

ENERGY SAVING IN WALKING BEAM FURNACES AT ARCELORMITTAL (BREMEN, GERMANY) BY A NEW CONCEPT FOR SKID PIPE INSULATION

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INTRODUCTION

In the iron and steel making process, hot rolling accounts for only approximately 10% of the energy consumption. Yet 1.5 to 2 GJ/t of 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/t¹. Increasing energy costs and targets for the reduction of CO₂ 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 energy efficiency reduce energy consumption and reduce CO₂ emissions. The target of ArcelorMittal Bremen GmbH, Germany, and FBB Engineering GmbH is to optimise the hot rolling process from an energy point of view, reduce CO₂ 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 furnaces. This paper discusses how energy consumption and energy loss can be reduced in reheating furnaces of hot rolling mills by using new lightweight refractory materials and a new lining concept for the skid pipe insulation.

ARCELORMITTAL BREMEN, GERMANY

ArcelorMittal Bremen GmbH was founded in 1957 and since 2001 has been a 100%

subsidiary ArcelorMittal group.

ArcelorMittal is the biggest steel manufacturer worldwide with 320,000 employees in 61 production locations and in 27 countries around the world.

The annual tonnage of ArcelorMittal Bremen is up to 4 Mio. t produced by a workforce of about 3,000.

The main markets and applications are automotive and construction industry, packaging industry, mechanical engineering, energy sectors and appliance industry.

HOT ROLLING MILL

- Slab stock
- 3 walking beam furnaces (WBF 1, 2, 3)
- 1 continuous roughing mill, 1 seven stand finishing mill
- 3 down coilers

Tab. I: Specifications of the hot rolling mill

Annual capacity	Max.	4.8 Mt/a
	Max. realised	3.6 Mt/a
Slab	Width	550 – 2,200 mm
	Thickness	180 - 250 mm
	Max. length	15,000 mm
Transfer bar	Max. thickness	76 mm
Strip	Width	600 – 2,150 mm
	Thickness	1.50 – 28.5 mm
	Speed	2.0 – 23.2 m/s
Coils	Max. weight	45 tons
	Outside diameter	600 – 2,150 mm

Steel grades:

Normal carbon grades, Low + Ultra low carbon grades, HSS / UHSS, X-grades, Stainless steel

The characteristics of WBF 1 and 2:

- Furnace output: nominal 420 t/h
- Furnace length: 38.0 m
- Furnace width: 15.8 m
- Installed power: 304 MW
- Fuel: BOF and natural gas

This paper summarises the experiences with the new lightweight material and lining concept for the water cooled skid pipe system in walking beam furnaces no.1 (WBF 1) and no. 2 (WBF 2) at ArcelorMittal Bremen.

INITIAL SITUATION

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.

The previous lining and insulation of the skid pipe system in the walking beam furnaces at ArcelorMittal Bremen was done with modules made of high temperature insulation wool (HTIW). The specific material used for these modules was aluminium silicate wool, also referred to as refractory ceramic fibres (RCF) with a 1,400°C maximum temperature rating and a continuous use temperature of 1,250°C.

The lifetime of this insulation system was rather short and not satisfying. Especially the very low mechanical strength was a major problem. The scale collects on the upper side of the skid pipe and in-between the riders. It crushes on insulating material every time when the slab is moved and laid down on the riders. The pressure of the slab and scale on the fibrous material led to mechanical destruction and the modules fell off the tubes. In addition the modules were chemically attacked by

scale. Shrinkage and deterioration of the modules indicated a partial over-heating of this material with an application temperature (1,250°C) about 150°C lower than the maximum temperature rating (1,400°C).

Hence nearly every six month a furnace shut down was necessary for repair and maintenance of large areas where the fibrous insulating material had failed (Fig. 1).



Fig. 1: Destroyed insulating modules made of RCF in WBF 1

The health and safety discussion on HTIW and RCF in particular leads to extensive precautions for installation and removal of these modules. The replacement of HTIW by a non-classified insulation material was desired. Therefore new technical concepts for insulating the skid pipe system were evaluated. Important criteria were defined as:

- Higher mechanical strength
- Higher application temperature
- Better chemical resistance against attack by scale
- Longer durability

These criteria for the new insulating material could be fulfilled by dense castable.

However, ArcelorMittal also wanted to improve the energy efficiency and productivity of the furnace by:

- Lower energy loss through the skid pipe cooling system
- Reduced furnace shutdown time by using pre-fabricated insulating shells

LINING CONCEPT WITH PRE-FABRICATED INSULATING SHELLS

The skid pipe system is lined with pre-fabricated shells made of refractory castables, with the design of the shells adapted to the conditions in the furnace². The layout 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 (Fig. 2).



Fig. 2: Modular installation concept of skid pipe system in WBF 1

One 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, typically around 75%. This reduces the shutdown time of the furnace and increases the productivity. Time consuming jobs such as installation of forms (moulds) on the skids and posts, mixing, transportation and installing of the castable on site and curing time before removing the forms can be eliminated.

The insulating shells have a thermotechnical optimised sandwich design. Inside is a heat resistant metal sheet for attaching the shells on the pipes. The second layer is a blanket of high temperature insulation wool (AES-wool, alkaline-earth-silicate wool, non-classified fibre with low bio persistence) which is completely embedded in dense or lightweight

refractory castable as the third layer on the hot face (Fig. 3).

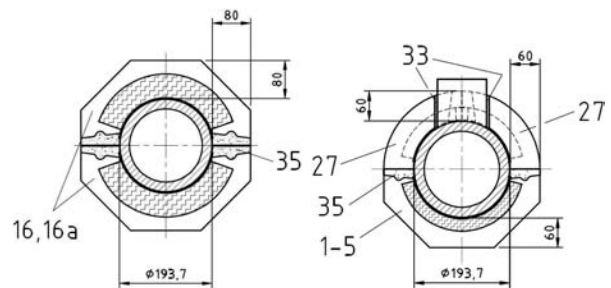


Fig. 3: Thermotechnical optimised sandwich design of pre-fabricated insulating shells for post (left) and skid pipe (right)

The most recent and key innovation step in the development of the energy efficient shells was the application of an insulating lightweight castable instead of the dense castable, as the outer layer.

Table II shows a comparison of typical product parameters between the dense castable and the lightweight castable FLB-11/150-II. 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 applications up to 1,500°C. SLA-92 was initially developed as an alternative to high temperature insulating wool (HTIW) or fibre materials^{3,4}, and is currently being used successfully in a variety of applications in the steel industry⁴⁻⁸. 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. II: Typical data of refractory castables for pre-fabricated insulating shells

	Dense castable	Lightweight castable
	FB-25/160-P1	FLB-11/150-I1
Chemical Composition [wt.%]		
Al ₂ O ₃	57	89
SiO ₂	38	0.1
CaO	2.3	10
Fe ₂ O ₃	1.1	0.1
Physical Properties		
Appl. Temp. [°C]	1,600	1,500
Bulk Density [g/cm ³]	2.5	1.1
CCS [MPa]		
110°C	95	5
1.200°C	85	5
1.400°C	90	6
Thermal Conductivity [W/mK]		
800°C	1.66	0.28
1.000°C	1.70	0.30
1.200°C	1.80	0.36

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. The tests were carried out using fully insulated pipe comparable to a post in a walking beam furnace. When replacing the dense with the lightweight shell system a considerable reduction of more than 60% in heat loss per square metre pipe surface was achieved (Fig. 4).

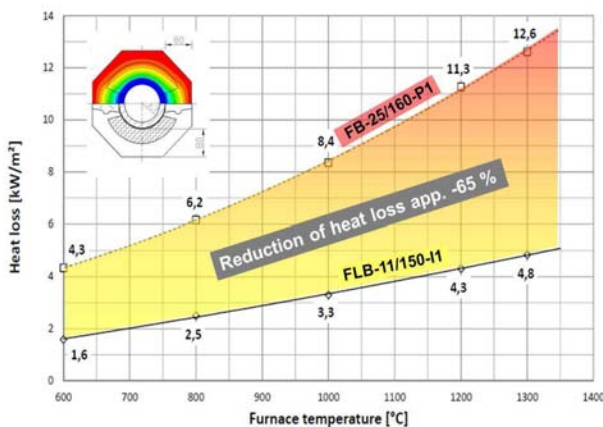


Fig. 4: Heat loss per m²_{pipe} for different refractory materials for skid pipe insulation shells (results from FBB test furnace)⁸.

The results from the test furnace are also confirmed by thermotechnical calculations by computational fluid dynamics (CFD)⁸.

INDUSTRIAL APPLICATION

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 following calculation of power loss, energy loss and costs is based on following basic conditions:

- Furnace operation time: approx. 300 d/y
- natural gas (average price): 0.03 €/kWh

After evaluation of different possibilities for insulating the skid pipe system the decision was made to test pre-fabricated shells made of lightweight castable. The area for the first test in WBF 1 was specified (see Fig. 5 and 6).

The yellow marked area in Fig. 5 shows a separate cooling circuit in the skid pipe system that allows comparison of the test results with the cooling cycle on a corresponding skid frame. In this yellow coloured area the new insulating system was installed on the posts and the skid pipe beginning of 2009. The blue coloured posts are not included in this test cooling circuit and remained insulated with RCF modules. Fig. 6 shows the corresponding photo of this test area in the furnace.

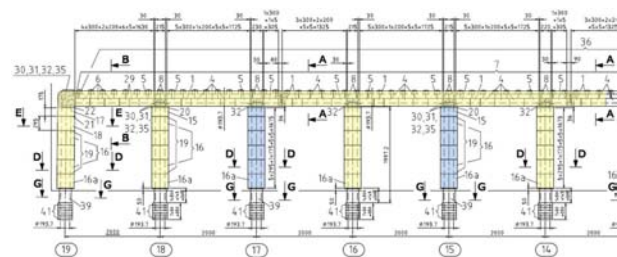


Fig. 5: Test area (yellow marked) for pre-fabricated shells made of lightweight castable



Fig. 6: Test area after installation of pre-fabricated shells made of light weight castable

This first performance test with the lightweight system proved the chemical and mechanical wear resistance and indicated high potential for energy saving. Consequently, it was decided to change from the existing insulating material to pre-fabricated shells made of lightweight castable in WBF 1 and WBF 2. During the following furnace shutdown in October 2010 the complete skid pipe system of WBF 1 was equipped with the new material. The exposed areas on the upper side of the skids, representing the zone of highest attack by scale, was also insulated with pre-fabricated shells. Here, shells made of dense castable FB-25/160-P1 were used in order to achieve a higher wear resistance (Fig. 7).



Fig. 7: Top shells made of dense castable on the upper side of the skids, light weight shells on the bottom side

RESULTS AND DISCUSSION

Water cooling system and heat loss data through the skid pipe system of WBF 1 before and after installation of the new lightweight concept are given in Fig. 8 and 9.

Fig. 8 shows the curve progression of the heat loss of the complete skid pipe system insulated with RCF-modules. Due to fast aging of the modules caused by chemical, mechanical, and thermal stress, the heat loss increased within only a few months (red arrow). Maintenance (green arrow) had to be performed regularly within short periods to keep the heat loss and cooling water temperature on an acceptable level. Mean value of heat loss with this insulating material was app. 1,260 GJ/d.

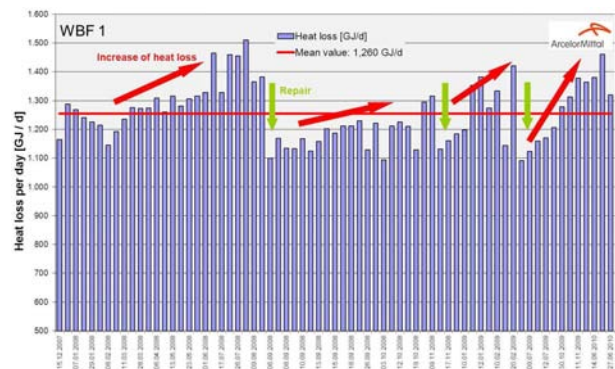


Fig. 8: Heat loss per day [GJ/d] of the complete skid pipe system insulated with ASW-Modules

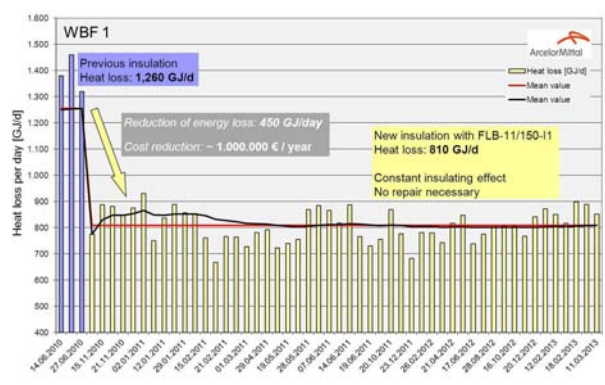


Fig. 9: Heat loss per day [GJ/d] of the complete skid pipe system insulated with pre-fabricated light weight shells FLB-11/150-I1

After changing the skid pipe insulation to the light weight shells the average heat loss is app. 810 GJ/d and a reduction of energy loss of 450 GJ/d (= 35%) is achieved (Fig. 9).

Even after more than 2.5 years in operation there is still a constant and stable insulating effect on this level. During this period, almost no maintenance or repair of the insulating material was required, so the productivity of the furnace increased.

The cost reduction per furnace achieved by this new material and by reduced energy losses is at least € 900,000 per year. The investment costs for the new lining concept for the complete skid pipe system of WBF 1 were app. € 750,000. This includes the cost of the insulating materials the costs for removal of the old insulation and installation of the new one. Hence the payback period for this investment was less than one year.

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-II and a thermotechnical optimised sandwich construction, can significantly reduce the heat losses to the cooling system of the skid pipe system in pusher type and walking beam furnaces. Trials and CFD calculations show a potential of more than 60% reduction of heat losses when compared with dense castable shells. The industrial application of the new lightweight shell system in two 420t/h walking beam furnaces at ArcelorMittal Bremen GmbH, Germany, resulted in an overall energy saving of 35% when compared to previous installed RCF modules. 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 less than one year.

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