basic models that describe thermodynamic properties (Heats) simultaneously with mass balance of idealized chemical reaction that is supposed to occur inside the reactor.

In Tubarão steelmaking such model arrived with the implementation of its BOF process in 1983. Since then, Tubarão engineers have been implementing some updating models to handle: operational deviation, new raw materials and new complexities demanded by new steel grades requirements. This procedure brought some trouble: the model became too complex to be handled and some operational vices were incorporated to it.

In order to solve these problems and to go back to the road cost optimization, productivity quality, and safety, a new model also based on thermodynamic, mass balance and statistic (although updated with new sub models, tools and data) already developed by ArcelorMittal Global R&D was implemented in Tubarão steelmaking plant.

2 BASIC OXYGEN FURNACE (BOF)

BOF steelmaking is a process where liquid high carbon dirty basic metal (hot metal), produced through iron ore reduction by carbon inside a reactor named Blast furnace (BF), and solid metal scrap is converted to steel using pure oxygen injection and some specific fluxes (mainly limes).

In order to work properly, BOF is settled with some significant peripheral systems (Figure 1) that have different functions as: oxygen injection; materials additions; gas collection, cleaning and stoking, furnace tilt, materials weighing, slag disposal, etc. Such complexes process is supported by automation systems.

The steelmaking process can reach very high temperature (higher than 1600°C), because of so, BOF needs some special ceramic material named refractories to protect its metallic shell.

Based on a model (blow charge model) recommendation, steelmaking process starts with the scrap charge in BOF via scrap box. Afterwards, hot metal is poured inside the furnace by tilting a hot metal ladle. After that, a water cooled lance is inserted into the furnace, and, throughout that, a supersonic oxygen jet impinges metallic charge, triggering some high temperature chemical reactions. During the first five minutes of oxygen injection some fluxes materials are added to the bath in order to produce a specific slag. Along the refining time (oxygen injection time) some impurities are removed by gas (eg. carbon) and other trough out the slag (eg. Si, Mn, P, S). After the total oxygen injection, which defines the process termination, the temperature and the oxygen content measurements, and, a steel sample collection are performed. The sample is sent to the main laboratory do analyze its chemical composition and, if it fits the requirements, BOF tilts and the steel taps into steel ladle while the chemical composition adjustment is performed via alloy additions. Slag is also removed from BOF to clean it to the next batch.

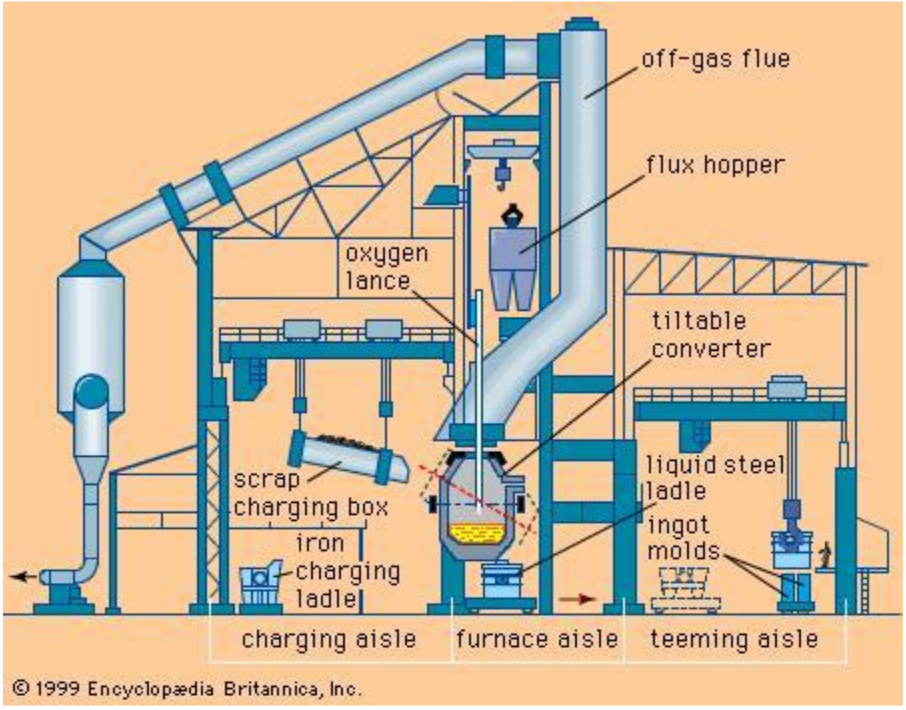

Figure 1. Basic Oxygen Furnace and its ancillary equipments [1]

3 GSMPM SOFTWARE SUITE

GSMPM stands for Global Steel Making Process Models and is a software solution (Figure 2) developed by ArcelorMittal Global R&D in order to: minimize external costs, provide flexibility to the plants on the changes and create an environment of sustainable knowledge supported by experts. It comprises a large set of models giving support to all the steps the heat goes under in the steelmaking shop. Figure 3 shows all the heat steps and the corresponding GSMPM models available.

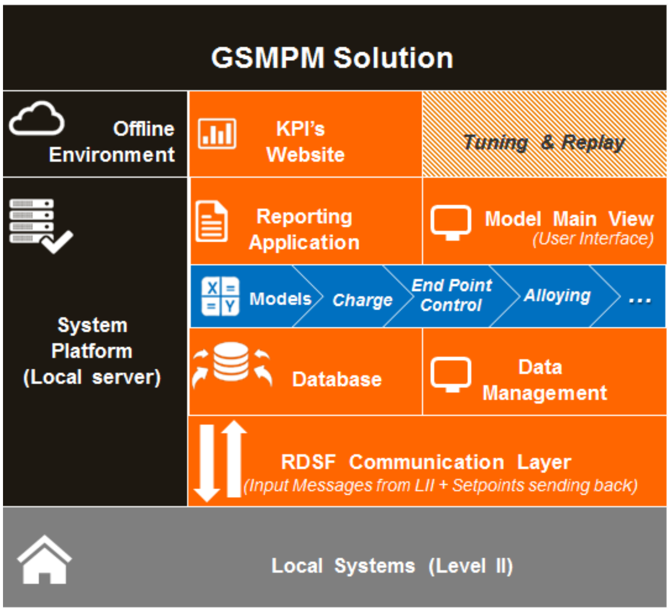

Figure 2. GSMPM software suite.

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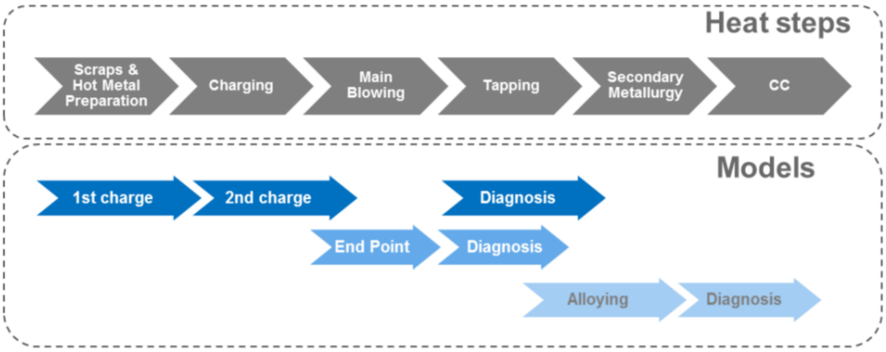

Figure 3. Steelmaking process x models.

The system employs a client / server architecture based on Windows operating system, a MS SQL Server database and a file mapping based data exchange technology to guarantee the proper communication between the different services. The communication with the clients is done through TCPIP SQL Server port while the data exchange with the steelmaking process computer is achieved by binaries messages also over TCPIP. A diagram explaining the relation between the services and the other systems is shown in a simplified way in Figure 4.

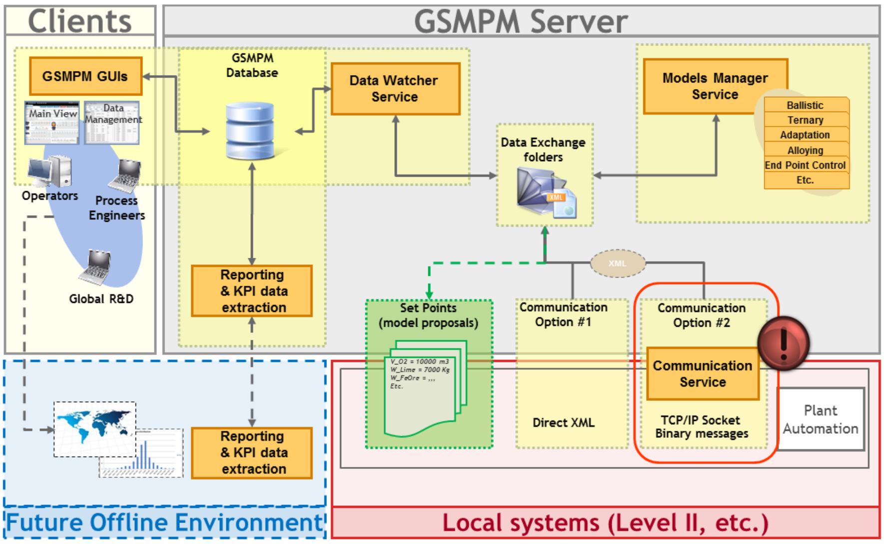

Figure 4. System architecture.

3.1 GSMPM Blow Charge model

The charge model is composed of the first and second charge models, where the first charge is responsible for the calculation of the scraps and hot metal, while the second one defines the fluxes, oxygen and coolants, or heaters, and needs to hit the heat targeted values (temperature and chemical composition) at blow end. The main objective of the charge model is to bring cost-effective recommendations on material amounts, stabilizing and minimizing end point control adjustments using for this the slag optimization module and the diagnosis step for self-learning and auto adaptation. The model is composed of three distinct modules: the ballistic, slag optimization and the diagnostic modules.

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The ballistic model is responsible for solving the mass and thermal balance of the heat, and these are some of its characteristics:

- Contains an optimization model with linear (SIMPLEX) solver
- Solves energy & mass balances considering process constraints
- Needs a slag optimization module

The ballistic model uses a linear optimization technique (SIMPLEX) to determine the best solution (lower cost solution) capable of fulfilling all the requirements set (steel specification, operational conditions, equipment restrictions, strategies) while also attending to the thermal and mass balances. The Figure 5 shows the evaluation of the set of solutions according to addition of new restrictions.

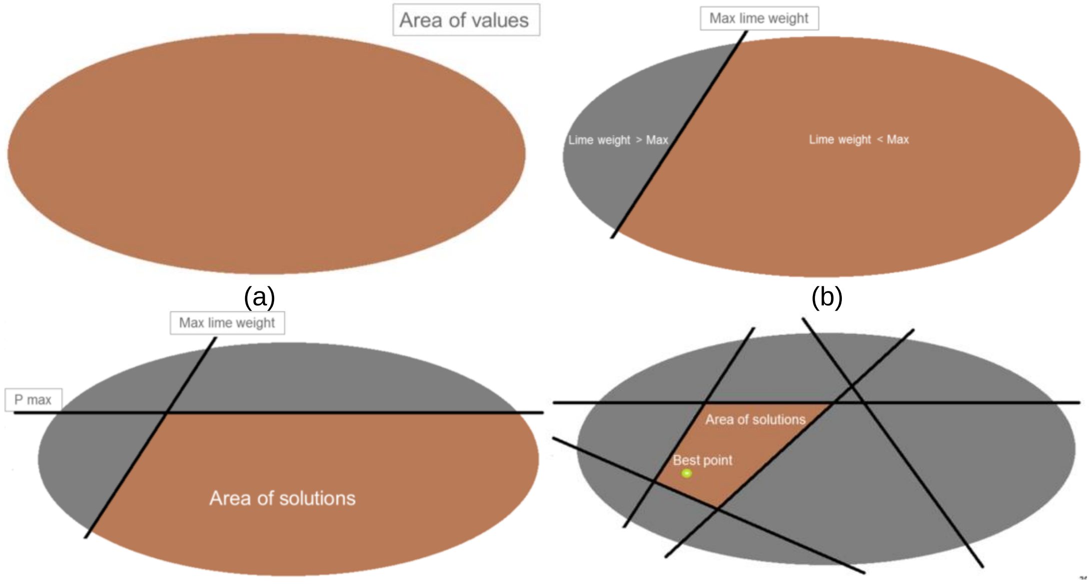

Figure 5. Simplex solution area. (a) Full area of possible solutions. (b) One restriction added. (c) Two restrictions. (d) Five restrictions solution set.

The restrictions added can be related to the heat (e.g. carbon less than 0.05%, blow end temperature equal to 1650ºC), equipment restriction (e.g. lime should be less than 20 tons), strategy (e.g. add preferably 6 tons of recycled coolant material) or operational condition (e.g. Fe in slag equal to 17%, MgO equal to 5%, or minimum slag weight 30 tons).

The second model is the slag optimization and its propositions are:

- An evaluation model which overlays the Ballistic module
- Evaluates several slag compositions possibilities
- Propose the “best” point to the user

The third and last module is the Diagnosis. The main functions of the diagnose models are:

- Confronting model’s equations to actual data
- Calculating deviations

The output of the diagnosis is a set of deviations called residuals which tries to compensate the bias generated for not knowing, or not measured, sources of errors or also included measurements errors. The residuals are calculated comparing the values foreseen at the beginning of the heat with the measured values obtained at

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the end and will be used to offset, those equations selected for adaptation, in the next heat.
Taking for example the basicity equation:

$$B = CaO/SiO_2$$

This can be calculated by the following expression, based on the weights measured of materials containing CaO and SiO2 added to the heat:

$$CaO \text{ inputs} - \text{Basicity} \times SiO_2 \text{ inputs} + b_{basicity} = 0$$

For the first and second charge models, the basicity is targeted (according to the slag optimization module): relationship allowing adjusting the CaO inputs according to the SiO_2 inputs. If the equation is not adapted: $b_{basicity} = 0$. If the equation is adapted: $b_{basicity}$ = adapted value. During the taping of the heat, a slag sample is taken and analysed. The slag analysis is so used for diagnosis, as all the inputs are known, as well as the actual basicity, the deviation ($b_{basicity}$) is thus calculated as: $b_{basicity}$ = Basicity x SiO_2 inputs - CaO inputs. If the equation is adapted, the calculated $b_{basicity}$ will be adapted to be taken into account for the next heat.

3.2 GSMPM Blow Charge model implementation

The implementation of the model was conducted since the initial discussions by a multidisciplinary team composed of engineers from the plant and a local researcher, and also, researchers from foreign centers.
The project was divided into two big parts separated by a go / non go decision. The first one had the following steps:

1. Data acquisition;
2. System configuration;
3. Standalone evaluation;
4. Technical architecture discussion;
5. Project definition.

After the consolidation of the viability of the project and the consequently go decision, the second part of the project took place:

1. Plant development;
2. Shadow mode / operators training;
3. Validation;
4. Project closure.

The two parts together summed up a two years development.

4 RESULTS AND DISCUSSION

Figure 6 shows the main screen of GSMPM where the second charge model tab is being shown. At this screen it is possible to see all the heat input data (scraps and hot metal), the targets (temperature and chemical composition range), fluxes calculated / added, estimate chemical composition of the steel and slag, current adaptation parameters amongst other information.

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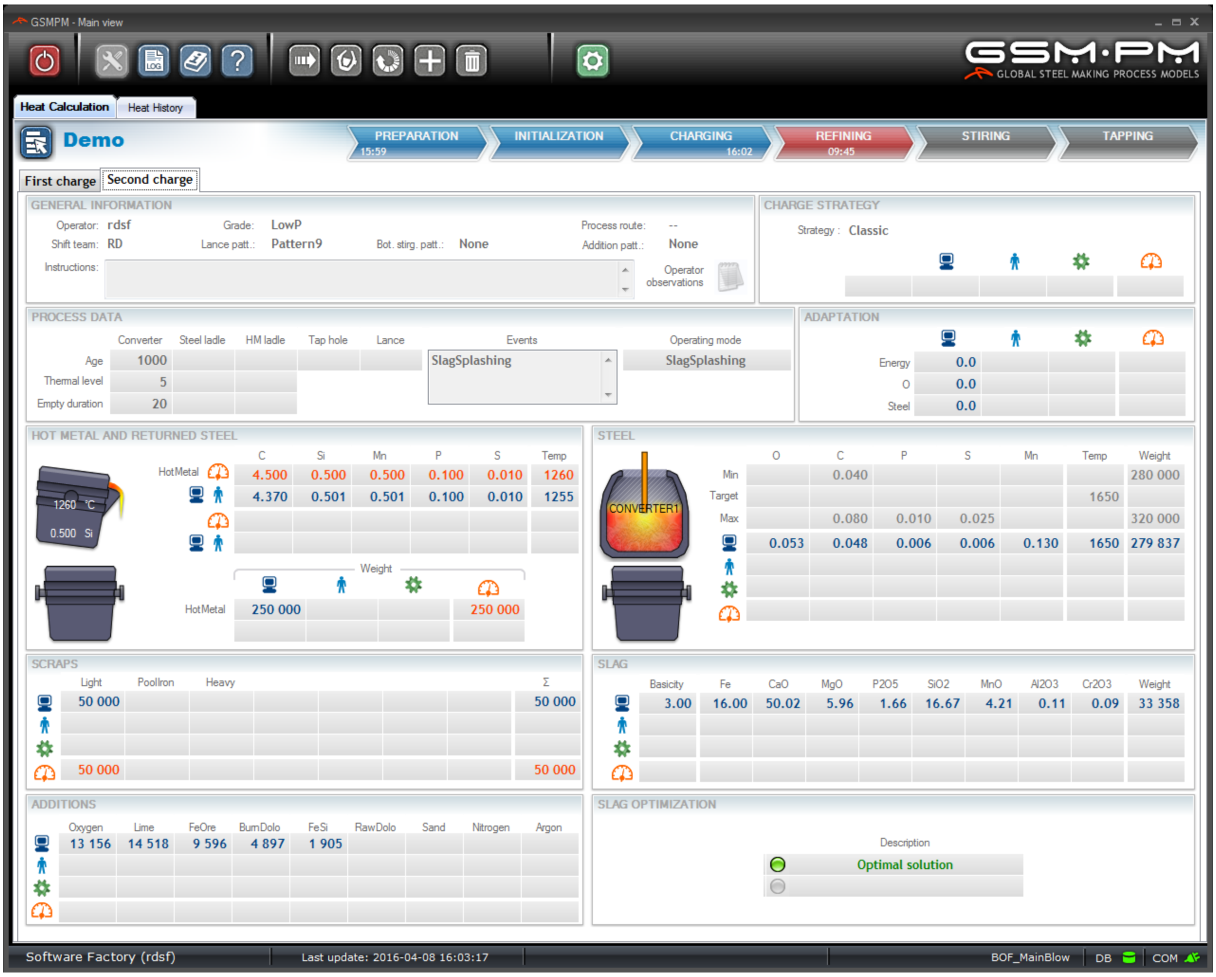

Figure 6. GSMPM main screen

The new system also implements a data management tool (Figure 7) making it easy for the technical staff to change any necessary parameter to adapt the model to the current practice or materials.

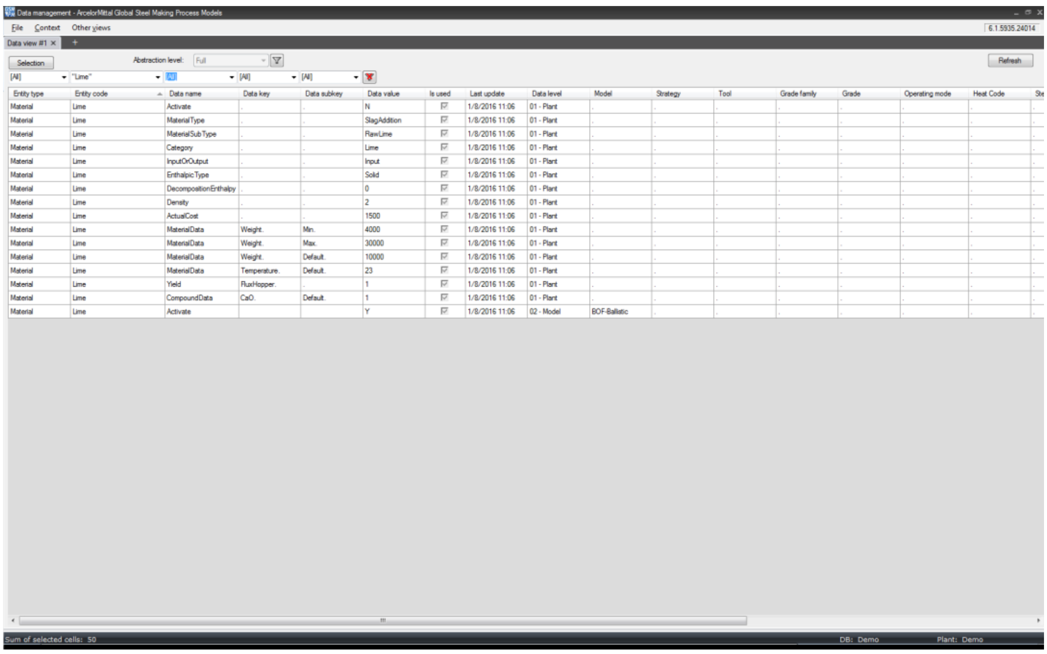
Figure 7. Data management interface

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In order to get the model running according to the current practices of Tubarao Plant, and get the most from both, process and system, the strategies had to be somehow designed and well formatted before being input into the system. Strategies like maximizing the use of byproducts up to our production limit, maximizing yield up to the ladle capacity taking into account the alloying to be added or rules to minimize iron in slag and slag formation are examples of such work. With all the plant strategies designed and materials and known process characteristics, they were entered into the system. The system was then put into test in parallel with the old one. The tests ran for three months, while all the calculated values were compared and verified to be within reasonable expected values and the rules were adapted as the results deviated from the expectation. So the system was rolled out in October 2015 and it achieved a very fast utilization rate, greater than 99%, showing also an expressive reduction on lime consumption, which can be clearly seen in the graph in Figure 8.

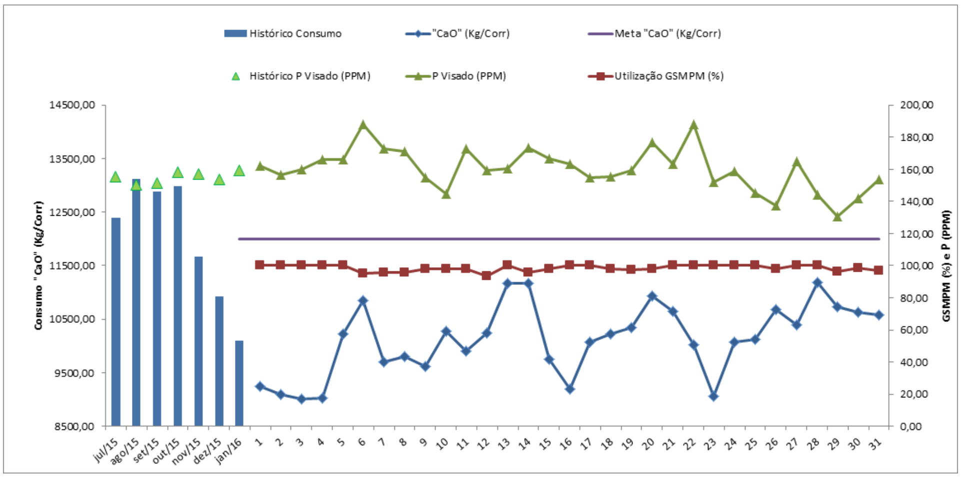

Figure 8. Model utilization rate and CaO consumption

5 CONCLUSION

The blow charge model is completely implemented and integrated with the other already existing systems and is also part of the current practices and operational routine. The system has been running since October 2015 showing an excellent performance on fluxes consumptions reduction while also presenting a good performance on the main steelmaking KPIs achievements (carbon, phosphorus and temperature at blowing end). The major operational parameters can now be changed by the technical staff, making the changes procedure much easier and fast to happen.

This model has been running in some others steelmaking plants in the world, and all the knowledge and expertise acquired in every implementation brought in a rich background to this global solution.

Besides, the great expertise of ArcelorMittal Global R&D team combined with the practical every-day use of the model by all these steelmaking plants, and the know-how of the local team, will allow continuous improvements of the suite in the future.

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6 FUTURE WORKS

As stated before, the blow charge calculation is part of the suite of available software from ArcelorMittal R&D. There are other modules, some ready to be installed others forecasted, for primary and secondary refining as for steelmaking in general, or even other equipments related to steel production. Future implementation projects will depend on the availability, and also the profitability, of the R&D software compared to 3rd party software, considering there is no restrict strategy established today on this subject.

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