

MAIN RUNNERS COOLED BY FORCED AIR: EXPERIENCE TERNIUM PLANT GENERAL SAVIO¹

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Abstract

Ternium Siderar plans to increase Blast furnace #2 production level from 5200 to 7200 THM / day, for this it was necessary to improve the cast house design, especially the main runners. Some of the improvements achieved during relining of blast furnace N°2 were the improvement in parameters that define the operating conditions and the cooling system in the runners. The project involved the next different stages: (1) operational design, (2) thermal and structural analysis for different alternatives, (3) refractory linings construction (pre-cast and security lining), (4) metallic structure assembly. Apart from this, the application conditions of working cement were controlled during the first campaigns. First results show there was an improvement in campaign length, and refractory consumption decreased

Key words: Main runner; Refractory consumption; Cooling system; Relining.

¹ *Technical contribution to the 3rd International Meeting on Ironmaking, September 22 – 26, 2008, São Luís City – Maranhão State – Brazil*

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1 INTRODUCTION

During the first half of year 2009 TERNIUM SIDERAR is going to increase the production from 2.5 to 4 million THM per year.

In the relining of blast furnace N°2 that was carried out between November 2007 and January 2008 the production capacity was increased. The outstanding parameters for this relining were:

Table 1: Features Blast Furnace #2 – Ternium Siderar.

	Before relining 2007	After relining 2007
Hearth diameter [m]	12,33	12,33
Inner volume [m ³]	2421	2601
Working volume [m ³]	2134	2340
Number of Tap holes	2	2
Number of Tuyeres	27	27
Number of Stoves	3	3
Top system	Paul Wurth	Paul Wurth
Production[THM/D]	5200	7200

To reach this objective it was necessary to re-design the cast house, for this we considered the increase of iron and slag volume to evacuate.

Ternium Siderar considered three different design alternatives to face this growth in productivity: (1) to have three tap holes, (2) use interchangeable runners, (3) use runners cooled by forced air. The first alternative was ruled out because it was not physically possible as it interfered with other equipment operation. The investment required for the second alternative was much higher than that for the third one.

Engineering studies were done to analyze the design of runners cooled by forced air, considering the following production target.

Table 2: Production data (Operational Conditions).

Production capacity [THM/D]	7200
Slag volume [kg/THM]	280
Casting time [minutes]	180-240
Time of closed tap hole [minutes]	15
Tapping speed [THM/min.]	5.0
Slag speed[THM/min.]	1.6

2 STUDIES

2.1 Levels in the Main Trough

As a first step it was necessary to take into account the volume, caudal and speed of iron and slag to (1) maintain the production level, (2) enclose wear speed, (3) guarantee iron quality and the cast house's proper operation.

Figure 1 shows the most important levels that define the fluid dynamic behavior in the main trough.

Table 3 lists those levels.

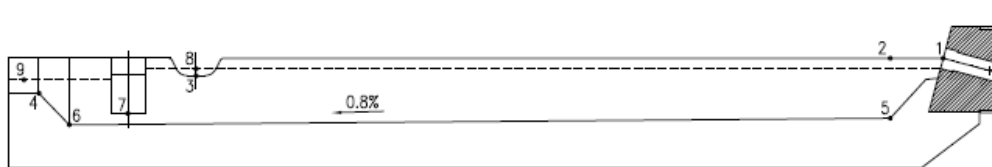


Figure 1: Levels in the longitudinal profile of the main trough.

Table 3: Main levels in the main through.

	LEVELS
1	working point
2	free borad
3	slag level
4	iron level
5	impact area
6	end of the main trough (slope)
7	skimmer level
8	slag flotation
9	hot metal flotation

It is necessary to conserve the level differences to guarantee the three objectives mentioned.

Table 4: lists the principal level relations

LEVELS	OPERATIVE PARAMETEER	
1	5	Floor wear by erosion and abrasion
5	3	Iron volume
5	6	Iron speed
3	4	Driving force for iron drain
5	4	Residence time/ productivity
1	8	Driving force for slag drain
1	3	Slag volume

Regarding efficient protection of the taphole, it is recommended to form the mushroom with an estimated wall of 1 m.

From the outside, the taphole must be 100 mm above the level of liquid flotation. In this way, splashing is reduced and, in general, the possibility of dirtying the seat of the taphole gun.

The furnace taphole extension (capilla) can be extended up to 600-650 mm without risks of uncertainty.

It is also necessary to keep a proper length or residence time in the main trough to guarantee the appropriate iron quality, what means to permit the slag and iron separation as it is discussed in the next section.

2.2 Length Between the Taphole and the Slag Runner

Three regions are identified in the slag runner. The first one is the impact area, where the hot metal stream has a turbulent flow. This area extends 2 or 3 m from the taphole. It is a mixture of hot metal and slag, with a residence time of 10 seconds. The second area is defined as the part where the slag drops rise to the flotation line. This region has an extension of 1 or 2 m. Lastly, the third region is defined as the zone where the hot metal drops descend. In general, it has a length of 10 m and its end should be in the slag runner.

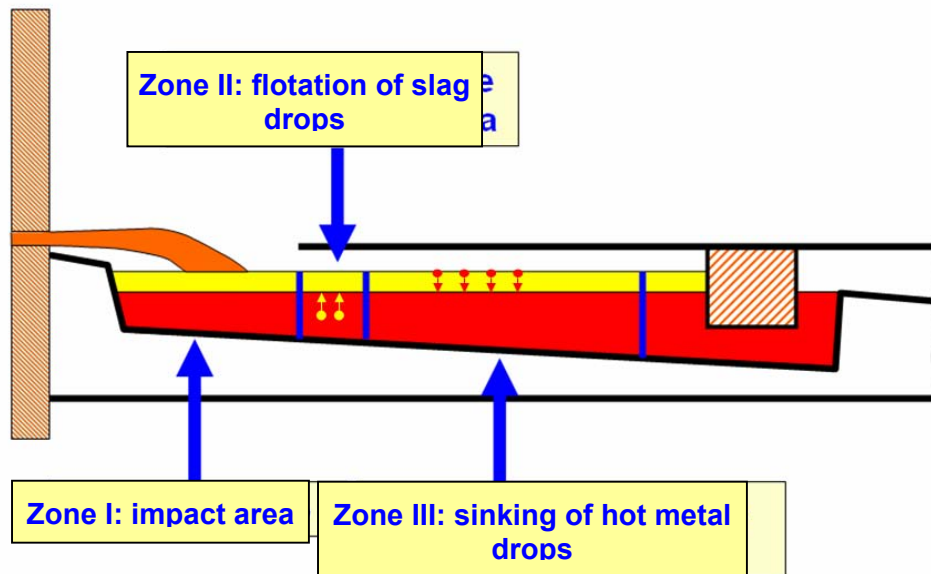


Figure 2: Slag and hot metal separation.

2.3 Taphole Angle

Directly associated to the kinetic energy that passes the tapping stream at the beginning of the tapping procedure. This energy is transferred to the refractory in the impact area. Thus, more the angle, more the wear of the working lining (floor and side walls). The ideal condition is 0° , and no more than 10° in the real case.

Moreover, it is important to highlight that the bigger taphole angle is, more the time to separate the slag from the hot metal. This point will be detailed in the next item.

Currently Siderar blast furnaces have a taphole angle 10° .

3 THERMAL ANALYSIS

Ternium Siderar carried out thermal and stress-strain studies of the main through of blast furnace N°2. For this it was used the finite element method.

Figure 3 shows the temperature of the refractory sidewall and the metallic shell of the main through in two different conditions: new and wear. It is considered the critical point, 3 meters from the taphole in the inter phase slag-iron.

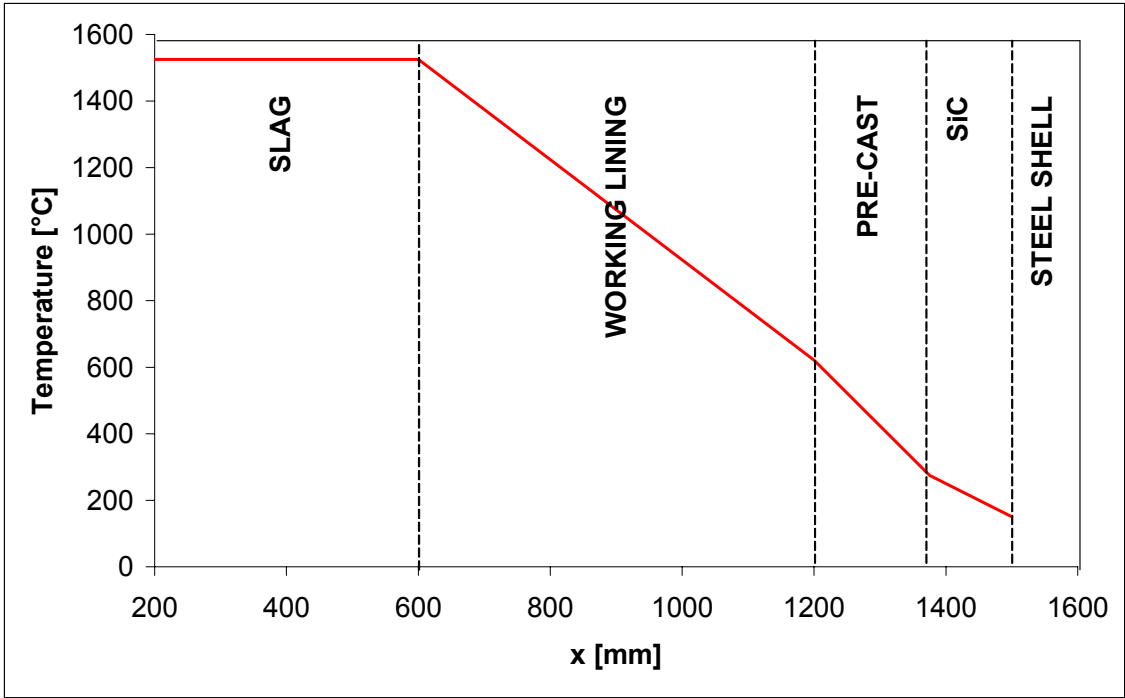


Figure 3: Temperature profile 3 m from de taphole, inter phase slag-iron.

It can also be observed in the study results that cooling by forced air has an influence in iron temperature. Figure 4 shows the time involved in temperature decrease for different operating conditions.

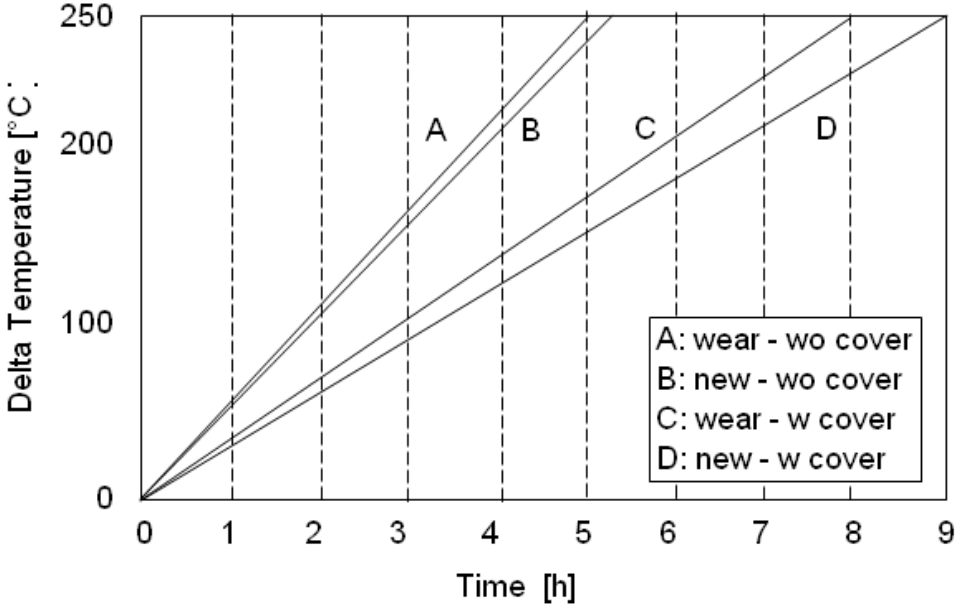


Figure 4: Mean temperature decrease of liquid metal in function of time, cooling speed, when the iron is not flowing

Table 5 compares the influence of different thermal transfer mechanisms in the next conditions: (1) new-wear, (2) with-without cover.

Table 5: Thermal transfer mechanisms.

	DISSIPATION MECHANISMS	NEW		WEAR	
		W/C	WO/C	W/C	WO/C
LATERAL	COND / CONV	32.7	21.3	30.8	19.9
INFERIOR	COND / CONV	27.1	17.6	25.6	16.5
SUPERIOR	CONV	8.6	5.6	8.1	5.2
	RAD	31.6	55.5	35.5	58.4

It can be observed that the principal mechanism of energy dissipation is radiation through the slag surface. This surface increases substantially when the cover is not put on.

It is important to notice that cooling speed is highest when the lining is wear, this is due to the larger exposed surface of slag and iron which increases the heat loss by radiation, and not by the cooling system.

The heat dissipated by convection hardly varies (for example: from 8.6 to 8.1) compared to the variation in radiation lost (for example: from 31.6 to 35.5).

In the successive steps to check the cooling engineering with numeric models, it was determinate the temperature variation in air ducts along the inner surface of the runner.

It can be seen in Figure 5 that when the cooling system is working at 100% capacity, the air that gets in at 50°C then gets out at 149.5°C

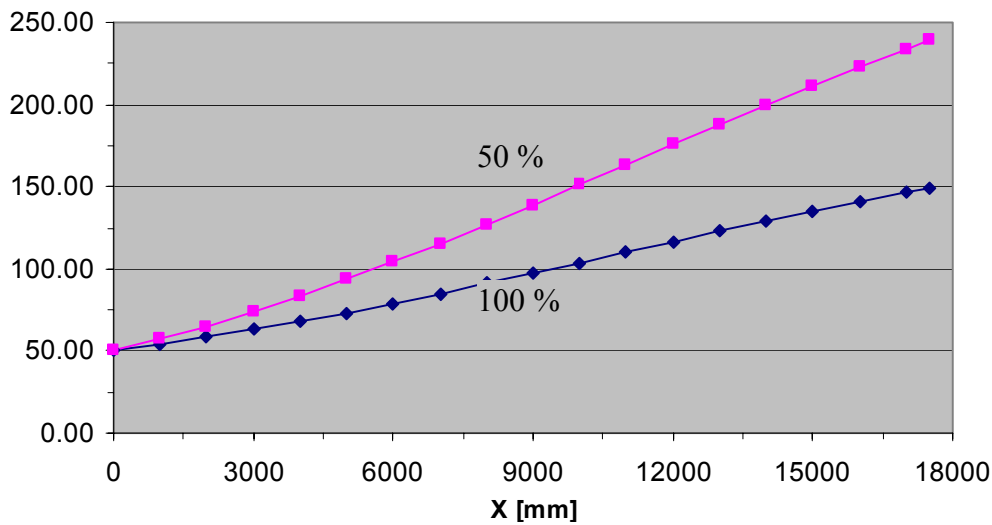


Figure 5: Temperature variation of air along the cooling ducts.

4 STRESS STRAIN ANALYSIS

Figure 6 shows the longitudinal expansion in the working lining (200mm) and the metallic shell (20mm)

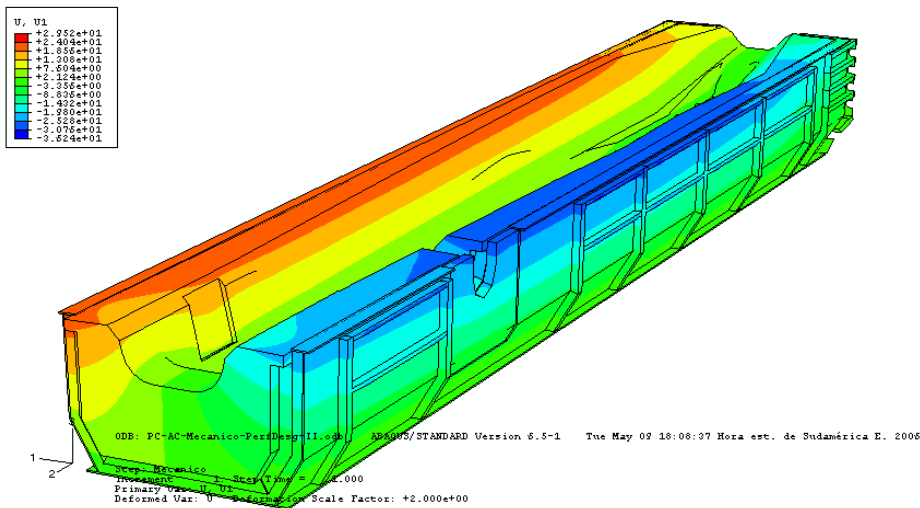


Figure 6: Relative displacement of the working lining and the metallic shell.

In general we can observe Von Mises equivalent stress lower than 150 MPa on sidewalls and floor. Figure 7 shows in grey colour the tensile stress superior than the yield strength; in this case they are located in two sectors: (1) Slag runner side, (2) near the taphole.

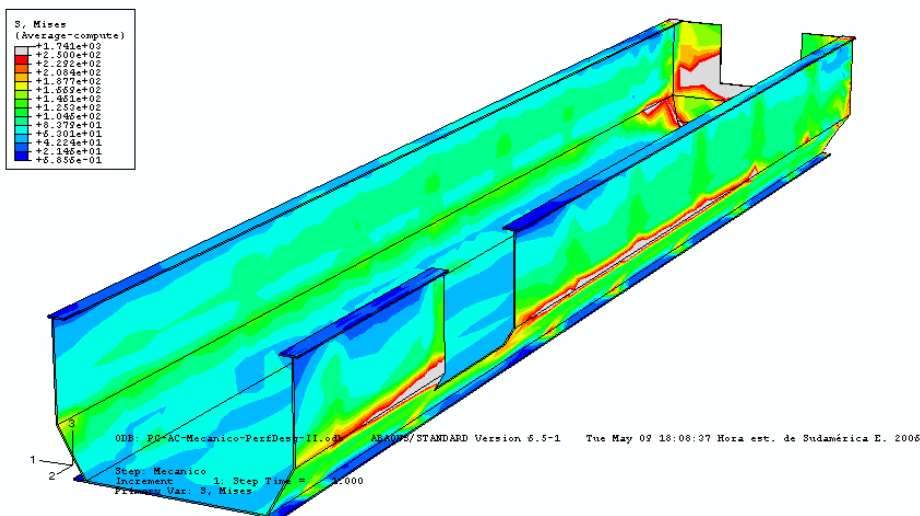


Figure 7: Tensile stress distribution in the metallic shell.

Tensile stress level in the working lining is low, less than 5 MPa. An outstanding point in tensile distribution determination is that there is a zone where the material is exposed to compressive stress and other zone where it is exposed to traction stress, as showed in Figure 8.

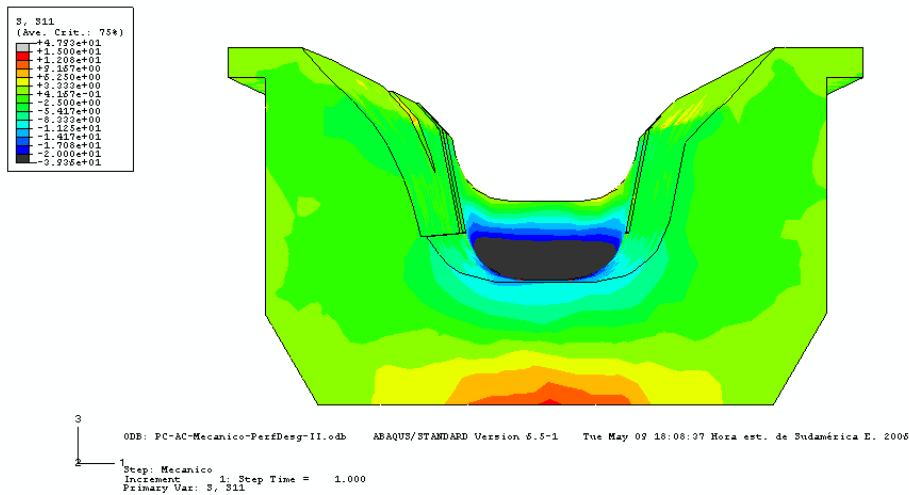


Figure 8: Tensile stress distribution in the refractory working lining

5 NEW RUNNERS CONSTRUCTION

From thermo mechanical studies the quality of refractory materials needed were defined. In this presentation we will focus on security and conductive linings. It is necessary to have a maximum dimensional stability in the security lining. To fulfil this requirement it was necessary to pre- cast the lining in the supplier's plant. Then a controlled thermal treatment and dry were practiced. Figure 9 shows the assembly of the security lining.



Figure 9: Pre cast security lining

The conductive lining must guarantee a good thermal transfer between the security lining and the cooling ducts. Figure 10 shows the security lining casting.



Figure 10: Security lining casting.

6 DISCUSSIONS AND CONCLUSIONS

6.1 Dimensions, Levels and Length of the Main Through

The cast house operating conditions are stable, with a grate decrease in operators' intervention, especially in the skimmer zone and iron level, the same is valid for slag drain.

6.2 Thermal Conditions

The finite element method prediction is coincident to the thermocouple values observed during operation.

The thermal profile of the working lining presents a cold face temperature of 620°C, this value is higher than the limit for oxidation phenomena activation in the refractory material (400-450°C), however it is much smaller than the antique temperature in the runner without cooling by forced air.

Besides this, despite the cold face temperature of the refractory lining is above 400-450°C, it is not observed separation between the working and security linings, what does not permit the oxidation in the cold face.

The refractory sidewall is exposed to a higher thermal gradient, this fact presents advantages and disadvantages: an advantage is that the thermal gradient does not inhibit the thermo physical and thermo chemical wear mechanisms. A disadvantage is the inner tension gradient, however it can be observed that they are relatively low and in the zone where the refractory would be exposed to traction, historically there is no wear in the refractory.

The cooling by forced air has no influence in the thermal level of iron. Otherwise, it is important to mention that the maximum time runner remains not casting is shortened.

This means there is a 20% decrease in maximum time permissible before the iron loses its flowing capacity in the skimmer.

6.3 Thermo Mechanical Conditions

Cooling by ducts and the conductive SiC lining fix the shell temperature in 150°C, this constant value in the hole metallic shell grants a structural stability defined by design.

It is important to notice that the value predicted by the model is coincident to the value obtained during operation.

7 REMARKS

The main results in this design can be summarized in:

- (1) Decrease in non availability of cast house: the campaign extension without repairs was +40%, what let a decrease in the non available time from 17 to 12 min/1000THM, approx.
- (2) Influence of the cooling on the refractory consumption: alter 18 month operating it is observed a refractory consumption decrease, valuated in -25% approx.
- (3) Thermo mechanical stability of the steel shell: in the continuous monitoring of air and shell temperature, design values are observed.



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