ISSN 1983-4764

NEW TECHNOLOGICAL TRENDS FOR EFFICIENCY INCREASE OF REHEATING FURNACES[1]

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Abstract

Since the first developments of reheating furnaces, many equipment have been designed and constructed with technologies answering on-time needs. These requirements were dictated by external constraints, such as the technological states of the art, computation capacities, volatility of fuel prices and development of new steel grades requiring new processes. Today, steel makers face new markets conditions and new constraints imposing high levels of competitiveness and innovation to keep benefits on standard massive markets and beyond. Steel producer equipment, in order to match with these new challenges, have to combine reliability, flexibility and energy savings, as well as to respect environment regulations. Many of today's operating equipment require upgrades to fulfill all these expectations. Using an experience coming from the 80's, CMI developed new reheating furnace concepts, under the label Optimfl@me. Developed with BAT's (Best Available Technologies), these applications lead to optimizations of existing and future equipment in terms of efficiency, flexibility, availability, heating quality and many more. Based on a high expertise level, supported by in-house simulation tools, Optimfl@me applications improvements have been demonstrated on revamping and new projects worldwide.

Key words: Reheating Furnaces, Hot Strip and Plate Mill, Optimfl@me Furnace.

NOVAS TENDÊNCIAS TECNOLÓGICAS PARA AUMENTAR A EFICIÊNCIA DE FORNOS DE REAQUECIMENTO

Resumo

Desde os primeiros desenvolvimentos dos fornos de reaquecimento, muitos equipamentos têm sido projetados e construídos com tecnologias que atendiam às necessidades decorrente das últimas épocas. Esses requisitos eram ditados por restrições externas, tais como os estados da arte tecnológicos, capacidades computacionais, a volatilidade dos preços dos combustíveis e o desenvolvimento de novos tipos do aço que requeriam novos processos. Atualmente, as siderúrgicas enfrentam novas condições de mercado e novas restrições que demandam altos níveis de competitividade e de inovação para manter os lucros em grandes mercados de volumes e além desses. Os equipamentos para a produção de aço, a fim de atender a esses novos desafios, devem combinar confiabilidade, flexibilidade e economia de energia, bem como respeitar as normas ambientais. Muitos dos equipamentos atualmente em operação precisam de upgrades para corresponder a essas expectativas. Utilizando uma experiência surgida nos anos 1980, a CMI desenvolveu um novo conceito em forno de reaquecimento, sob a marca Optimfl@me. Desenvolvido com as tecnologias BAT (*Best Available Technologies*), essas aplicações levam à otimização dos equipamentos existentes e futuros em termos de eficiência, flexibilidade, disponibilidade, qualidade de aquecimento e muito mais. Com base em um alto nível de especialização, apoiadas em ferramentas de simulação internamente desenvolvidas, as melhorias das aplicações Optimfl@me têm sido demonstradas em reformas e novos projetos em vários lugares do mundo.

Palavras-chave: Fornos de reaquecimento; Tiras a quente e laminador de chapas; Forno Optimfl@me.

[1] *Technical contribution to the 48th Rolling Seminar – Processes, Rolled and Coated Products, October, 24th-27th, 2011, Santos, SP, Brazil.*
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ISSN 1983-4764

1 INTRODUCTION

Using an important experience acquired since 1980, CMI Thermline developed several new technologies and philosophies for the design of new reheating furnace and the improvement of existing furnaces, which have been merged into the optimfl@me concept.
This concept is described hereafter and shown in two project examples: a new equipment, commissioned a short time ago, i.e. two reheating furnaces for Maghreb Steel in Morocco and the modification of an existing furnace, i.e. a bloom reheating furnace built in 1985 for UzmetKombinat in Uzbekistan.

2 REHEATING FURNACES – MAGHREB STEEL

In 2007, Maghreb Steel decided to invest in a new hot mill plant in Casablanca, Morocco, planned to produce 1 million tons of hot roll coil per year and 0.5 million tons of Steel plates per year. For this purpose, Maghreb Steel purchased in 2008, a new Steckel mill and a new plate mill for a single new hot mill workshop.
CMI Thermline recommendation was to install 2 reheating furnaces feeding a single roller table line, a 250 tons per hour walking-beam reheating furnace feeding slabs to the Steckel Mill and a 136 tons per hour pusher reheating furnace feeding slabs to the Plate Mill.
In 2010, these furnaces have been successfully commissioned, confirming the technical developments of CMI Thermline implemented in these two equipment, that today stand under the trade mark optimfl@ame.

2.1 Technical Development Basis

Reheat furnaces must deliver to hot mills, steel products at a suitable average temperature and temperature uniformity. The key factor of the process is to match reheating targets while maximising the level of production, minimizing operation costs and minimizing pollutant emissions. The furnace productivity, heating quality, flexibility and pollutant emissions are thus the most important features of the reheat process, that were considered by CMI Thermline in the development of the Optimfl@me concept.

2.1.1 Productivity

The productivity of the reheating furnace is linked to the three main issues:

- *capacity of the heating equipment to maximise the heat transfer to the products, while respecting the uniformity tolerance.* The length of the furnace and the size of the heat exchanger influence the global efficiency of the furnace, and have to be optimised regarding the averaged working conditions of the mill. Naturally, the choices of the heating equipment and its implantation on the furnace have also an impact on the furnace productivity;
- *scale loss level*. High O_2 contents in the furnace chamber conduct to scale formation by surface oxidation of the steel products. A part of the scale falls on the hearth of the furnace, and the remaining scale is removed in the de-scaling devices before rolling. The scale losses depend on the residence time of the

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products above the activation temperature of the oxidation, and on other factors such as oxygen content in the flue gases or the particular steel grade;
- *furnace availability*, which depends mainly on maintenance time and production delays due to breakdowns.

2.1.2 Heating quality

The mill process requires a certain level of product temperature uniformity, through the thickness of the products and along their length. Depending on the rolling sequences and the products to roll, special thermal profiles can be necessary, such as for example head or tail overheating. The heating quality is the ability of the furnace to control the temperature uniformity of the products, taking into account the targets and the cooling phenomenon after discharging, between the discharging area and the mill stand.
The heating quality depends mainly on the burner technology (flame shape, etc.), on the arrangement of the burners in the furnace chamber, on the furnace shape and on the burner control system.
By controlling the heating quality, the average discharging temperature can be lowered to the minimum required, which lowers energy consumption and consequently the Total Cost of Ownership (TCO).

2.1.3 Environmental impact

Reheat furnaces are significant pollutant emitters of integrated steel plants. Two pollution types are particularly under concern:
- CO_2, main greenhouse gas;
- NO_x, which has negative impact on the ecosystem (acid rains, photochemical pollution, eutrophication), on the stratospheric ozone layer and on human health.

All over the world, and especially in Brazil, the respect of the most severe environmental laws is a key issue for steelmakers.
The quantity of CO_2 produced by the furnace is directly linked to the energy consumption, whereas NO_x emissions are produced in the flames, at high temperature and in specific mixing conditions. Moreover, a high oxygen content in flue gases favors NO_x emissions.

2.1.4 Reheating flexibility

The furnace flexibility is the capacity to manage the reheating of a heterogeneous product mix :
- various dimensions;
- various steel grades;
- various positions in the furnace (centred, staggered, aligned on a side, etc.);
- various charging temperatures.

While matching reheating targets: average temperature and uniformity at discharging.
The improvement of the flexibility has a positive impact on the mill process, and thus on the final quality of steel plates or hot rolled coils. Moreover, a high furnace flexibility is less energy intensive, because the burners give the minimum amount of energy needed by the products.

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2.1.5 Maintenance

The furnace design has a direct impact on the maintenance effort. Bad choices at the conception can lead to a very important maintenance effort to maintain the nominal performances.
Many conception choices can lead to rapid deterioration of the performances or the availability of the furnace, for example:

- choices regarding the mechanical equipment : angles of inclined ramps, diameter and material of wheels, size of the beams, etc.
- choices reading the combustion equipment : valves and instrumentation.
- choices regarding scale removal.

2.2 Technologies

Based on these important considerations, CMI Thermline designed a new furnace concept, optimfl@me, which merges patents developed specifically to answer the major needs of today's steelmakers and which has demonstrated particularly encouraging results at the Maghreb Steel plant.

2.2.1 Furnace design

The furnaces are designed with 3 main sections (Figure 1):

- a *recuperative section* that recovers the energy of the waste gases.
- an *active section*, equipped with side burners operated in ONOFFSoft mode, that transfers the majority of the heat from the combustion to the slabs.
- the *discharging chamber*, equipped with roof burners and side burners, operated in proportional mode.

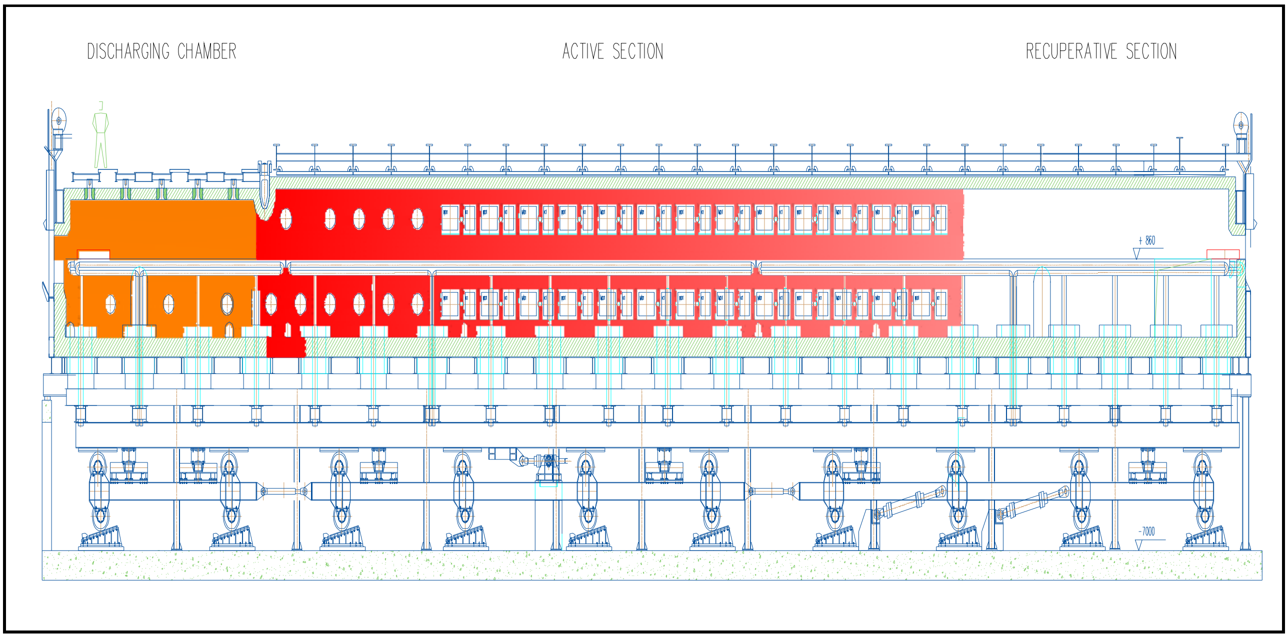

Figure 1. Reheating furnace profile.

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2.2.2 Control philosophy

The active section is especially designed to offer the best performances for any working conditions. The control can be schematically visualized in Figure 2.

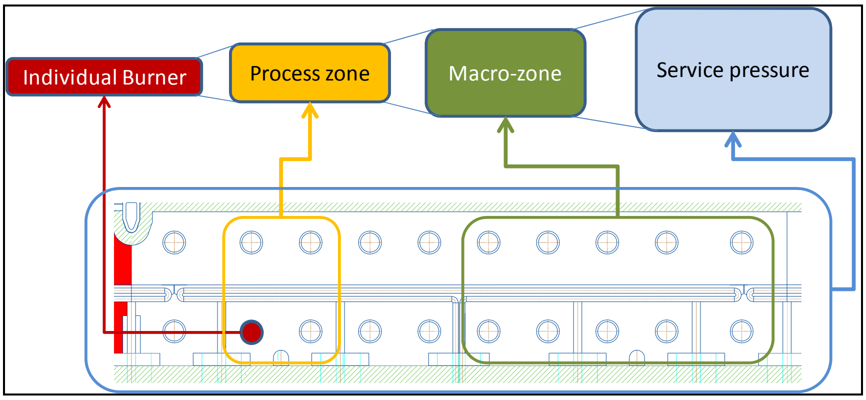

Figure 2. Control scheme.

The objectives of this control philosophy are summarized in Figure 3.

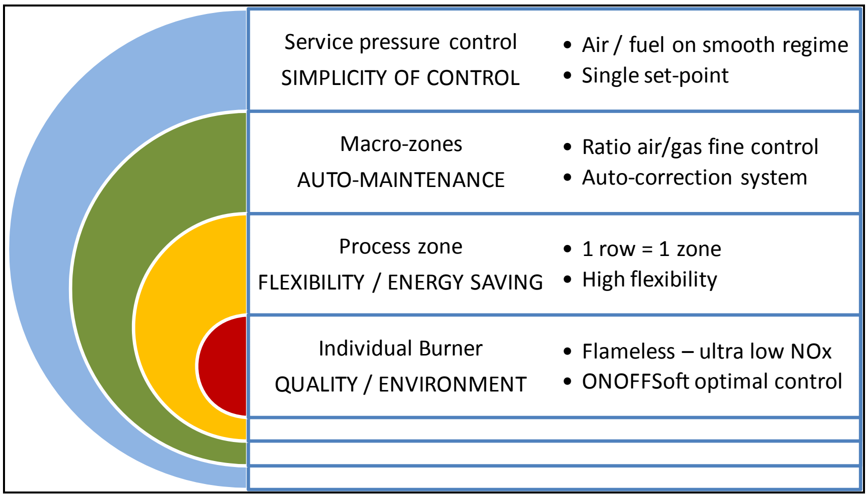

Figure 3. Control philosophy objectives.

2.2.3 On/Off soft

The common main difficulties with the On/Off control is that the firing “blocs” can generate pressure fluctuations in the furnace and in upstream piping, if the firing sequences are not properly organized.

CMI Thermline has developed a firing sequence organizer, called On/Off Soft, to eliminate such problems.

Each burner is independent regarding the firing sequences. The On/Off Soft will:

- gather the heat demands of each burner at regular interval;
- an optimization algorithm under constraints will find the best firing sequence that gives a regular flow in the collectors. If necessary, the On/Off Soft will “cut” the firing blocks in several parts.

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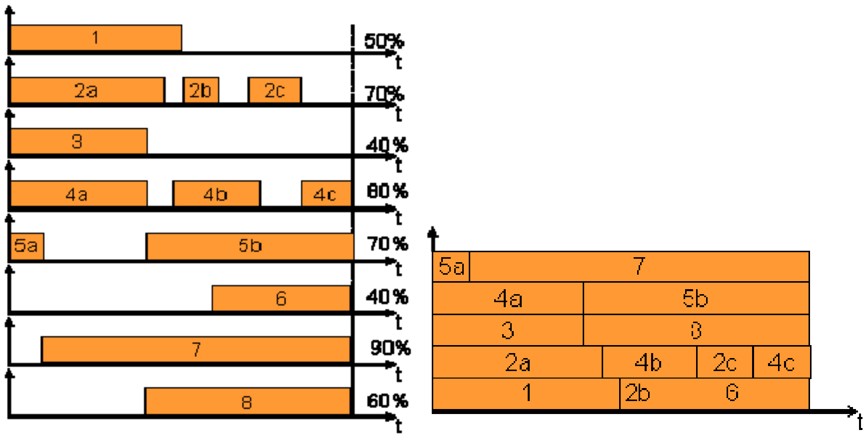

Figure 4. On/off soft.

Figure 5 gives some results collected on an OptimFl@me furnace in operation. It shows the very high performance of the algorithm.

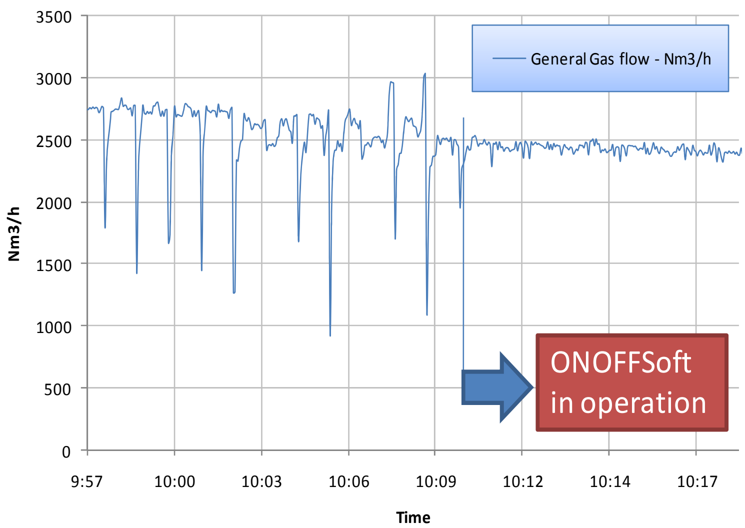

Figure 5. On/off soft results.

2.2.4 Discharging chamber

The patented discharging chamber of the Optimfl@me furnace is separated from the active section by a roof nose and a wall on the hearth. This last section is equipped with roof burners and side burners in lower zones.
This configuration is essential for the process:

- it avoids the waste gases from the active section to create perturbations in the soaking of the slabs.
- the roof burners are the best solution to ensure an uniform soaking, as the entire zone must be at the same temperature.
- the lower zone side burners are controlled in order to avoid pressure fluctuation near the door, as their heat demand is always significant (compensation of skids losses).

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The main advantage of the discharging chamber is a better management of the stoppages and restarts of the furnace, for example during roll changes. The working conditions are the following:

- at the stoppage, the discharging temperature is maintained in the chamber, and the burners are stopped in the active section;
- some minutes before the declared restart, the level 2 system increases the heat demand in the active section, to be ready to run the furnace at nominal pacing;
- at restart, the slabs of the chamber are ready for discharging, and the previous slabs will have the necessary residence time to arrive at the target at discharging position.

This strategy offers the following advantages:

- minimized scale losses during stoppages;
- minimized energy consumption during stoppages.

2.2.5 R-TOP level 2 system

The Optimfl@me furnace will give its nominal performances when operating with the Level 2 optimizing system developed by CMI Thermline, called R-TOP®.
The R-TOP® is built around a central core, that consists in predicting the furnace future to apply an optimal control in any conditions, as shown in Figure 6.

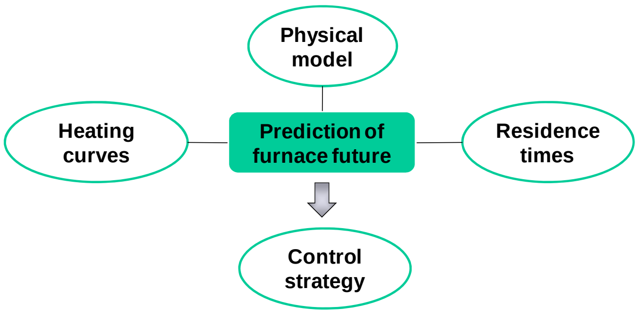

Figure 6. R-TOP® Functions.

The main original functions of the R-TOP® are:

- a real physical model that predicts the 2-dimensional thermal state of the slabs;
- an accurate residence time calculation, that determines the remaining time of the slab before discharging and deduced the most optimal paths to reach the final target, taking into account mill stoppages;
- a calculation at each event of the optimal heating curves, that consider eventual constraints regarding metallurgy, decarburization, etc.;
- a unique strategy of heating control, as the Level 2 determines from previous modules the heat balance on each slab, and calculate directly the necessary heat demand at each burner.

2.2.6 Scale management

A common reheat furnace maintenance problem deals with scale removal from the hearth of the furnace. The scale can be minimized but cannot be avoided. The majority of scale deposit in the furnace is typically observed:

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- near the discharging wall, because of the mechanical stress from the discharging machine;
- at the skids staggering, due to the mechanical stress when changing of supporting points, and the thermo-mechanical stress induced by the hot steel surface meeting the cold pads.

The Optimfl@me furnace is especially designed to minimize and manage the scale losses. Scale is minimized by:

- the R-TOP optimizing system that ensures optimal curves based on physical calculation;
- the macro-zone control that properly control the air-fuel ratio and minimizes oxygen in the furnace;
- the discharging chamber that protects the furnace from air ingress.

2.2.7 Easy maintenance modules

The Optimfl@me design is particularly oriented to facilitate and minimize the intervention of maintenance:

- no need to frequently check the burners tuning, as the macro-zone control correct eventual clogging of the piping, etc. The combustion conditions are kept all along the year;
- choice of On/Off valves with very long life duration (no mechanical stress, controlled leakage);
- module in the Level 1 that count the valves cycles and indicates which valve has to be changed in prevention;
- module in the Level 1 that compares the flow in clean conditions to the measured flow, to indicate an anomaly in the piping (clogging by naphthalene for example).

3 EFFICIENCY INCREASE OF EXISTING REHEATING FURNACE

Many of the equipment build in between 1970 and 1985 are still operating today. However, most of them do not comply with modern standards, in terms of energy consumption, heating qualities and environmental compliance.
Steel producers are facing increasingly competitive markets that require an efficient production chain that minimizes the energy consumption and increases product qualities. Reheating furnaces represent an important amount of operational costs in a hot mill facility, particularly in terms of energy consumption. An expanding necessity is thus appearing, that requires to adapt these equipment to economically reasonable and environmental acceptable operating conditions.
Based on the Optimfl@ame technology, several technical packages described hereafter, have been developed and implemented in existing equipment as shown in the example of UzmetKombinat, presented in Figure 7.
The technical packages that lead to efficiency increases are divided as follows:

- structural modification – product mix modification, capacity increase, heat quality improvements;
- mechanical modification – product transport & heating quality improvement;
- combustion improvement – energy efficiency and environmental impact improvement;

- energy recovery – energy efficiency and environmental impact improvement;
- level 1 and automation improvement – energy and heating quality efficiency, production quality;
- level 2 optimizing systems - energy efficiency improvement, production repeatability, reactivity increase.

3.1 UzmetKombinat (UZB) Project

Figure 7. Reheating furnace UZB.

In 2009, CMI Thermline commissioned a revamping project at the UzmetKombinet (UZB) facility in Uzbekistan. UZB desired to increase the efficiency of its Russian built walking beam reheating furnace for blooms build in 1985.

This furnace was operated with an analogue level 1 automation system. No Level 2 optimizing system was installed on this furnace.

The strategy applied by CMI in such projects is to start with a detailed audit, analyzing the current operation data and furnace key figures in order to simulated the actual configuration of the furnace. This simulation allows to rapidly point out the major improvement possibilities needed for reaching up-to-date energy consumption and heating quality values.

The second step is the modeling of new configurations integrating the technical packages in order to calculate the future consumption values and scale loss gains. In this way, the optimal configuration for the best return on investment is defined.

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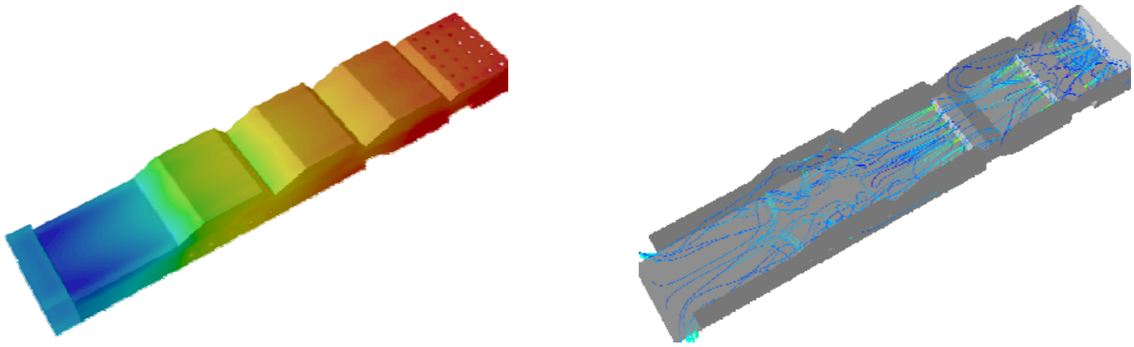

Figure 8. Heat and flow simulations.

Once the solution is approved by the customer, the best revamping strategy is elaborate in order to minimize the mill stoppage duration.

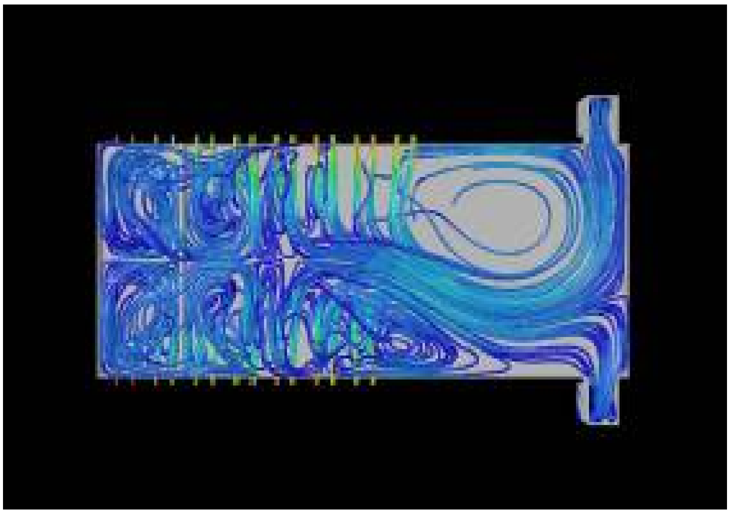

Figure 9. Flow simulation.

After this analysis, CMI Thermline recommended the following modification to UZB that were integrated in the existing furnace:

- mechanical package: in order to reduce drastically the skid marks, a staggering of the existing skids has been integrated;
- structural package: a very important modification of the refractory lining has been undertaken;
- level 1 and automation package: the complete level 0 and level 1 automation system has been replaced in order to ensure a proper handling control and a optimal combustion control;
- level 2 package: an R-TOP® optimizing application has been installed in order minimize the fuel consumption, decrease the scale formation and to ensure an optimal heating repeatability.

This project was undertaken on a turnkey mode. CMI Thermline assumed the complete project scope, i.e. engineering, erection and commissioning. It has been successfully commissioned with the following results.

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3.2 Results

The measured encouraging results achieved at commissioning of the modifications are as follows:

- the production capacity has been increased from initially 100 tons per hour to 122 tons per hour;
- at the discharging temperature interval of 1.230°C to 1.250°C, the difference of center to skin temperature of the blooms has been decreased from 44°C to 28°C;
- the initial specific consumption of 490 Kcal per kg of reheated steel has been decreased to 305 Kcal per kg of reheated steel;
- the initial scale production of 1,2 % at maximum production has been improved to 0.75%.

4 CONCLUSION

As shown in these two examples, the encouraging results of the Optimfl@me technologies present secure advantages than can be implemented either in new or existing reheating furnaces in order to allow steel producers to reach operation criteria matching with the current market challenges.