Dissemination of the heating technology research results for emission minimization and process optimization towards todays fossil-free heating agenda

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Report on current practices, an overview

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Content

1 Current practices in conventional mills 3
1.1 Type of reheating furnaces 3
1.2 Figures 4
1.3 Typical layout of a reheating furnace 4
2 Consumption 5
3 Best practices 6

1 Current practices in conventional mills

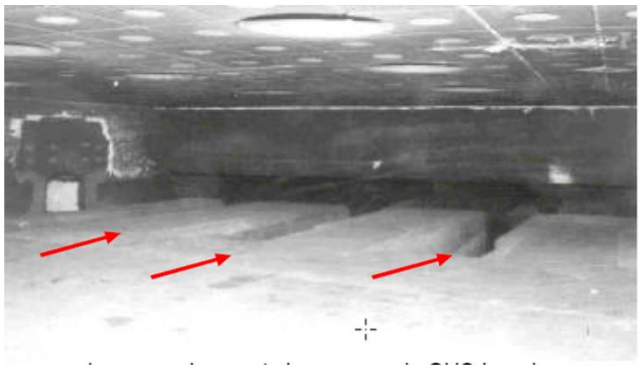
In conventional rolling mills one to even four reheating furnaces (Figure 1) are installed to reheat programmed slabs fast, homogeneous and in an economical way up to the target temperature. The economical way is focussed on the lowest energy consumption. An homogenous reheating is important for technical reasons related to rolling, but also to assure the control of the thickness of the product.

Figure 1: Reheating furnace in a hot strip mill

1.1 Type of reheating furnaces

Two types of furnaces are being used: walking beam and pusher furnaces. Today in Europe almost all strip mills are equipped with walking beam furnaces to avoid scratches on the bottom side of the slab. In other continents as the USA still pusher furnaces are being used. In general if a plant is producing automotive steels walking beam furnaces are a prerequisite.

Walking beam furnace



Pusher furnace

Figure 2: Internal view of a walking beam and pusher furnace

1.2 Figures

- Typically 450 ton of steel are reheated in 1 hour
- A typical width of a furnace is 11.5m and a length of 60m. Hereby the maximum slab length is 11mm
- The length of a furnace varies form 30 to 70 m
- The width can be up to 15m
- The minimum time of a slab inside the furnace is 130 to 140 minutes in an oxidised atmosphere, scale is being formed
- The reheating temperature depends on the grade and varies between 1100 and 1250°C

1.3 Typical layout of a reheating furnace

A typical layout of a reheating furnace is presented in the next figure. Slabs are first charged in a pre-heating zone, with no burners installed. The slabs move than to the heating zone and are heated up to the required temperature, about 90% of the energy is applied in this zone. The heating zone is followed by a soaking zone also equipped with burners with about 10% of the power. Important is the evacuation of emission gasses, mostly in contra-flow of the hot rolled product. A heat exchanger is used to preheat the air to the burners.

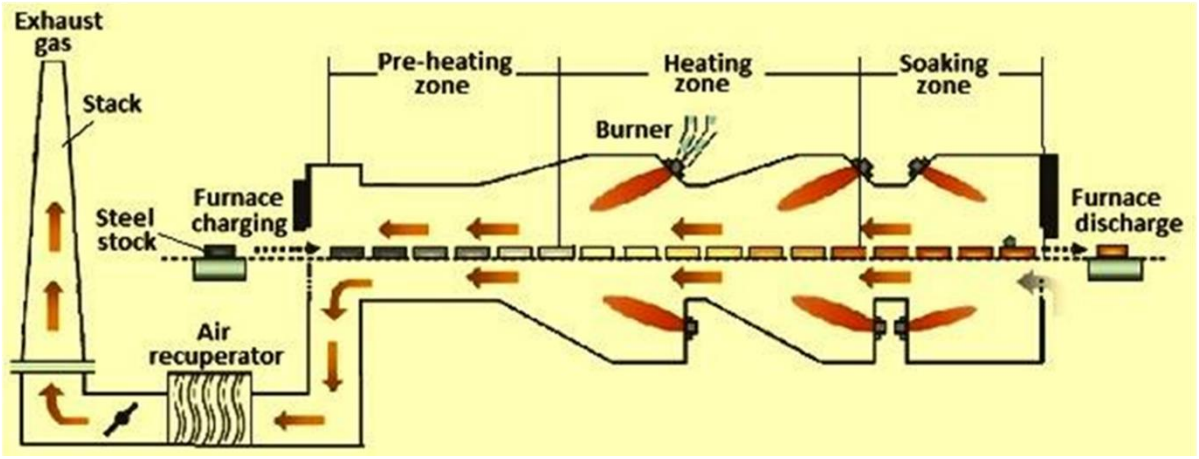


Figure 3: Typical layout of a reheating furnace

The furnace is divided in different control zones with a certain number of gas or fuel burners. Each control zone is equipped with thermocouples to measure the wall and zone temperature. The temperature of the slab is not measured as a correct measurement is not possible due to the oxide layer. The temperature of the slabs are calculated with a computer model. The control temperature of the zones can be entered by an operator but in most cases the control is automatic with the use of furnace model. The furnace is equipped with an on-line gas analysis device (mass-spectrometer) for the analysis of the supply gasses. By this it is possible to perform accurate calculations of:

- Gas density (required for flow measurement and flow calculation)
- The energy-content (required for the furnace model)
- The air supply (required for the air factor)

Depending on the required reheating temperature, based on the metallurgy, the discharging temperature is varying from 1100 to 1250°C. As most mills not have a coil box the temperature of the tail has to be about 20°C higher.

2 Consumption

Inside a walking beam furnace for slabs about 150 to 200 burners are installed (Figure 1Figure 4). Most burners are installed at the sides but additional burners can also be mounted on the top side of the furnace.

Figure 4 : Installation of burners

Reheating furnaces are also equipped with different systems to recover the heat of the gas flow and to preheat the air to the burners. Heat recuperation is performed by a batch of heat exchangers or recuperators installed on the gas exhaust channels of the furnace (Figure 5). In the recuperators the entry gasses of about 675°C are cooled to 300°C at the exit. The air to the burners is preheated up to 500°C.

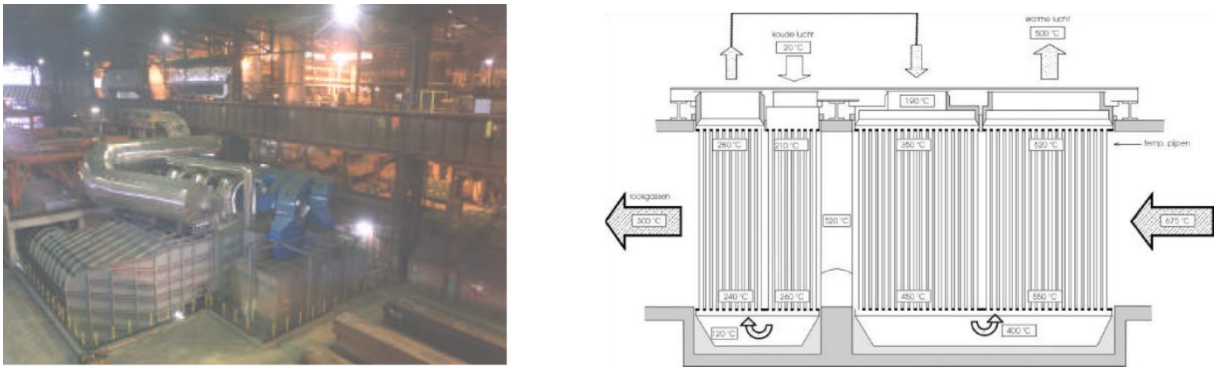


Figure 5 : Heat recuperators

The average consumption of a reheating furnace is illustrated in the next table :

Parameter	Unit	Average
Natural Gas	MJ/ton	739.9
Converter Gas	MJ/ton	142.8
Coke Gas	MJ/ton	499.9
BF Gas	MJ/ton	15.9
Total Technological Fuels	**MJ/ton**	1,398.4
Oxygen	Nm³/ton	0.0
Nitrogen	Nm³/ton	0.6
Compressed Air	Nm³/ton	16.7
Industrial Water	Nm³/ton	3.9
Electricity	kWh/ton	78.1
Steam	kg/ton	4.8

3 Best practices

The best practices for a reheating furnace are :

- A total fuel consumption of 1150 MJ/ton. Steckell mills or compact mills even up to 1000 to 900 MJ/ton.
- To apply hot charging: some mills apply hot charging up to 60%, at temperatures up to 750°C. Hot charging is limited mainly by the slab yard management, the maximum temperature of cranes and scarfing requirements.
- Heat loss during storage in the slab yard can be reduced by heat retention boxes
- A transfer bar thickness of 40mm, to limit heat losses. The transfer thickness is limited by the strength of the crop shear and the reduction of the finishing mill.
- Burner technology:
    - Two main types of burners are used in reheating furnaces:
        - Jet-flame burners (long flame), used in frontal and side walls (typically 1 MW-8 MW)
        - Flat-flame burners, used on the roof (typically 200 kW – 1 MW)
    - Normally, burners are operated with preheated air (~500°C, central recuperator) to partially recover the energy content of the flue gases (~800ºC at furnace outlet).
    - In order to increase the burner efficiency, preheated air temperature can be increased by:
        - Self-recuperative burners (power limited to about 300 kW). Each burner exhausts flues through an air recuperator (air preheated at 600-700°C). Normally used in tunnel furnaces (CSP), and heat treatment furnaces (direct and indirect firing).
        - Regenerative burners. Air and flue gases are sequentially flown through a ceramic regenerator, achieving preheated air temperatures of ~1000ºC.
    - On the other hand, to increase the efficiency (and to enhance productivity), oxygen-enhanced combustion can be used :

    - Oxygen can be injected in standard air-fuel burners to increase the O2 level of oxidizer from 21% O2 to about 25% O2
    - Oxygen lancing can be used to upgrade standard air-fuel burners, so that global O2 level in oxidizer is increased to about 50% O2
    - Oxy-fuel burners using 100% O2 (no air)
    - Hybrid air-oxy-fuel burners. Used e.g. in ladle heaters (air-fuel refractory drying and oxy-fuel heating).
- Regarding fuel flexibility, burners can be operated with a certain range of fuel gas (the Wobbe index is an usual metric for gas interchangeability). Also, in dual-fuel burners, two types of fuel gases can be used (e.g. NG and BOFG) by separate gas lances. In some cases, gas blend is done upstream (mixing station), and depending on the blend one or the other lance is used.
- Regarding NOx level:
    - Standard burners. High NOx level, especially with high air temperature.
    - Low NOx burners: staged air-fuel burners or flameless burners (aiming to delay air-fuel mixture and to enhance the flue gas recirculation so that peak flame temperature is reduced).
- Two types of burners are advised:
    - Flat-flame air-fuel burners, flexible fuel operation, low NOx. Already validated for 100% H2.
    - Jet-flame air-fuel burners, flexible fuel operation, low NOx. Validated for 65% H2.

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