IMPROVEMENT OF THE CONVERTER PROCESS AT ARCELOR MITTAL FOS SUR MER STEELMAKING PLANT[1]

Mabelly Pierre[2]
Bertrand Bele[3]
Raoul Comparini[4]
Eric Perrin[4]
Samuel da Silva[4]

Abstract

In the frame of the business plan, an important process work is done in order to increase the steelmaking tool productivity, quality levels and reliability. This paper presents the results obtained at ARCELOR MITTAL Fos sur mer steelmaking plant in the field of the converter process improvement. Production of high quality steel is a crucial objective for the industry. The Fos steel plant is involved in the production of high yield strength steel and pipe grade steel. This paper describes the work carried out in the converter area in order to achieve the lowest phosphorus content in the best economical condition. The work performed has involved some work on the converter core model in order to improve its accuracy, robustness and to implement new phenomenological description of the metal – slag interactions.

Key words: Converter; Phosphorus; Adaptation; Model

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[2] *Arcelor Mediterranée.*

[3] *ARSA Arcelor research center: process research center of the ARCELOR MITTAL group*

[4] *ARCELOR MITTAL*

1 INTRODUCTION

ARCELOR MITTAL Fos sur mer steelmaking plant located in south of France has a yearly slab capacity of 4,5 Mt. A business plan is launched in order to reach a yearly slab capacity of 5,3 Mt in 2010. The Figure 1 presents the product mix and market share of the steel plants. The customers belong mostly to the Mediterranean market (Italy, Spain, Greece, Turkey, Portugal). The table 1 resumes briefly the main steelmaking tools.

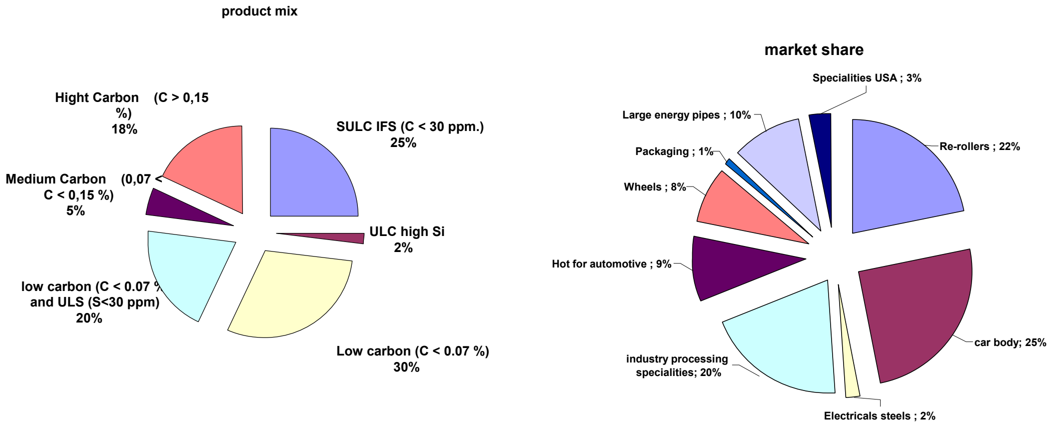

Figure 1: ARCELOR MITTAL steelmaking product mix and market share

Table 1: Fos steelmaking tool description

	Type	**Nb**	**Capacity**
Hot metal desulphuration	CaC2 injected in torpedo	2 strands.	Torpedo : 380 t
Ladle	Stirring with porous plug	17	335 t
BOF	LET – sublance Slag retention with dart and Infrared camera	2	335 t
Secondary metallurgy	Steel desulphuration station **(STAD)**	1	Ar lance Ca wire injection
	CAS – OB	1	
	RH		8 steam ejectors
Continuous caster	Curve	2 strands : 850-1600 x 223 mm	V max : 1,85 m/min
	Verticale curved	2 strands : 1050-2200x 223 mm	V max 1,65 m/min

Production of high quality steel is a crucial objective for the industry. As seen in the picture n°1, the Fos steel plant is involved in the production of high yield strength steel and pipe grade steel. The Fos steel plant produce classical sweet pipe grades from the grade X52 up to X90 with BDWTT requirements and sour pipe application steel grades. This high quality steel production require very low level residual elements (phosphorus, sulphur, nitrogen, copper…) and the stability of the others elements. For these steel, a major concern is the reduction of the phosphorus content. A sharp reduction of the phosphorus elements allows a decrease in the intergranular segregation during continuous casting, thereby improving the ductility and the toughness.

2 PRESENTATION OF THE CONVERTER PROCESS IN FOS

The Fos steel plant is equipped with 2 vessels able to process 335T charges. The process is based on a combined blowing process developed 20 years ago in collaboration with ARSA (ex IRSID): the LET process. The main amount of oxygen is blown by a top lance with a nominal output of 1200Nm3/min. Bottom blowing is performed a flow rate of 10Nm3/min through the use of a tuyere. The bottom blowing gas contributes to a reduction of the disequilibrium between the slag and the steel at the end of the blowing phase. Iron oxide contents are typically decreased by 2 to 3 % compared to a classical LD process. The blowing phase is followed by a stirring / rinsing phase. During this phase, argon or nitrogen gas is used at a typical rate of 15Nm3/min in order to reduce oxygen activity, carbon and phosphorus content before tapping. Slag splashing is used after the end of the tapping phase in order to increase the lining life of the converter: campaigns of 4500 – 5000 heats are obtained.[4] A good viscosity and melting temperature of the slag is obtained by a massive use of dolomite in order to withstand the high temperature observed at FOS: 1680°C on average with a 20% of the production (mainly the high yield strength steel) with end of blowing temperature exceeding 1700°C.

3 RECENT IMPROVEMENTS IN THE FIELD OF THE CONVERTER PROCESS

3.1 On Line Diagnostic of the Converter Model Inputs

Process measurements are inevitably corrupted by different kind of errors during measurement, processing and transmission. The difference between the measured and the true value of a physical variable, which is called the total error, can be expressed as a sum of three kinds of errors:

- Random error, which is an unpredictable error induced by measurement noises, signal conversion noise, device inaccuracy, power supply fluctuation… Random error explains the difference between two same measurements carried on under the same process conditions, on the same operating point, but at different time.
- Gross error, which are caused by non-random events such as calibrating error, wear of the measurement device, sensor fault, solid deposit,…
- Ignored event by the model; In the case of the converter process, these can be, for example the fall of some dust, slag or scraps coming from the chimney or the converter mouth inside the converter vessel.

The converter process is typically a process very sensitive to measurements errors because of its lack of dynamical measurements. A ballistic model is performing a one shot calculation of the charge inputs according to the scraps weight, pig iron temperature, analysis and weight. Fortunately, a sublance in used at Fos during the last blowing minutes; this sublance can, during this dynamic stage of blowing, correct one part of these errors by the correction of the iron ore coolant weight and the oxygen volume. The error is then compensate for the actual heat but not fully detected and corrected. These errors can have deleterious impact on the further heats because off the numerical adaptation of the ballistic model parameters.

Data reconciliation has been developed in order to reduce the amplitude of the total error by filtering out the random part of it (see for instance [1]T, [2], [3]). The difference with other filtering techniques is that data reconciliation uses some explicit process models: Data reconciliation (DR) adjusts the noisy measurements by having them satisfy the process models. The DR is used at Fos in order to make an adaptation and a diagnostic on the process model.

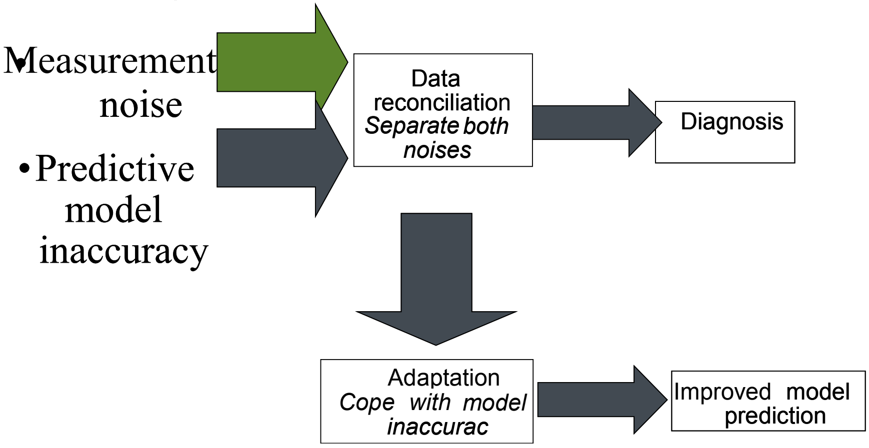

Figure 3: Principle of data reconciliation uses in the Fos converter model

The reconciled estimates are expected to be more accurate and consistent with the known relationship between process variables such as material and thermal balances. Note that measurement data must be redundant with the process model, this technique requires more measured data than truly needed to completely satisfy system balances.

Data reconciliation formulation

Process models are used as a constraint on the estimates x_i. Since the noises are assumed to be normally distributed, a good estimation of the true values is a solution of the following least square minimization problem under nonlinear constraints:

$$\min_{x_i}\left(\sum \frac{x_i - y}{\sigma_i}{}_i\right)$$

$$g_k(x_i) = 0$$

In the frame of the converter ballistic model, the balances - constraints involved for data reconciliation are:

- Oxygen balance : consumption of oxygen in order to oxidize the C,Si, Mn,Ti,Al,… input in the converter
- Thermal balance, that link the oxidation and melting energies
- Iron balance between the converter input and the ladle weight measured at the secondary metallurgy entry,
- Slag analysis balance on the following elements : [CaO], [SiO2], [MgO], [FeO]

Measurements involved are for example: the pig iron weight and temperature, the slag analysis, the secondary combustion ratio, the end of blowing carbon and temperature measurements ... By the use of Data reconciliation, each of the ballistic model balances are respected with some minimal modification of the measurements. The solution can be found using nonlinear programming algorithm practically available for instance with the function Fmincon in the optimization toolbox of Matlab or the optimization procedure fdonlp2 in the on-line Fortran platform.

In the diagnostic mode, the calculated deviations are matched to some deviation limits: when deviation exceeds these limits an alarm is set and the heat is ignored for the further adaptation treatments. Thanks to this diagnosis some measurement errors or ignored events by the model can be detected and treated. The diagnostic ability / fault detection ratio of the data reconciliation system is shown in the following picture.

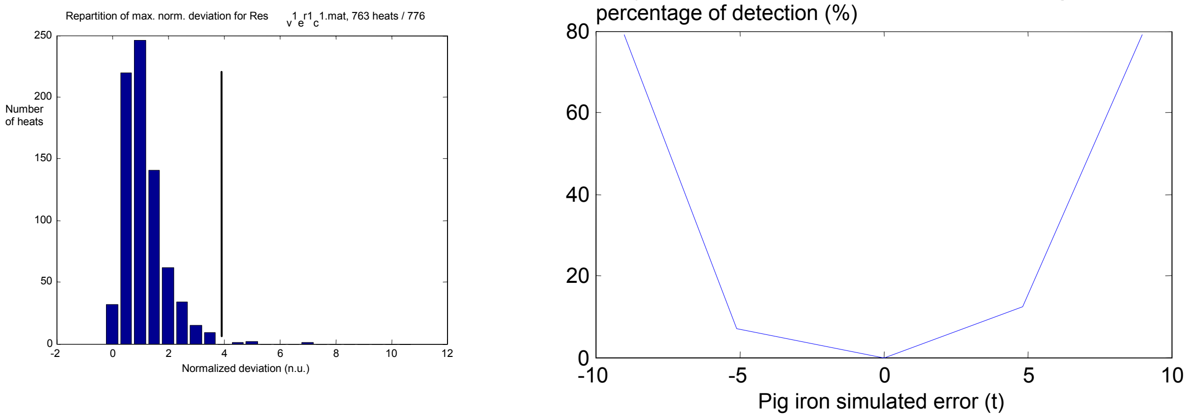

Figure 4: fault detection ratio of the pig iron weight measurements according to the simulated error.

3.2 Renewal of the Ballistic Model

As previously explained, the phosphorus content achieved at the end of the converter process is a major concern for the production of high quality steel grades. Typically, for pipes application (HIC), a maximum phosphorus content of 80 to 120ppm must be obtained before tapping. This converter limit allows a final maximum content of 150ppm at the casting machine after massive allowing at tapping (1% up to 1.7% of Manganese in these grades), the desulphuration at secondary metallurgy (by metal / slag exchange → 20ppm max level)…. These low phosphorus levels are not so obvious to be economically obtained in the Fos context because of the high temperature (> 1700°C in this case) and high MgO analysis of the slag (typically 6.5% of MgO in the slag).

The main enhancements performed in the new model are the introduction of some slag analysis target and a better description of the metal – slag exchanges. The objective is to reduce the scattering of the basicity index $B = \frac{[CaO]}{[SiO_2]}$ in order to maximize the phosphorus partition coefficient and, then, to optimize the slag mass and iron losses. The following graph shows the effect of the basicity index of the equilibrium phosphorus estimated by the EqMelt software developed by ARSA.

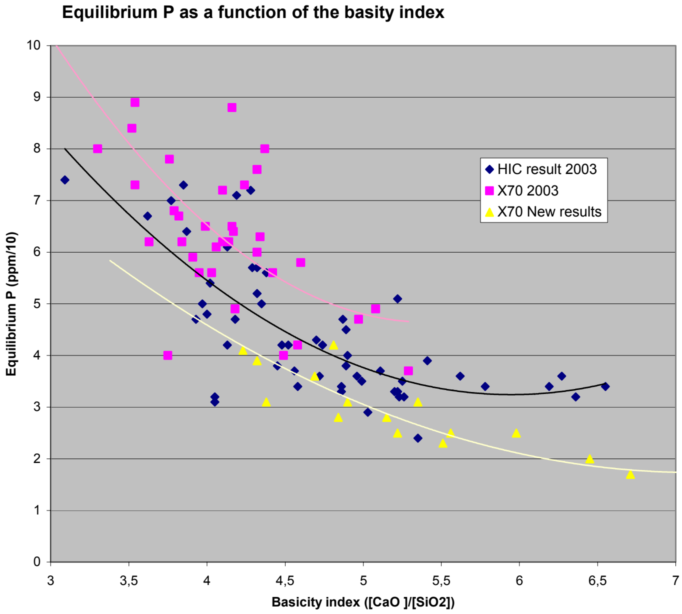

Figure 5: impact of the basicity index on the equilibrium P

The dephosphorisation ability of the slag is classically calculated according the partition coefficient Lp :

$L_p = \frac{\lfloor P_{slag} \rfloor}{[Pst]}$; $[P_{St}]$: Phosphorus target in the steel; $[P_{slag}]$: Phosphorus in the slag

The ballistic model is handling the dephosphorisation as a constraint on the slag mass and quality connected to the phosphorus entries in the converter.

$$Ent.P \leq m_{st} \times [P_{st}] + m_{slag} \times L_p \times [P_{st}]$$

m_{slag} : slag mass at the end of blowing ; $Ent.P$: Phosphorus mass entry

As shown on the figure n°5, the partition coefficient L_p can be described in the classical pseudo ternary diagram CaO' - SiO2' - FeOn' . Mass conservation of the oxidized input is used in order to calculate their mass in the slag. A special attention is paid to :

- The calculation of [FeOn] content that is calculated thank a regressed model taking into account the final carbon content, temperature and target basicity of the slag.
- The slag basicity that is controlled in a limited range. Additional addition of lime, ferrosilicon or silica is used in order to increase the slag mass without a degradation of the slag basicity.

The lime excess in the slag is an important variable for the calculation of L_p. The lime excess is described thanks to the coefficient A' derived from the following equation giving the lime excess curve in the ternary diagrams:

$$[CaO'] = A' - a \times [FeOn'] - b \times [FeOn']^2$$

The phosphorus partition coefficient is given by the following formula:

$$Lp^* = \{(\mathrm{Coeff\_1} + \mathrm{Coeff\_2} \times A' + \mathrm{Coeff\_3} \times A'^{2}) + (\mathrm{Coeff\_4} \times T°C) + (\mathrm{Coeff\_5} + \mathrm{Coeff\_6} \times A' + \mathrm{Coeff\_7} \times A'^{2}) \times [FeOn'] + (\mathrm{Coeff\_8} + \mathrm{Coeff\_9} \times A' + \mathrm{Coeff\_10} \times A'^{2}) \times [FeOn']^{2}\}$$

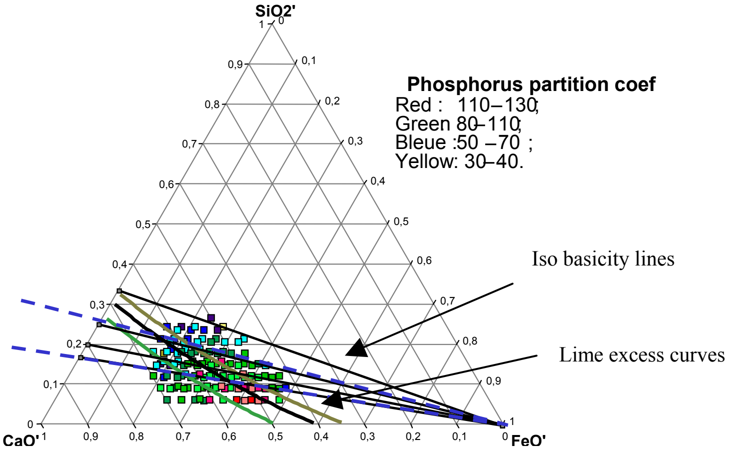

Figure 6: Measured Lp coefficient as a function of the position in the pseudo ternary diagram [SiO'] – [CaO'] – [FeOn']

This Lp* is corrected in order to take into account the effects of the [MgO] & [MnO] concentration on the dephosphorisation coefficient. These effects are shown on the following graphs:

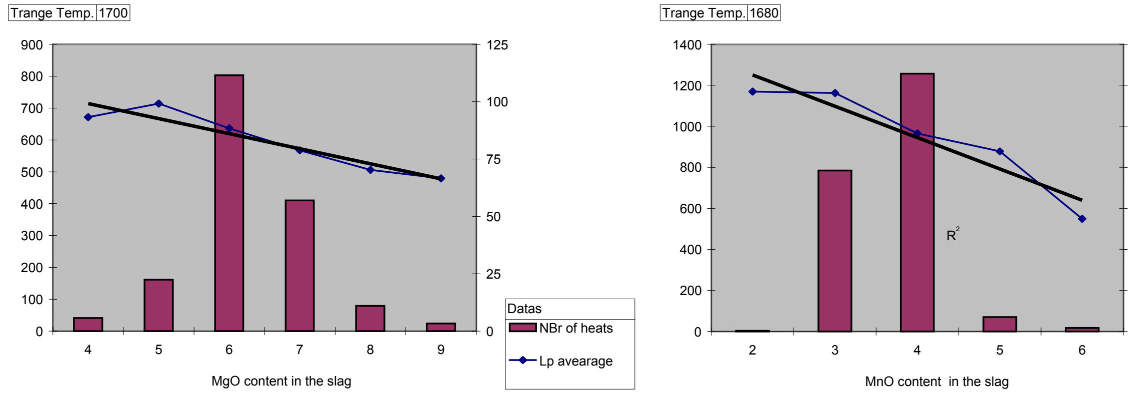

Figure 7: Effects of MgO and MnO addition on the Lp coefficients

3.3 Slag Retention

The slag retention at the converter is a major issue in order to reduce the phosphorus pick-up during the following treatment at the secondary metallurgy. This is particularly the case when the ladle treatment involves desulphuration by metal – slag exchanges (Porous plug and top lance stirring at the STAD station) The 2 converters are therefore equipped by:

- Slag retention device: darts
- Slag detection device: an AMEPA infrared camera.

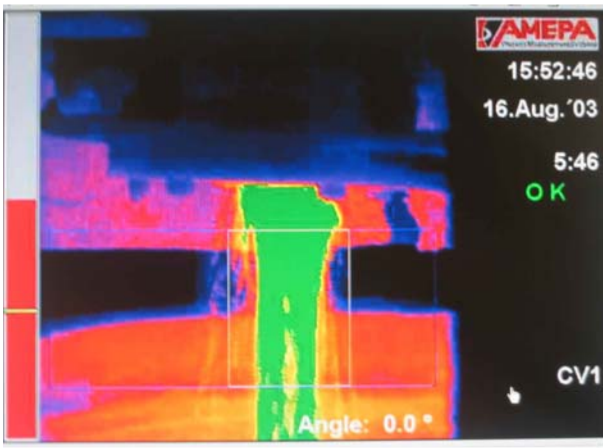

Figure 8: Infrared detection of slag at the end of tapping

The number of pixel given by the AMEPA software is used in order to evaluate the slag carryover. Depending on the steel grade requirement and the following operation to be performed at the SM, An on-line model is calculating the slag mass, the possible phosphorus pick-up and an eventual deslagging decision.

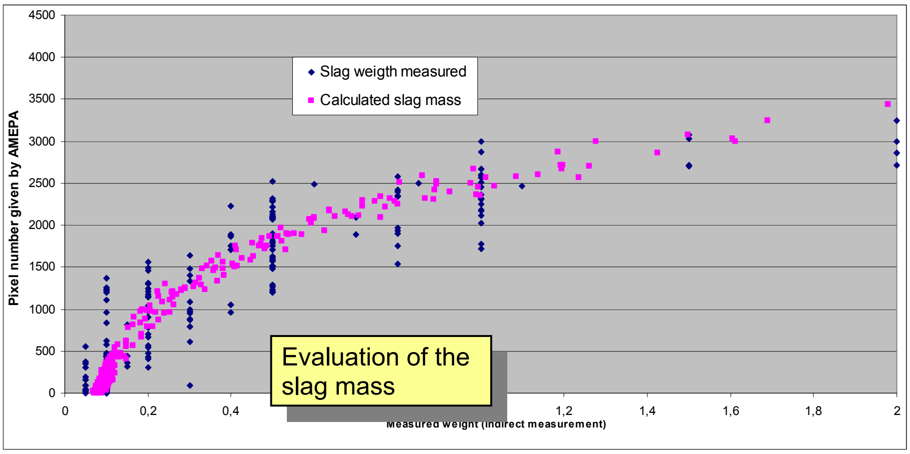

Figure 9: Correlation between the evaluated slag mass and the number of pixel delivered by the AMEPA camera.

4 INDUSTRIAL RESULTS AND CONCLUSION

Thanks to the explained improvements, the capability to ensure the phosphorus content measured at the casting machine has been improved by a ratio of 80% without any negative impacts on the over blowing ratio and the iron oxide content in the slag.

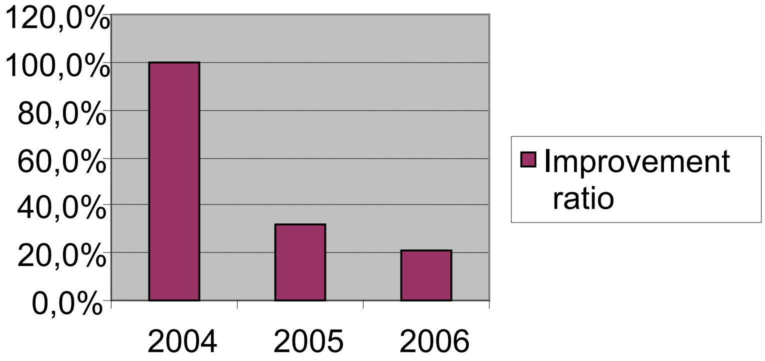

Figure 10. Relative improvement of the phosphorus success ratio for pipe & high yield strength steel grades.

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