Double regenerative burners for reheating furnaces: an innovative concept to substantially improve energy efficiency

CMI's patented Double Regenerative Burner (DRB) technology for reheating furnaces considerably lowers CO, CO_2 and NOx emissions, while at the same time allowing the replacement of natural gas by less expensive blast furnace gas, despite its low calorific value.

Authors: Luc Malpa and Liliana Cioriciu
CMI INDUSTRY Metals

Fig 1 **CMI Optifl@me reheating furnace**

The iron and steel industry is responsible for producing 30% of industrial greenhouse gas emissions, of which the fueling of reheating furnaces accounts for a significant 45% of this value. The blast furnace produces over 90% of the CO_2 from an integrated steelworks, but most of this 'waste' gas is used in reheating furnaces where the CO is thus converted to CO_2.

During thermo-reduction – the transformation of iron oxides into liquid iron – blast furnaces emit high volumes of low calorie blast furnace gas (BFG), containing a high proportion of carbon monoxide and nitrogen. The low calorific value of this gas, which is ten times lower than that of natural gas (NG) and 3-5 times lower than coke oven gas (COG), drastically limits its use for industrial application. Specifically, when used in the steel industry's standard reheat furnace burners, BFG must be mixed with a rich gas such as COG or NG as the very high flame temperatures required in the reheating furnaces, typically 1,250°C, cannot be reached using BFG alone. This restriction also makes this gas unusable with today's best available technology (BAT) burners. A typical gas mixed gas used in a reheating furnace is 20% BFG with 80% NG (based on volume).

In some cases this means that the quantity of BFG cannot be maximised, so the excess BFG is either sold at a low price to produce electricity or occasionally burnt to atmosphere and the resulting greenhouse gas is released into the atmosphere.

OPTIMFL@ME® REHEAT FURNACE DESIGN

The development of new steel grades by steelmakers have led to a need for better temperature control and reduced scale losses, as well as ever reducing energy consumption during the reheating processes. This has involved increasingly sophisticated reheating furnace process control requirements and improving their combustion efficiency performance. The associated lower energy consumption and decreased oxidation of steel has been achieved through computer simulation of gas flow, temperature calculations of heated stock, studies and evaluation of scale formation and gas analysis. Based on a combination of BAT and its extensive internal process know-how and experience, CMI developed a new reheating furnace concept to address all of the above market needs.

The CMI reheating furnace (see *Figure1*) is designed to effectively equalise the temperature gradient within the steel slab, bloom or billet, by optimising the transfer of generated heat to the surface of the steel stock to be heated. This provides excellent temperature uniformity, while avoiding scale formation and skid marks. Besides these quality driven parameters, the latest generation of CMI's reheating furnaces also addresses environmental and operational concerns and enables lower fuel consumption by reducing heat losses from the furnace to the minimum, and increase availability and flexibility of operations.

When compared to proportional combustion mode, used in conventional reheating furnace designs, the Optimfl@me® concept offers the following competitive advantages:

- A yearly gain of more than 1% of furnace investment cost
- Discharging temperature decrease of about 10°C, which also improves the homogenity of the final product
- Lowest NOx emissions on the market
- Considerable scale reduction of around 10%
- Fuel consumption savings of up to 10%
- A yearly furnace output increase of up to 5% with the same furnace capacity

DOUBLE REGENERATIVE BURNERS

While the new furnace concept has been successfully implemented in several revamp projects and newly installed reheating furnaces in many parts of the world, CMI has devoted resources to developing a new generation of burners, providing another major improvement for its customers. This latest innovation is the Double Regenerative Burner (DRB), for which a patent application has been filed (see *Figure 2*).

A first trial was successfully conducted in the Galati plant of ArcelorMittal in Romania, using a prototype burner, followed by a major contract to replace two slab reheating furnaces with a new single one – the largest furnace in Europe. This furnace at ArcelorMittal's hot strip mill in Ghent, Belgium, has a combustion area length of 66m (see *Figure 3*) and is the first project where the double regenerative burners are to be installed on an industrial scale, with the aim to considerably reduce operating costs through combustion of blast furnace gas. This project is supported by the EU 'LIFE' programme, a financial instrument supporting environmental, nature conservation and climate action projects throughout the EU. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value, encouraging advances in innovative technologies, aiming at a positive environmental impact.

This specific project aims at considerably lowering CO + CO_2 emissions (greenhouse gases), as well as at ▷

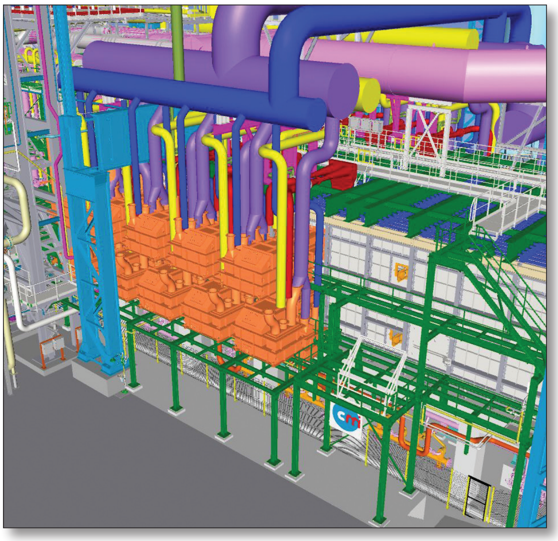

Fig 2 3D view of DRB positioned in the entry section of the reheating furnace

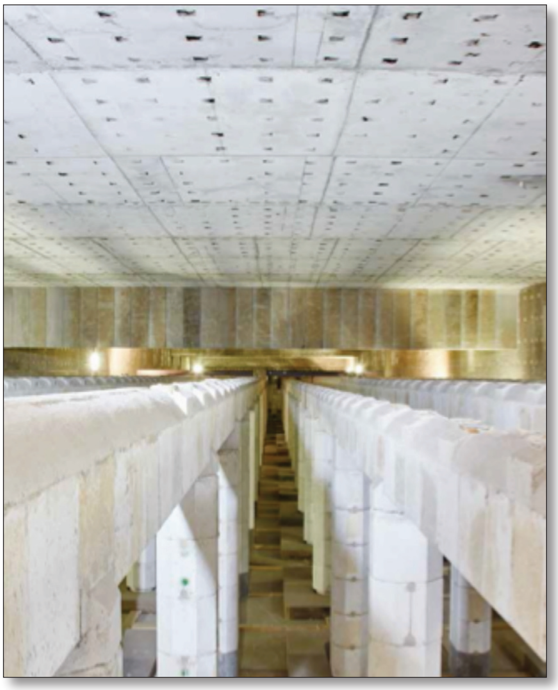

Fig 3 View inside the new reheating furnace at ArcelorMittal, Ghent

Fig 4 **Burner location inside a slab reheating furnace**

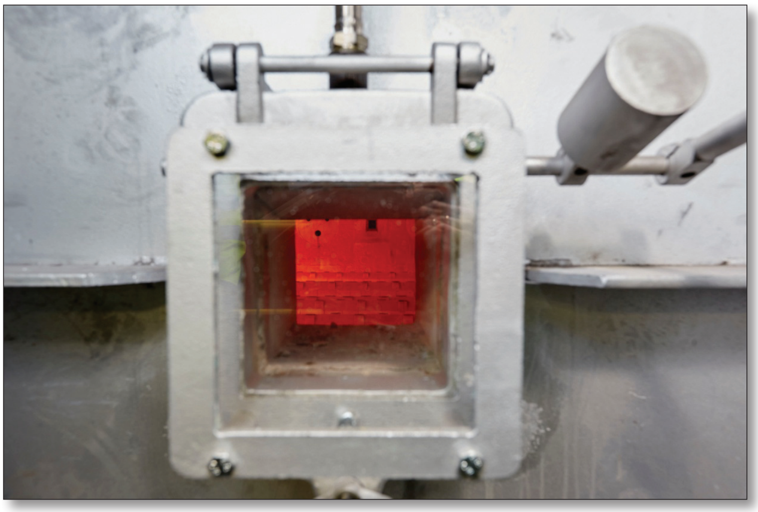

Fig 5 **Inspection window into the slab reheating furnace**

the replacement of NG by less expensive BFG, with the possibility to exclusively use BFG despite its low calorific value. This will result in:

- A reduction of NG consumption of a rolling mill complex by 9%
- A considerable increase of BFG to feed slab reheating furnaces allows reduction of NG consumption by 90%
- Abatement of carcinogenic NOx emissions in the furnace exhaust fumes below $150mg/Nm^3$

Regenerative burner systems are well proven in the steel industry and are increasingly used for all types of furnaces, as they not only allow for very low energy consumption, but also provide a considerable reduction of CO_2 and NOx emissions. The major energy savings achieved will result in a shorter return of investment period, particularly when installed in new furnaces.

Additionally, the CMI's new DRB technology allows the pre-heating of BFG and air in an innovative combustion process within the burner, using a state-of-the-art fume-exhaust system installed inside the burner itself. This technology allows very high temperatures of up to 1,000°C to be reached both for the BFG and combustion air. At this temperature BFG can be used in the furnace reheating process without addition of expensive high calorie content gas, such as natural gas. The project includes the design and installation of a pair of 7MW DRBs. This design was finalised by CMI in 2015, and installation at ArcelorMittal is imminent.

Applying the DRB technology to integrated steel plants operating these types of furnaces in Europe potentially results in a yearly energy saving of ~30,500 megajoules (MJ) per furnace, which translates into preventing ~1.7 M tonnes of carbon dioxide from being emitted into the atmosphere.

KEY DETAILS

- DRB technology can operate with up to 100% low calorific value BFG while respecting safety regulations and the environment
- It provides low and easy maintenance requirements
- It is possible to switch from double regenerative burner mode to single regenerative burner mode, and allows for the use of either BFG only or mixed gas (BFG mixed with NG, or other gases)
- Innovative mixed medium design inside the burners
- Expected annual replacement rate of 5% instead of 100% for single medium solutions, ie, burners last for 20 years
- Compact burner design reduces space needed for installation. An in-furnace view is shown in *Figure 4.*
- Easy retro-fitting on existing furnaces due to its reduced combustion chamber height

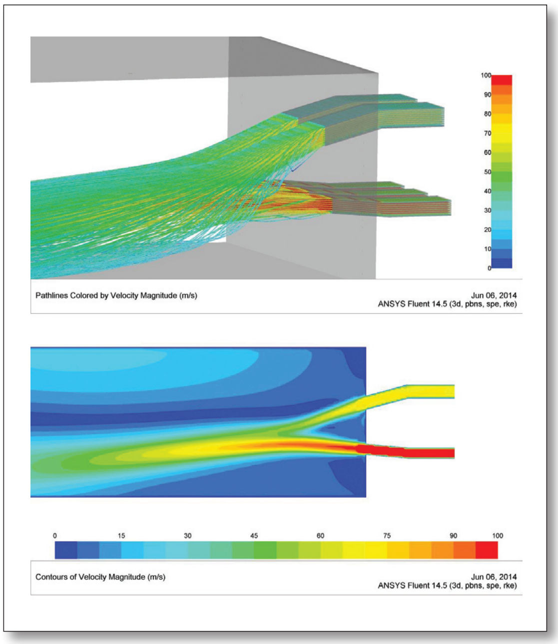

Fig 6 **CFD modelling and thermal calculation of fluid flows at the entry and exit of the regenerators**

- Optimised arrangement of connecting piping
- Unit heating capacity up to 7MW to be installed per 3m of furnace length, compared to today's BAT of 4MW maximum
- DRB technology is the only solution to reach the required adiabatic flame temperature using unmixed BFG
- New concept of fluids injection into the furnace:
- Separate, horizontal rectangular slots for both blast furnace gas and combustion air
- Blast furnace gas injected into the furnace to limit the oxidation of the heated products
- Distinct injection speeds of 100m/s for BFG and 70m/s for combustion air, thus ensuring efficient combustion
- Burners are not fixed onto the furnace structure (estimated weight – 12t per burner):
- No special design is needed for the furnace wall steel structure or refractory lining
- Possibility to easily remove the burner when back space is available (possible installation on wheels and rails)
- Possibility to change or maintain the diffusers from outside of the furnace chamber (access between burner and furnace wall)
- Provision of inspection window (see *Figure 5*)

MODELLING TO VALIDATE THE DESIGN

CMI used its R&D facilities in a combination of laboratory-scale burner testing and Computational Fluid Dynamics (CFD) modelling to investigate and then optimise burner design and performance before starting trial tests in Romania.

Modelling of fluids flows at the entry and exit of the regenerators as illustrated in *Figure 6* was performed in order to:

- Ensure an even distribution of the flows throughout the regeneration media
- Reduce the pressure losses corresponding to the speed changes (acceleration of hot fluids up to 100m/s)
- Reduce the dead volume mainly for BFG and accordingly reduce the purging time

Modelling of the flame inside the furnace by numeric simulation to optimise the diffuser arrangement in order to:

- Insure flameless and complete combustion (no CO)
- Avoid impact of the flame on slabs and roof to limit oxidation and overheating
- Determine the impact of waste gas flow from upstream heating zone
- Determine the influence between burners side by side and top and bottom
- Reduce the air-gas ratio (expected 10% maximum)

CONCLUSIONS

A first trial has provided enough encouraging data and results to convince the world's biggest steelmaker ArcelorMittal to invest in this new technology with the aim of considerably reducing operating costs through combustion of blast furnace gas, while considerably lowering CO + CO_2 emissions.

DRB technology can operate with up to 100% BFG while respecting safety regulations and the environment. Additionally it provides low and easy maintenance requirements.

The replacement of COG and NG by less expansive BFG, with the possibility to exclusively use BFG despite its low calorific value, is resulting in major advantages for steelmakers, such as the reduction of the overall natural gas consumption of a rolling mill complex by 9%, and of a slab reheating furnace by up to 90%. Additionally, carcinogenic NOx emissions in the furnace exhaust fumes will decrease to below 150mg/Nm^3, the 'healthy benchmark' for NOx emission values set by the World Health Organisation. **MS**

Luc Malpa is Product Manager Reheating Furnaces and Liliana Cioriciu is Technical Expert Reheating Furnaces, both with CMI INDUSTRY Metals, Seraing, Belgium.

CONTACTS: luc.malpas@cmigroupe.com
liliana.cioriciu@cmigroupe.com