REDUCTION OF HEAT LOSSES ON THE SKID PIPE SYSTEM OF A PUSHER TYPE FURNACE AT VOESTALPINE GROBBLECH GMBH IN LINZ, AUSTRIA

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INTRODUCTION

In the iron and steel making process, hot rolling only accounts for approximately 10% of the energy consumption. Yet 1.5 to 2 GJ/t steel are consumed for hot rolling, and 80% of this energy is utilised for reheating of the slab. The rolling itself requires only 0.3 to 0.4 GJ/t [1].

Increasing energy costs and targets for the reduction of CO_2 emissions provide a constant challenge for all high temperature process users to optimise their processes. In addition to raw material and labour costs, the costs for energy and environmental requirements play an increasingly important role.

New technical solutions are required to improve the energy efficiency and reduce the energy consumption, and consequently the CO_2 emissions. The target of voestalpine Grobblech GmbH and FBB Engineering GmbH is to optimise the hot rolling process from an energy point of view, reduce CO_2 emissions, and reduce the operational cost of the reheating furnaces. Another important aspect is the increase in productivity by reducing the shutdown time of the furnace. Cooperation in partnership between the operator of the kiln and the supplier of refractory materials is an essential requirement for achieving these goals.

This paper discusses how energy consumption and energy loss can be reduced in reheating furnaces of hot rolling mills by new lightweight refractory materials and a new lining concept for the skid pipe insulation.

VOESTALPINE GROBBLECH GMBH LINZ

Voestalpine Grobblech GmbH was founded in 1958 and since 2001, has been a 100% subsidiary of voestalpine Stahl in Linz, Austria. Voestalpine AG is divided into four divisions in 60 countries with approximately 40,000 employees in approximately 360 production and sales locations.

The annual tonnage of voestalpine Grobblech GmbH is 800,000t produced by a workforce of about 640.

The main markets and applications for heavy plates are:
- Energy industry (offshore industry)
- Sour gas resistant tube sheets
- Steel and bridge construction
- Shipbuilding and automotive industry
- Mining industry
- Others

Figure 1 shows an overview of the rolling mill facilities. The reheating of slabs is carried out in two water cooled pusher type furnaces, where the slabs are heated over a three hour period to temperatures from 1,100 to 1,200°C. Figure 2 shows a drawing of the pusher type furnace 1 (PTF 1).

The characteristics of PTF 1 are:
- Furnace output: nominal 110 t/h
- Nominal capacity: 700,000 t/y
- Furnace length: 30,500 mm
- Furnace width: 6,600 mm
- Burners: Low NO_x generation
- Number of burners: 42 in side wall, 16 in roof
- Installed power: 63 MW
- Specific energy consumption: 320 kWh/t
- Energy consumption: 224,000 MWh/y
- Fuel: coke oven gas
- Furnace temperatures (app.):
  - Charging zone: 900°C
  - Pre-heating zone: 1,200°C
  - Heating zone: max. 1,280 °C
  - Soaking zone: 1,200°C
- Furnace operation: process computer-assisted control

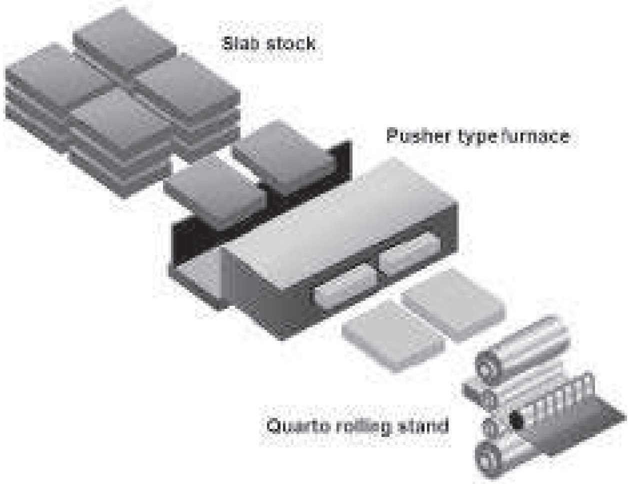

Fig. 1: Production facilities at voestalpine Grobblech GmbH Linz, Austria

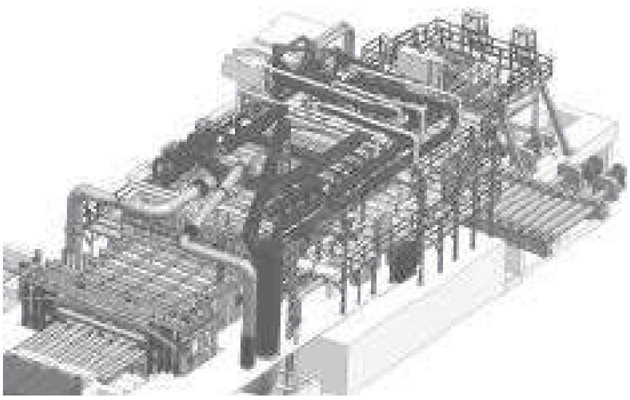

Fig. 2: Pusher type furnace 1 (PTF 1)

This paper summarises the experiences with the new lining concept for the water cooled skid pipe system in voestalpine Grobblech GmbH furnaces as shown in figure 3. There is a separate cooling section for each skid (no. 1-6) and three additional cooling circuits for posts and crossover pipes: cooling circuit 1 for charging zone (CZ), circuit 2 for heating zone (HZ) and circuit 3 for soaking zone (SZ).

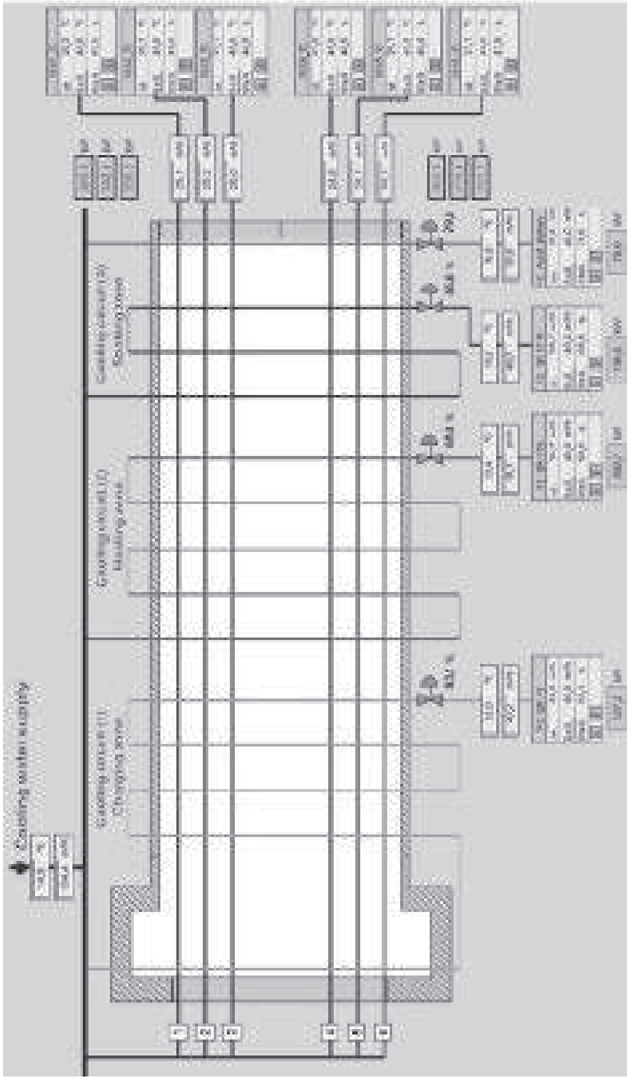

Fig. 3: Complete cooling system of pusher type furnace, one cooling circuit for each skid, three cooling circuits for posts and crossover pipes

The furnace loses heat to the cooling water of the skid pipe system. This is typically 10 – 15% of the total energy provided for heating the furnace. These losses can be reduced by better insulating characteristics and properties of the refractory lining for the skid pipe system.
Before presenting the development at voestalpine Grobblech GmbH the new refractory lining concept and the materials used will be discussed.

LINING CONCEPT WITH PRE-FABRICATED INSULATING SHELLS

The skid pipe system is lined with pre-fabricated shells, where the design of the shells is adapted to the conditions in the reheating furnace. The lay out and configuration of the shells is created using a modular concept in order to minimise the number of different parts and to allow easy installation (figure 4).

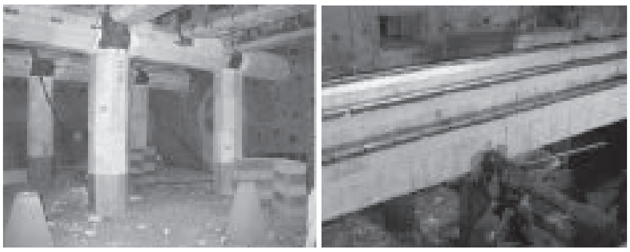

Fig. 4: Modular installation concept of skid pipe system in a 110 t/h pusher type furnace at voestalpine Grobblech GmbH Linz, Austria

The big advantage of this innovative modular installation concept using pre-fabricated parts, over an on-site castable installation, is a significant reduction of installation time. This is typically around 75%. This reduces the shutdown time of the furnace and increases the productivity. Time consuming jobs such as installation of shuttering on the skids and pipes, mixing and transportation of the castable on site and the curing time before removing the shuttering can be eliminated.
The insulating shells have got a thermotechnical optimised sandwich design. Inside there is a heat resistant metal sheet responsible for high mechanical stability. The second layer is a blanket of high temperature insulation wool (AES-wool, low bio persistence) which is completely embedded in dense or lightweight refractory castable as the third layer on the hot face (figure 5).

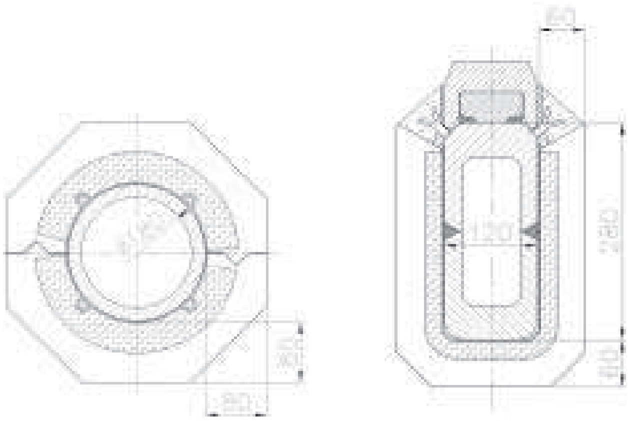

Fig. 5: Thermotechnical optimised sandwich design of pre-fabricated insulating shells for post (left) and skid pipe (right)

The most recent and key innovation step in the development of the shells was the application of an insulating lightweight castable instead of the dense castable, as the outer layer. Table 1 shows a comparison of typical product parameters between the dense castable and the lightweight castable FLB-11/150-I1. The big difference in bulk density, 2.5 compared to 1.1g/cm³, leads to a significant reduction in thermal conductivity. This is in the range of 75-80%. Therefore the heat losses through the shell into the cooling water can be significantly reduced.
The key component of the lightweight castable is SLA-92, an innovative raw material for high temperature insulation up to 1,500°C. Data for this raw material are given in table 2, and the microstructure and pore size distribution are shown in figure 6. SLA-92 was initially developed as an alternative to high temperature insulating wool (HTIW) or fibre materials [2,3], and is currently being used successfully in a variety of applications including reheating furnaces in the steel industry [3-7]. The microporous structure is responsible for low thermal conductivity, because it hampers heat transfer by radiation at temperatures exceeding 1,000°C. It also results in a high thermal shock resistance of insulating refractories based on SLA-92, because crack propagation is hampered.

Tab. 1: Typical data of refractory castables for shells

	Dense castable	Lightweight castable
	FB-25/160-P1	FLB-11/150-I1
Chemical Composition [wt.%]		
Al_2O_3	57	89
SiO_2	38	0.1
CaO	2.3	10
Fe_2O_3	1.1	0.1
Physical Properties		
Appl. Temp. [°C]	1,600	1,500
Bulk Density [g/cm³]	**2.5**	**1.1**
Cold Crushing Strength [MPa]		
110°C	95	5
1.200°C	85	5
1.400°C	90	6
Thermal Conductivity [W/mK]		
200°C	1.60	0.30
800°C	1.66	0.28
1.000°C	**1.70**	**0.30**
1.200°C	**1.80**	**0.36**
Perm. Linear Change [%]		
1.000°C	–0.1	–0.1
1.200°C	0.1	–0.2
1.450°C	0.5	–0.3

Tab. 2: SLA-92 product data

Mineralogical composition	
Main phase	CA6 (~ 90%)
Minor phase	Corundum
Chemical analysis [mass-%]	
Al_2O_3	91
CaO	8.5
Fe_2O_3	0.04
SiO_2	0.07
Na_2O	0.4
Physical properties	
Bulk density [g/cm³]	0.8
Lose bulk density [kg/l]	0.5
Apparent porosity [vol.-%]	70 – 75
Available sizes	
3 – 6 mm	
1 – 3 mm	
0 – 1 mm	

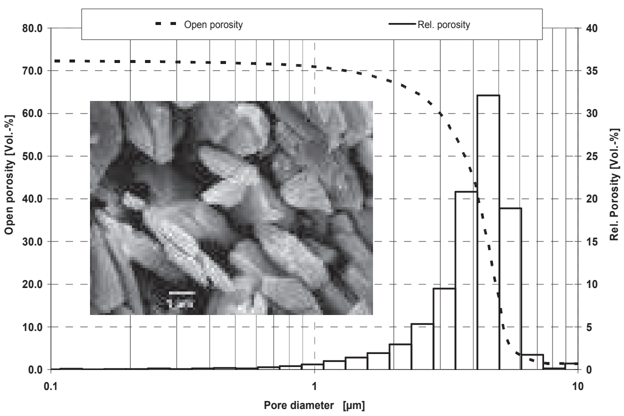

Fig. 6: SLA-92 microstructure of calcium hexaluminate platelets (scanning electron microscope) and micropore size distribution (Hg-intrusion method)

PRE-TESTS AND CALCULATIONS

Before the new lightweight shells were introduced in rolling mills, pre-tests were made in a test furnace at FBB Engineering GmbH at temperatures up to 1,300°C. The tests were carried out using an all side insulated pipe comparable to a post in a pusher type furnace. These tests were conducted under ideal conditions e.g. in an inert furnace atmosphere and no scale.

When replacing the dense with the lightweight shell system, a considerable reduction in heat loss per square metre pipe surface (more than 50%) was achieved (figure 7).

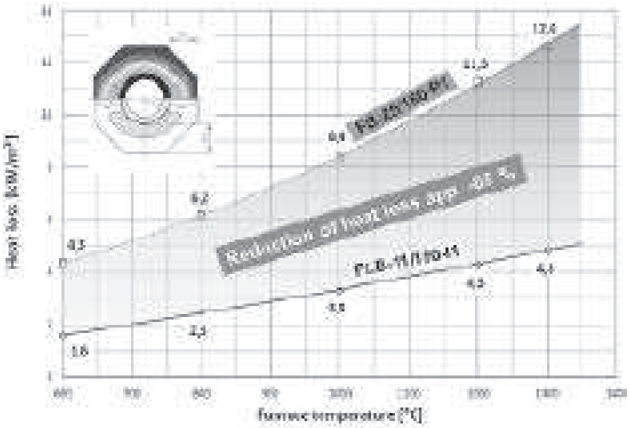

Fig. 7: Heat loss per m^2_{pipe} for different refractory materials for skid pipe insulation shells (results from FBB test furnace) [7].

Thermotechnical calculations by computational fluid dynamics (CFD) show that installations with lightweight castable FLB-11/150-I1 (BD=1.1 kg/dm³) can reduce heat loss by 50% or more when compared to dense castable (BD=2.5 kg/dm³) [7]. Results are shown in figure 8.

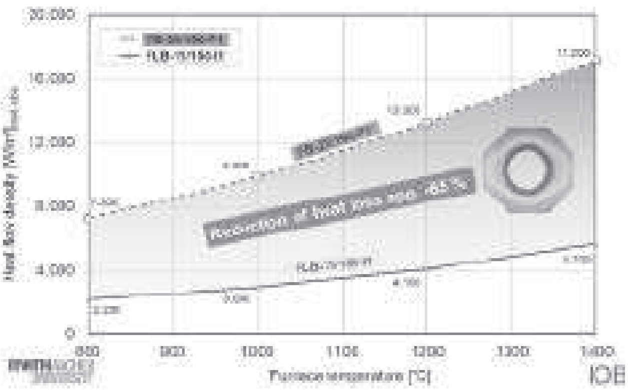

Fig. 8: Density of heat flow [W/m^2_{pipe}] for a post between 800°C and 1.400°C furnace temperature for different refractory materials of the insulation shells (CFD calculation).

INDUSTRIAL APPLICATION IN A 110 t/h PUSHER TYPE FURNACE

The temperature increase of the cooling water in the skid pipe system between entering and leaving the kiln and the water flow rate are the indicators of the efficiency of the insulation. The calculation of power loss, energy loss and costs is based on following basic conditions:

– Production: approx. 330 days/year
– Price for natural gas: approx. 0.03 €/kWh
– CO_2: 0.2 kg/kWh $_{natural\ gas}$

At the beginning of 2010 the first skid (no. 1) was completely lined with the new lightweight shells. A first evaluation of this skid no.1 in comparison with skids nos 2-5 lined with the dense shells proved the potential for energy saving with the new lightweight system (table 3). Consequently the remaining skids nos 2-5 were also lined with the new system at the end of 2010. During the following summer shut down in 2011 the remaining posts and crossover pipes were also equipped with the lightweight pre-fabricated shells.

Tab. 3: Comparison of skid no.1 insulated with lightweight castable and skids nos 2-5 (average value) insulated with dense castable shells

Skid	Water flow rate	Water temp. difference Out – In	Power loss/ skid	Energy loss/ skid
	[m³/h]	[°C]	[kW]	[MWh/y]
1	25.0	12.3	359	2.843
2-5	25.1	15.0	437	3.461
Diff.		–2.7	–78	–618
Rel. diff.			18%	

The complete skid pipe system of furnace PTF 1 was equipped with lightweight insulating shells made of FLB-11/150-I1. Only at the T-joints was the dense castable not replaced with the lightweight one. It was also not possible to replace the old dense lining with the new lightweight material at several positions of some crossover pipes due to the nature of the furnace construction.
Figure 9 shows an example of the layout of the lining with prefabricated shells for posts, crossover pipes and skid pipes in the soaking zone of PTF 1. Each shell is labelled for easy and fast installation according the drawing. The installation is completed with in-situ casting at the T-joint.
The first shell at the bottom of the posts (labelled 14S in figure 8) is made of dense castable instead of lightweight material. During operation of the kiln, scale drops on the kiln floor and is removed with heavy machinery during furnace maintenance. Therefore a high strength material at this position is mandatory. In this case that means that only 70% of the post length can be lined with lightweight material.

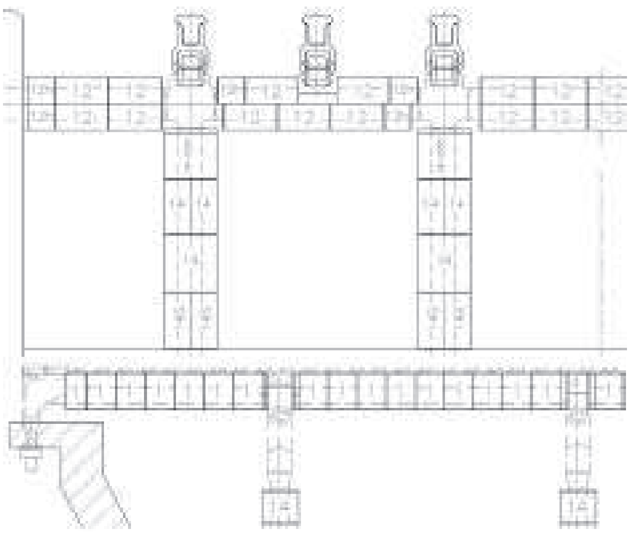

Fig. 9: Layout of insulation with pre-fabricated shells for posts, crossover pipes (above) and skids (below) in the soaking zone of PTF 1

In the charging zone (CZ) most of the posts have a height below 0.5 metre. Therefore less than 50% of the post´s surface can be lined with lightweight shells, and some posts stay completely lined with dense shells. In addition the T-joints are lined with dense material, so that the reduction of energy loss in this cooling circuit is very limited.
The data of the water cooling system of PTF 1 before and after the installation of the new lightweight concept are given in tables 4 and 5 as annualised figures. In addition to the energy loss through the cooling water, the annual CO_2 emission is also given. The water flow rate through the skid pipes (nos 1-6) could be reduced with the lightweight concept by 12% and, in addition, the water temperature difference could be reduced by 13%. The temperature increase of the cooling water was reduced in all cases between 16% in the charging and heating zone and 33% in the soaking zone.

Tab. 4: Data from water cooling circuits of the skid pipe system lined with dense castable shells (BD 2.5 g/cm³)

Cool. Cir-cuit	Water Flow rate	Water temp. diff. Out – In	Power loss	Energy loss	Costs	CO_2
	[m³/h]	[°C]	[kW]	[MWh/y]	[€/y]	[t/y]
S 1-6	169.6	14.3	2,802	22,192	665,746	4,438
CZ	37.4	8.3	363	2,874	86,225	575
HZ	39.7	10.2	472	3,740	112,195	748
SZ	39.6	6.4	297	2,352	70,567	470
Σ	286.3	11.8*	3,934	31,158	934,733	6,232

– S 1-6 Skid pipe 1-6
– CZ cooling circuit (1) charging zone
– HZ cooling circuit (2) heating zone
– SZ cooling circuit (3) soaking zone
* weighted average by water flow rate

Tab. 5: Data from water cooling circuits of the skid pipe system lined with lightweight castable shells (BD 1.1 g/cm³)

Cool. Circuit	Water Flow rate	Water temp. diff. Out – In	Power loss	Energy loss	Costs	CO_2
	[m³/h]	[°C]	[kW]	[MWh/y]	[€/y]	[t/y]
S 1-6	150,3	12,4	2.175	17.224	516,732	3,445
CZ	40,2	7,0	327	2.591	77,743	518
HZ	39,7	8,5	391	3.094	92,830	619
SZ	39,7	4,3	200	1.580	47,401	316
	269,9	9,9*	3.092	24.490	734,707	4,898

* weighted average by water flow rate

The average temperature increase of the entire cooling system, normalised to the amount of cooling water was reduced by 2.5°C. The energy savings differ between the areas of the skid pipe cooling system. For the skid pipes 1-6 a reduction of energy loss of about 22% was achieved. The furnace is equipped with conventional riders in the charging and the heating zone and with a hot rider system in the soaking zone. Rider geometry and system design have a big influence on the density of heat flow through the skid pipe. The skid surface which can be insulated is lower in the area of the hot rider system when compared to the area with the conventional rider system. This limits to some extent the potential for energy saving here.
In the cooling circuit SZ (soaking zone) the energy loss was reduced by approximately 33%. In total about 70-75% of the surface in the soaking zone was lined with lightweight castable shells, the remaining surface was still lined with dense castable shells as described above.

In the cooling circuits of the charging and heating zones the reduction of energy loss is lower at 10% and 17% respectively when compared to the soaking zone because the skid design and some installations in the furnace, limits the possibilities to install more lightweight insulating shells.
In Table 6 the overall energy loss of the two different lining concepts and the saving achieved with the new lightweight concept are given. For the complete pusher type furnace PTF 1 a reduction of energy loss of 21% is achieved. Based on the price of fuel of app. 0,03 €/kWh, that equates to a cost reduction of € 200.000 per year. In addition the CO_2 emissions can be reduced by up to 1,300 tons per year, which also accounts for a saving of several thousand Euros.

Tab. 6: Energy savings and cost reduction for complete pusher type furnace using lightweight castable instead of dense castable for insulating the skid pipe system

	Power loss	Energy loss	Costs	CO_2
	[kW]	[MWh/y]	[€/y]	[t/y]
Dense castable (RD = 2,5 kg/cm³)	3.934	31.158	934,733	6,232
Lightweight castable (RD = 1,1 kg/cm³)	3.092	24.490	734,707	4,898
Saving	842	6.668	200,026	1,334
	21 %			

Figure 10 shows the energy balance of PTF 1 with skid pipe system completely lined with pre-fabricated shells made of lightweight castable FLB-11/150-I1. The heat loss of the skid pipe cooling system amounts in this case to 9.6% when compared to 12.5-13% with the dense material shells previously used.

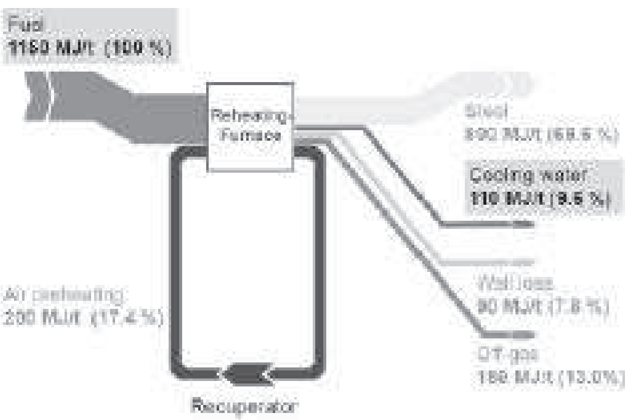

Fig. 10: Energy balance of PTF 1 after complete installation of skid pipe system with pre-fabricated insulating shells made of lightweight castable

The investment costs of the new insulating material lining concept for the complete skid pipe system of the furnace were app. € 170,000. The cost reduction achieved by reduced energy losses is € 200,000 per year. That means that the payback period for this installation, including costs for removal of the old insulation, is only one year. Meanwhile, these values are also confirmed by other steel manufacturers having experience with the new material concept.
Based on this extremely good result achieved in pusher type furnace 1 the new built pusher type furnace 2 which was commissioned at the beginning of 2012 was also equipped with the lightweight insulating shells. In this new furnace all the T-joint were also lined with a lightweight version so heat losses can be reduced even more.

CONCLUSION

The modular lining concept using prefabricated shells for the skid pipe system in reheating furnaces provides shorter installation times and reduces the downtime of the furnaces during maintenance, thus increasing the productivity.
The new lightweight shells based on the microporous castable FLB-11/150-I1 and a thermotechnical optimised sandwich construction, can significantly reduce the heat losses to the cooling system of the skid pipe system in reheating furnaces, both pusher type and walking beam furnaces. Trials in a test furnace and CFD calculations show a potential of more than 50% reduction of heat losses when compared with dense castable shells.
The industrial application of the new lightweight shell system in the 110t/h pusher type furnace 1 of voestalpine Grobblech GmbH Linz, Austria, resulted in an overall energy saving of 21% when compared to the dense castable shells. It has to be taken into account, that not all areas could be lined with the new lightweight concept because of the specific skid design and some installations within the furnace. This limited the saving to some extent.
The annualised energy saving gives a cost reduction which is higher than the installation cost for the new lining, resulting in a payback period of only one year. Consequently, the newly constructed pusher type furnace 2 at voestalpine Grobblech GmbH was also lined according to the lightweight shell concept. Here, the T-joint were also lined with lightweight castable.
The close and open co-operation between end-user, refractory supplier, and raw material supplier enabled the introduction of a new and innovative refractory lining concept which reduces the energy consumption of rolling mill furnaces and contributes to the reduction of CO_2 emissions. In this context voestalpine Grobblech GmbH was a pioneer in the realisation of innovative solutions in practice.

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