INTELLIGENT DESIGN OF BLAST FURNACE RUNNER BY TRB *

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Abstract
A global reflection on the design of blast furnace main runner was investigated in this paper. TRB Company used its skills and expertise to understand what the best option for this sensitive component is, including some innovative tools: intelligent block design for safety lining, thermal & thermomechanical numerical simulation, immersive measurement by thermocouples, IR thermal camera, 3D laser scanner.

Keywords: Main runner; Numerical simulation; Instrumentation; Laser scanner

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1 INTRODUCTION

Since latest decades, design of blast furnace runner has evolved a lot and TRB has been constantly elaborating a know-how in the implementation of innovative refractory lining. The introduction of Al2O3-SiC-C castable as a working lining in place of ramming mixes constituted a great enhancement [1]. Today, most of the Western Europe BF runners are divided into 4 elements:

- Working lining (castable or ramming mix),
- Safety lining (castable, ramming mix or bricks),
- Insulating layer (bricks or insulating boards),
- Structural support (concrete or metallic shell)

Considered before as a short life layer, the working lining was progressively thought as a long duration material. The castable formulation has been continuously enhanced, much work being carried on slag & iron corrosion resistance, oxidation resistance and installation techniques. Thermomechanical studies are nowadays performed to improve our knowledge of the castable behavior in service and working lining geometry was adapted. Recently, innovative tool such as 3D laser scanner has been used to have an accurate estimation of this specific layer everywhere and at each campaign end.
In the same time, the structural support has been improved, runners being supported by metallic shells instead of being embedded in a thick concrete floor.
The interest of the safety layers design, because of their distance from the hot metal, has only been considered in recent times. Today, this part of the structure appears as a key point, as it can provide more safety and reliability on the casthouse, lower wear rate of the working lining, bringing longer campaign length and lower refractory consumption.

2 DEVELOPMENT

Material and methods

Our designs are appreciated thanks to the overall approach of our studies which consider the operations of transport, assembling, dismantling and disposal. Our teams face increasingly varied challenges in the field of high temperatures and can design complex refractory setups to meet almost all types of stresses (thermal, mechanical, chemical).

Design

TRB standard main runner safety lining design is made of one casted bottom slab with rammed joints and two rows of precast block. Working lining is cast in situ. (see fig. 1).

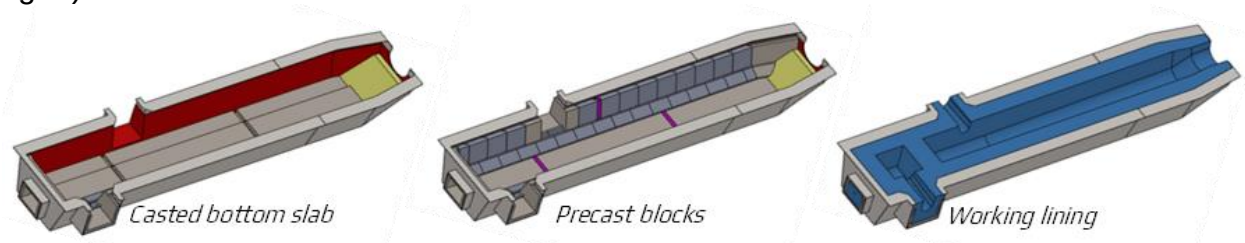


Figure 1 : *TRB standard main runner safety lining design*

Two rows of blocks guarantee a good resistance of the safety lining by reducing thermomecanical stresses. Casted safety lining usually has cracks due to thermomechanical stresses where precast has not. This is due to an increase of degrees of liberty between the blocks. Another advantage is the possibility to adapt the block material to the zone (slag or iron).

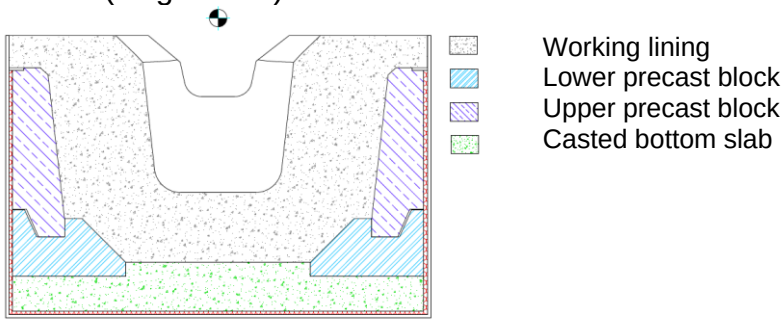


Figure 2 : *TRB main runner cross section design*

TRB always adapts its conception on the customers casing geometry as shown on figure 3.

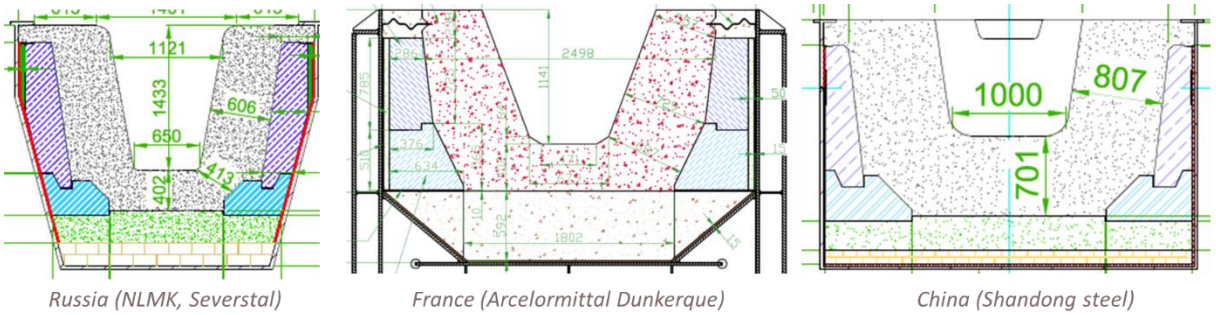


Figure 3 : *main runner design examples*

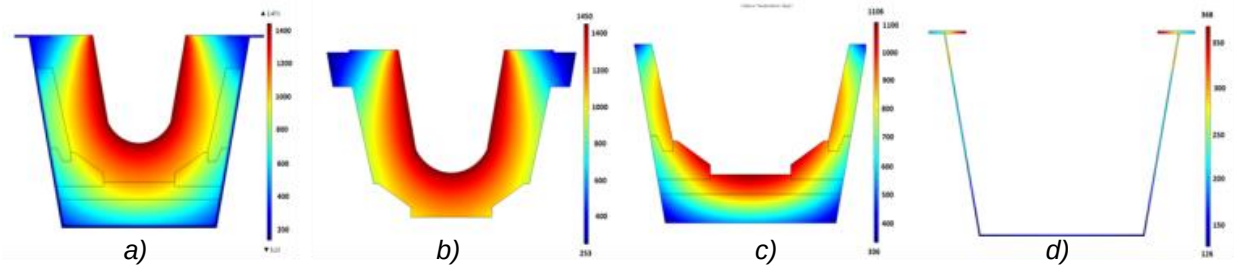
Material

TRB main runner safety lining are made of andalusite based castable for lower blocks, as it ensures an excellent iron resistance. Upper blocks are made of bauxite and silicon carbide based castable which guarantee a good slag resistance. Both are no carbon containing castable which prevent oxidation.

Results & Discussion

Numerical simulation

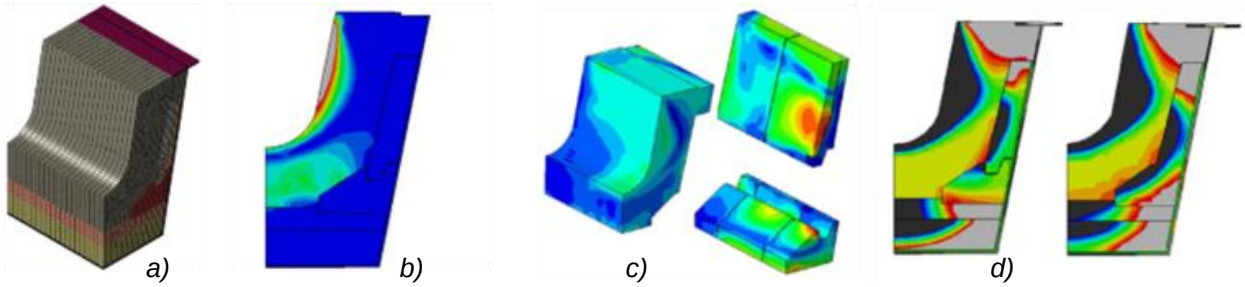
An analysis with steady or transient state helps us know accurately the thermal transfers by induction, convection or diffusion in the structures under study. Our models include complex thermal behaviors such as the conductivity non-linearity, the change of material phase, the modelling of contact resistance and the coupled thermal transfer conduction/diffusion as shown on fig. 4.



a) b) c) d)

Figure 4 : *section thermal profile: global (a), working lining (b), safety lining (c) and casing (d)*

More complex calculation can be done to understand stress due to heat transfer inside the castable layer. These studies allow stress optimization of safety lining design [2], [3]. Example on fig. 5.



a) b) c) d)

Figure 5 : *Thermomechanical calculation : 3D mesh (a), deformation analysis (b), stress analysis (c) and design comparison on principal stress (d)*

Performance

Our intelligent block design has many benefits: first is reducing installation time. Whereas casting safety lining in situ can sometimes takes days to set (shuttering time, casting time, curing time, drying time), assembly the precast block is very easy and takes few hours. We save a precious time during construction and thus save money too. Optimized design is decreasing the stress not only in the blocks themselves but in every layer: working lining and casing too [4]. Safety blocks lifetime can reach 15 million tons of cast iron.

Breakthrough detection and residual castable assessment

For many years, TRB has been developing a unique know-how in terms of instrumentation of refractory linings. Each system is tailor-made regarding the specificity and the complexity of the site. Our solutions cover the whole chain of measurements: from probe, wiring, processing unit, to the treatment algorithm development and alarms implementation.

TRB solution is made of copper plate placed on the back of safety block and sensors always in contact with these copper plate. A dynamic view of temperature evolution with alarms is possible in control room.

The system allows a real-time follow up of temperatures everywhere in the runner, alarms to prevent breakthrough and residual castable assessment.

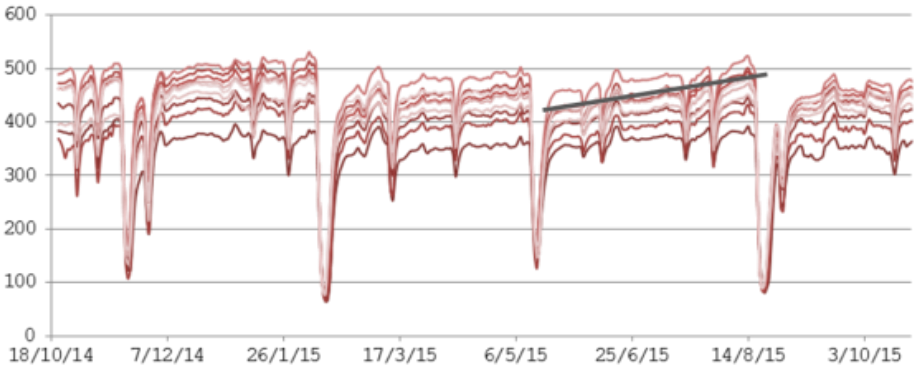


Figure 6 : *Steady evolution of the temperatures over the campaign: possible correlation with the wear of the main runner*

TRB's specific instrumentation has many advantages such as a large surface control all along the runner, no mechanical stress, an easy system to place and replace and the possibility for blocks to move freely.

Measurement by thermal camera

The cameras used by TRB provide a full mapping of the temperature range for the refractory structures in particularly extreme environments. The exploitation of the results, on a static or dynamic level, helps to understand the condition of the component.

It is possible to implement alarms on specific zone of the monitoring. That will increase safety and prevent any incident.

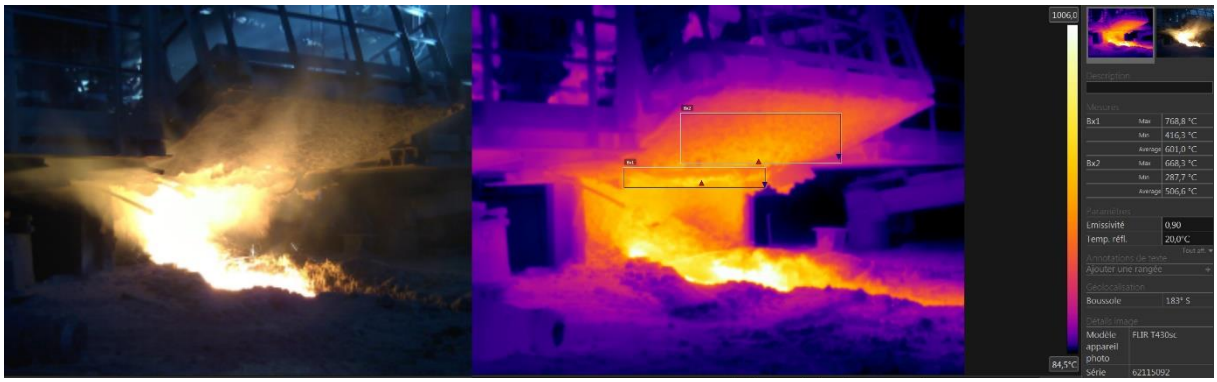


Figure 7 : *Follow-up of the temperatures on blast furnace castfloor*

TRB 3D scanner

The scanner allows precise as well as fast measuring on any type of part or structure. The superposition of several point clouds edited at different dates gives an accurate estimate of the wear thickness and the remaining refractory lining. It is possible to determine very quickly the critical areas and optimize the service life of the components.

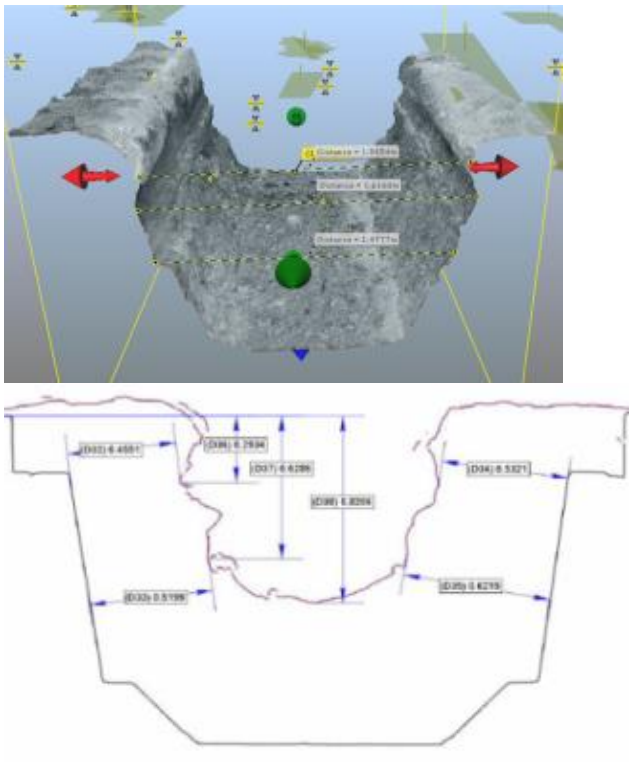


Figure 8 : *Point cloud from 3D laser scanner, measurements on cross section*

3 CONCLUSION

The TRB Company uses all the means of action it has available to design casthouse main runner.

Thermal and thermomechanical numerical simulation were performed to build the best design that will guarantee a better lifetime in every layer. Strong experience in refractory materials ensure the best castable choice in the whole geometry.
Thermal measurements are performed inside the refractory and on its skin. This innovative technology is the best way to have a perfect monitoring during operation. Wear measurements using 3D scan is a powerful tool to have an accurate measurement of the performance of each campaign.

Consequently, TRB intelligent design proved the efficiency of the method on site with excellent performance, money saving and more safety.

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