MÉTODOS MODERNOS DE REPAROS EM REVESTIMENTOS DE CADINHO DE ALTO-FORNO[1]

Rudolf Hebel[2]

Resumo

Nas últimas décadas, uma variedade de métodos de reparo de cadinhos de alto-forno tem sido desenvolvida. Diferentes opções a quente e a frio foram conduzidas com resultados bem sucedidos. Os métodos modernos mais importantes de reparo serão ilustrados e explicados neste trabalho, com diferentes exemplos. Métodos de remendos assim como combinações de reparos de revestimentos com técnicas modernas de monitoramento de seu desgaste também serão apresentadas.

Palavras-chave: Cadinho; Revestimento refratário; Manutenção preventiva; Métodos de reparo.

MODERN REPAIR METHODS OF BLAST FURNACE HEARTH LININGS

Abstract

In the last decades, a number of BF-hearth lining repair methods have been developed. Different hot and cold hearth lining repair methods were executed with good success. Using various examples, this paper illustrates and explains the most important modern hearth lining repair methods. It also presents patchwork repair methods as well as combinations of hearth lining repair work and modern hearth lining wear observation techniques.

Key words: Hearth; Refractory lining; Preventive maintenance; Repair methods.

[1] *Technical contribution to the 43rd Ironmaking and Raw Materials Seminar, 12h Brazilian Symposium on Iron Ore and 1st Brazilian Symposium on Agglomeration of Iron Ore, September 1st to 4th, 2013, Belo Horizonte, MG, Brazil.*

[2] *Dipl. Eng. Consultant, Paul Wurth Refractory & Engineering GmbH, Mainz-Kastel, Germany.*

1 INTRODUCTION

Around the world, a large number of Blast Furnaces exist in different countries of the so-called heavy metal industry. There are small Blast Furnaces with hearth diameters of less than 4 m exists as well as large ones of more than 15 m hearth diameter (Figure 1). A wide range of specific production rates were realized in the last decades. Improved burden conditions as well as improved process and operation developments has led to very high specific production rates of close to 90 THM/m^2 24 h.

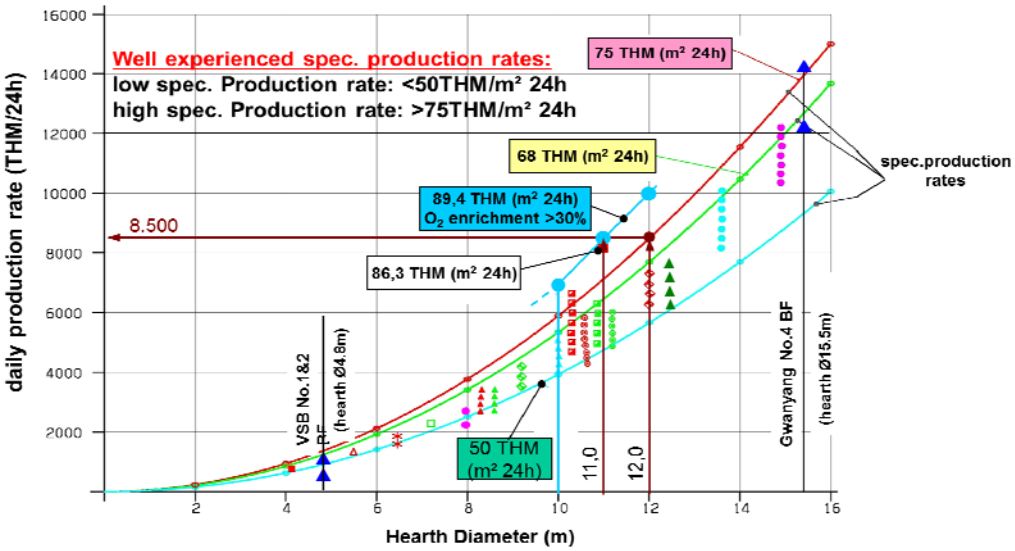

Figure 1. Daily production rates depending on BF-hearth diameters and specific production rates.

2 BLAST FURNACE HEARTH LINING WEAR OBSERVATION MANAGEMENT

One of the targets of BF owners is to reduce the investment by extending the BF-life campaign without intermediate repairs. Therefore several hearth lining wear observation managements have been developed, especially in the last two decades (Figure 2).

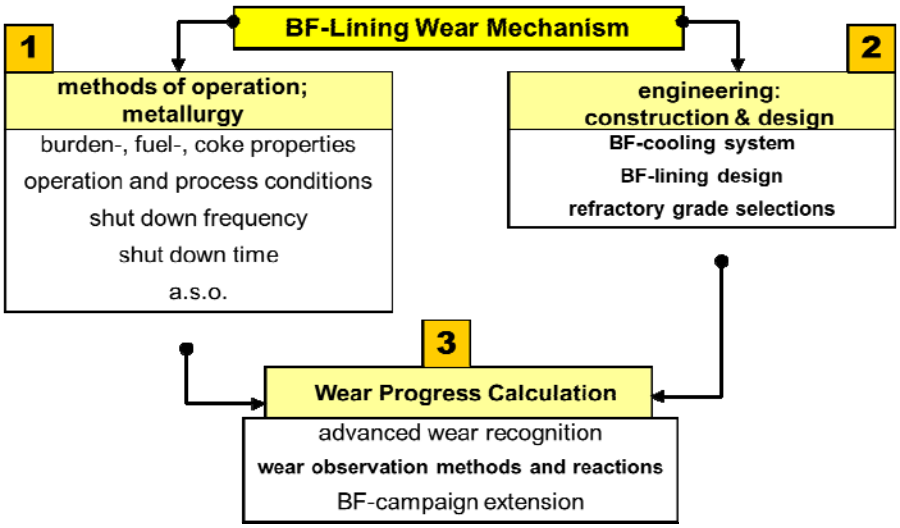

Figure 2. Hearth lining wear observation management.

Modern hearth lining wear observation management consists of:

- practical 3D FEM isothermal line calculations;
- development of several so called hearth lining measuring sections;
- installations of break out resistant, multiple thermocouple and heat flux measuring probes (MTP-sensor probes); and
- D FE model wear calculations and analyses;
- minimization of hearth lining break out risks; detection of premature hearth lining wear as shown in Figure 3.

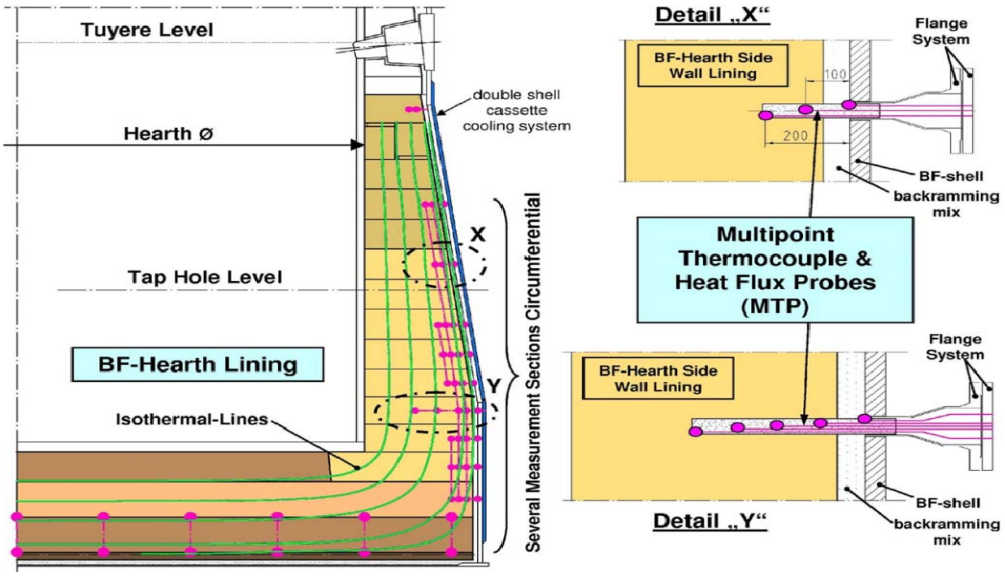

Figure 3. Measuring section of modern hearth lining MTP-sensor probe application.

3 HEARTH LINING CORE PROBE EXTRACTION

Modern hearth lining wear observation management is key to reaching the BF owners' target of hearth lining life with small maintenance budgets. Hearth lining core probe extraction as well as the necessary core probe investigation are part of modern hearth lining wear observation management (Figure 4).

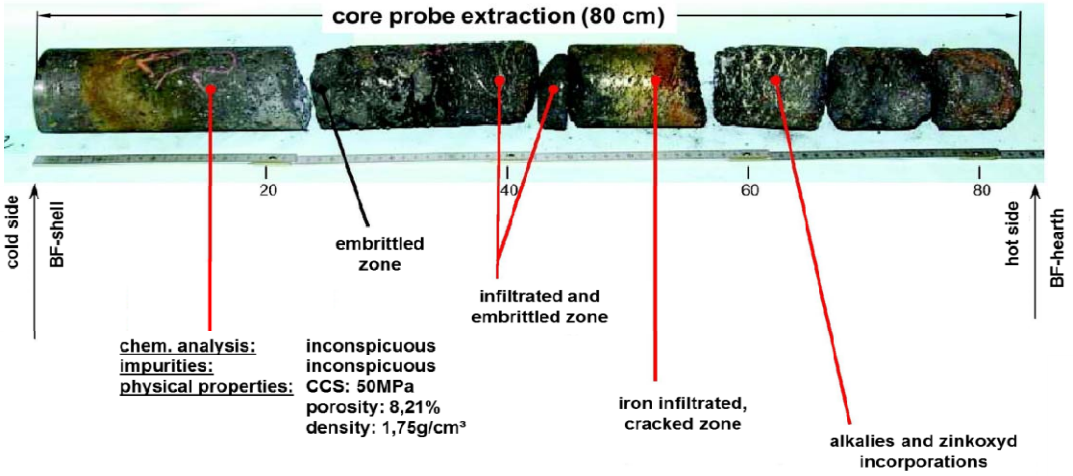

Figure 4. Core probe extraction and property investigations.

4 BF-HEARTH LINING INTERMEDIATE REPAIR METHODS

To reduce the investment and maintenance costs, the BF owner needs to select the right hearth lining intermediate repair method to extend the hearth lining life campaign as shown on Figure 5.
There are a number of different hearth lining intermediate repair methods available. Figure 5 shows the five most important intermediate repair methods.

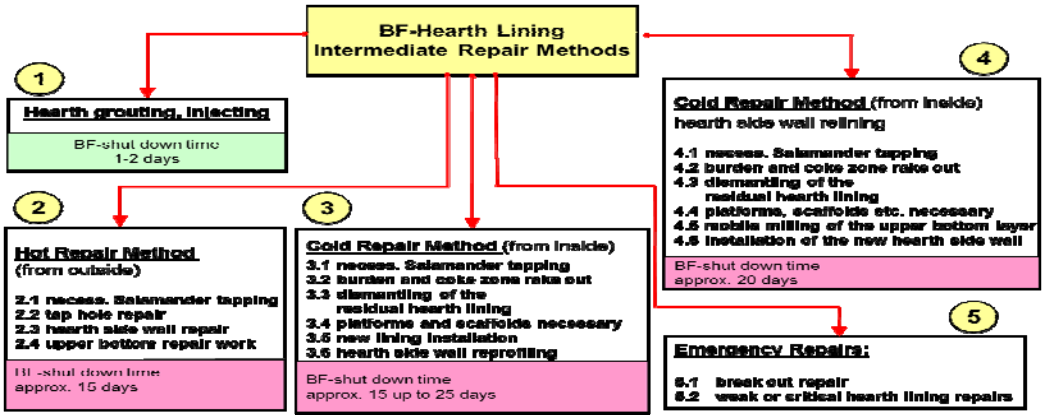

Figure 5. Selected hearth lining intermediate repair methods.

5 TAP HOLE AREA AND/OR HEARTH SIDE WALL GROUTING/INJECTING

Detected cracks inside the hearth side wall or in the tap hole lining area, as well as the big family of “heat resistances” like joints, gaps, embrittled zones etc.; located in the hearth lining, can be treated by grouting/injecting using self-flowing refractory castables based on high alumina / SiC-C (Figure 6).

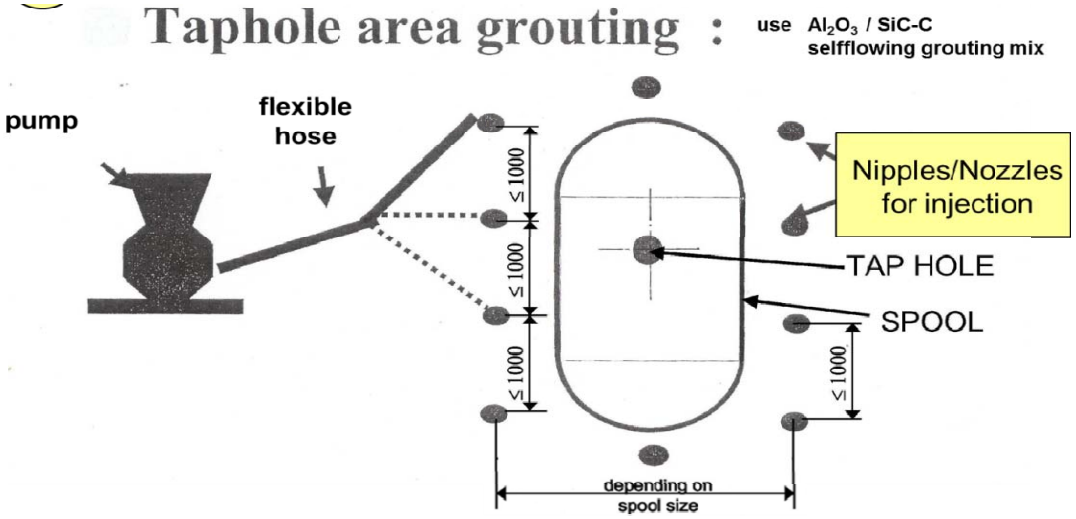

Figure 6. Sketch of tap hole area grouting/injecting.

6 HEARTH LINING HOT REPAIR METHOD (FROM OUTSIDE)

To work below the tap hole level, it is necessary to tap the salamander as depicted in Figure 7.

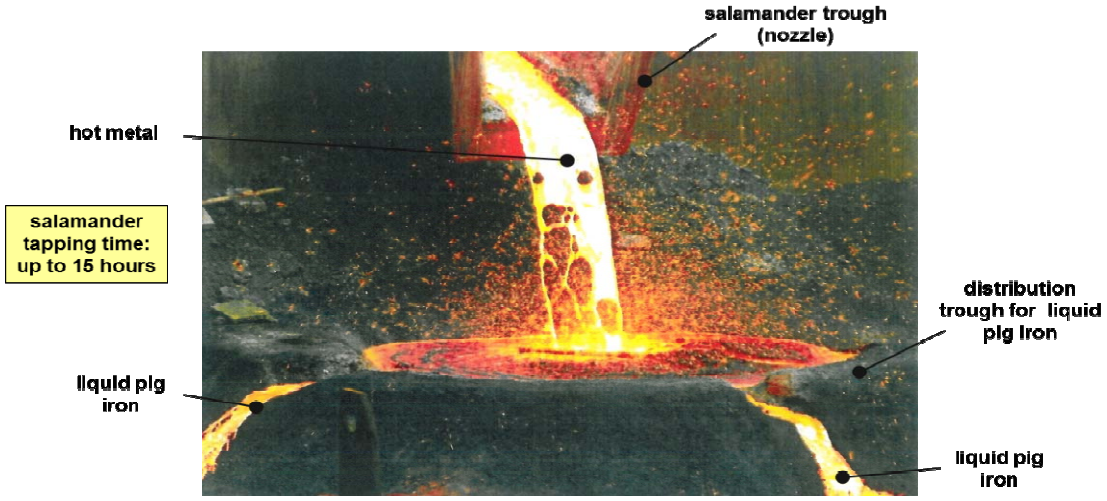

Figure 7. BF-hearth salamander tapping.

To select the ideal salamander tapping angle, it is necessary to calculate the actual hearth lining wear profile as well as the belonging isothermal line distribution (Figure 8).

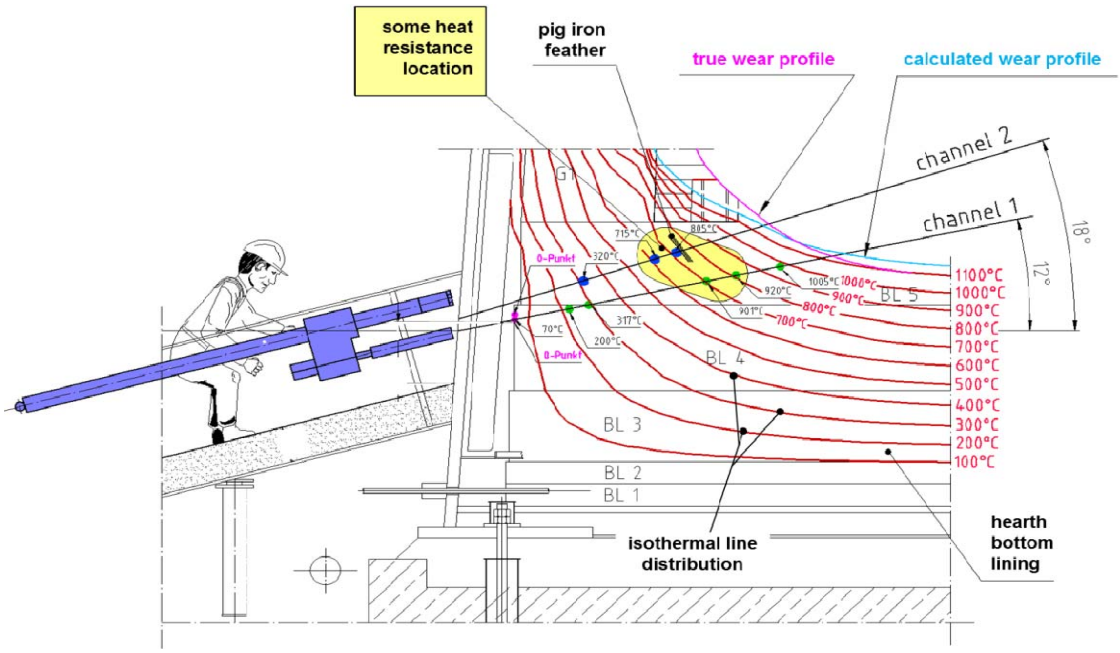

Figure 8. Determination of salamander tapping bore axis.

The hearth lining hot repair method from outside consists of (Figure 9):

- BF-shell plate cutting (open window repair method);
- fixation of the residual hearth blocks around the repair opening;
- dismantling of the residual hearth side wall in the open window area;
- rake out of the coke zone along the repair window;
- stabilization of the coke zone;
- coke zone back ramming;
- equalization of the lower support layer;
- installation of the new small hearth side wall blocks, including the large tap hole block;
- carbon block adaptation to the residual remaining hearth side wall;

- welding the BF-shell plate into the open window;
- grouting the gap between carbon block layers and the shell plate;
- lining the spool;
- installation of observation measuring probes (MTP-sensor probes);
- reinstallation of the cooling elements;
- restart the Blast Furnace.

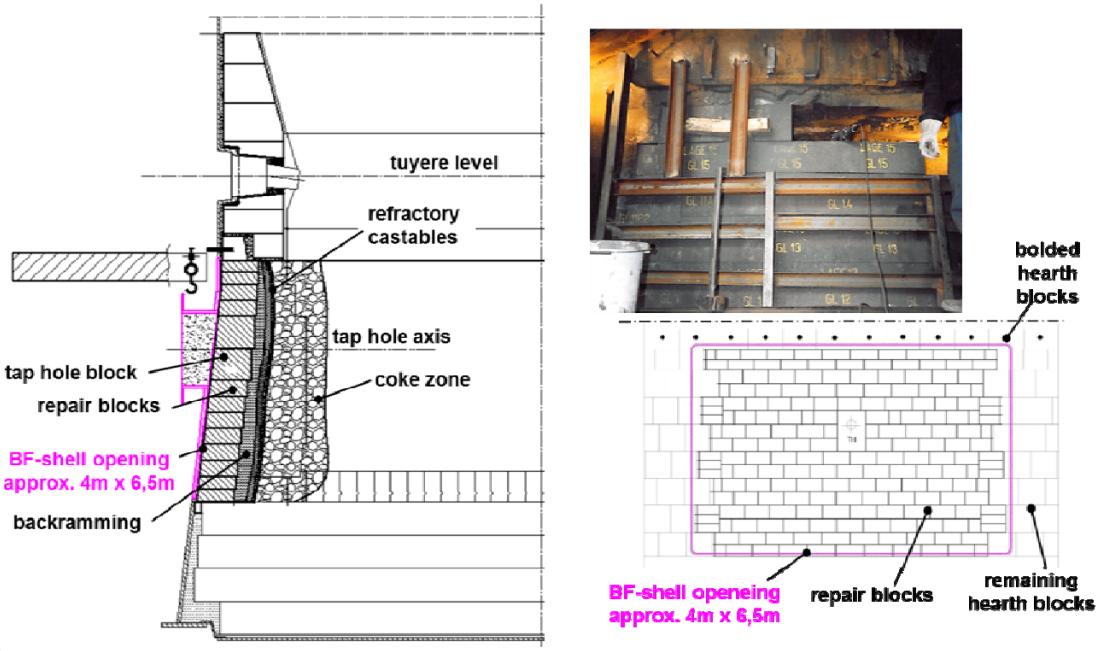

Figure 9. Hearth side wall and tap hole hot repair method (from outside shell).

7 HEARTH LINING COLD REPAIR METHOD (FROM INSIDE)

The main difference to the hot repair method is that the residual burden, the residual coke zone and the solid residual pig iron salamander have to be raked out before the new lining and/or the necessary re-profiling of the hearth bottom and/or the hearth side wall can start (Figure 10).
The main advantages of cold repair methods are:

- looking and checking inside the whole residual hearth lining;
- re-profiling of the whole hearth bottom and/or the whole hearth side wall, if necessary;
- remarkable extension of the hearth lining life campaign.

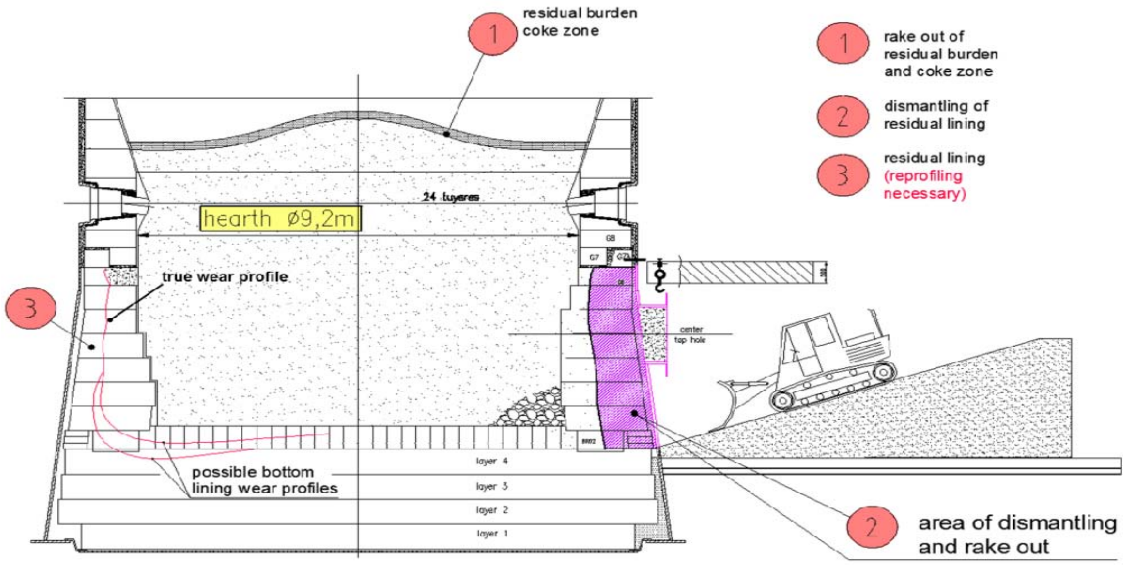

Figure 10. Hearth side wall cold repair method (from inside).

The remaining old hearth side wall lining together with the new repaired carbon block lining is shown in Figure 11.

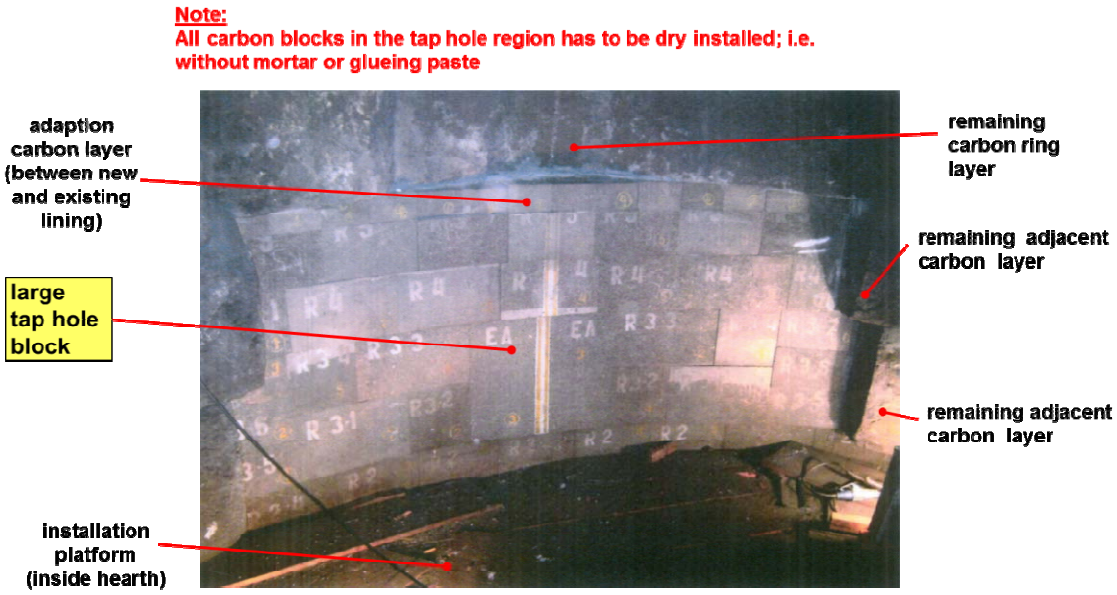

Figure 11. Finished repaired hearth side wall area with carbon.

Hearth lining re-profiling can be done as quickly as possible by using a pumpable, self-flowing hot metal and slag resistant refractory castable (Figure 12).

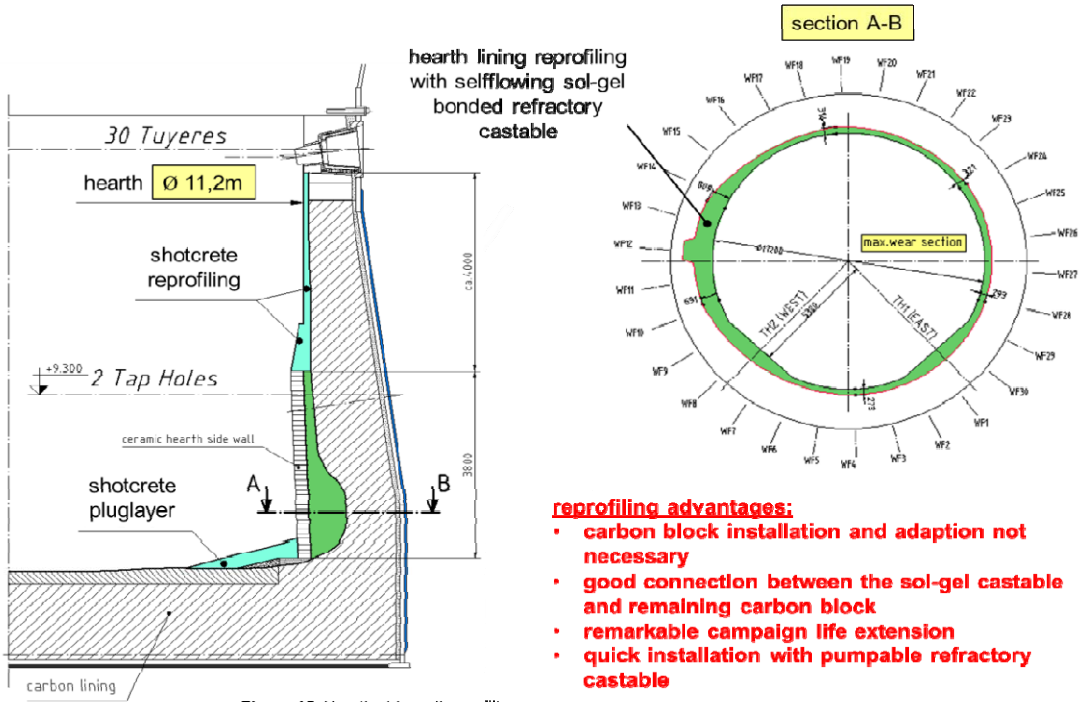

Figure 12. Hearth side wall re-profiling.

8 HEARTH SIDE WALL RELINING USING A MOBILE MILLING EQUIPMENT

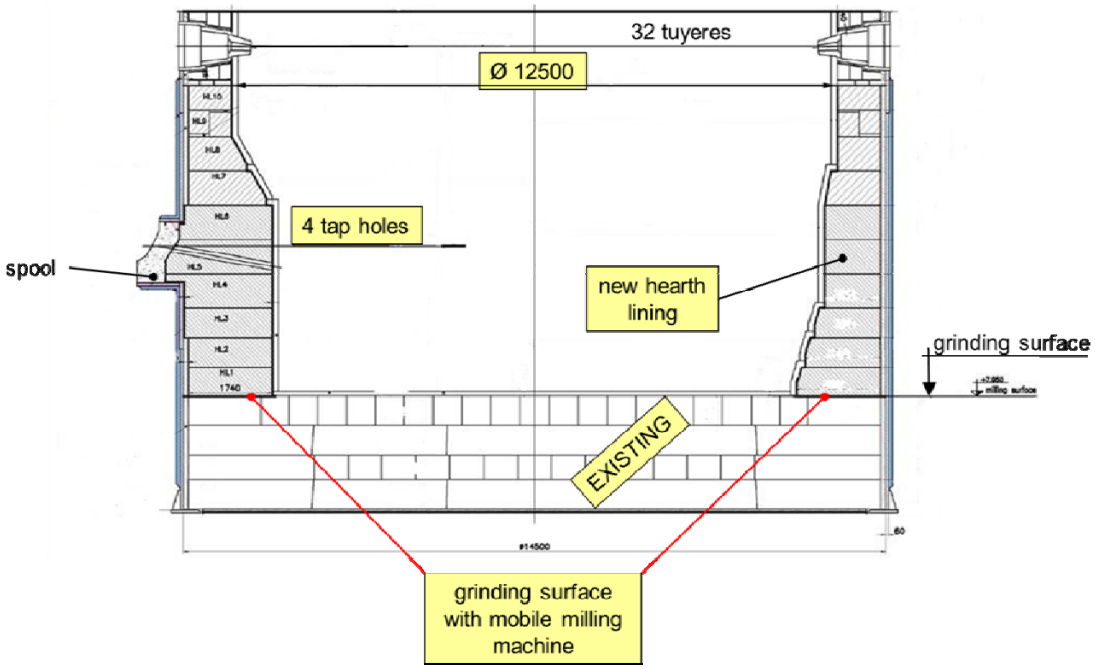

Figure 13. Leveling of the existing/remaining upper bottom layer using a mobile milling Equipment.

In a large number of existing BF-hearth linings, the bottom layers are in quite good condition after the scheduled running campaign, but the hearth side walls are eroded or weak. In such cases, only a new hearth side wall lining is necessary to extend the BF lining campaign. Mobile milling equipment is necessary to level by grinding the whole hearth bottom lining or the ring area beyond the new hearth side wall layers (Figure 13).

Figure 14 shows the available mobile milling equipment for leveling of hearth bottom layers as well as hearth side wall layers, too.
An experienced mobile milling team can accomplish the necessary BF-hearth lining leveling by grinding in a short time, depending on the BF-size and the leveling, respective grinding area.

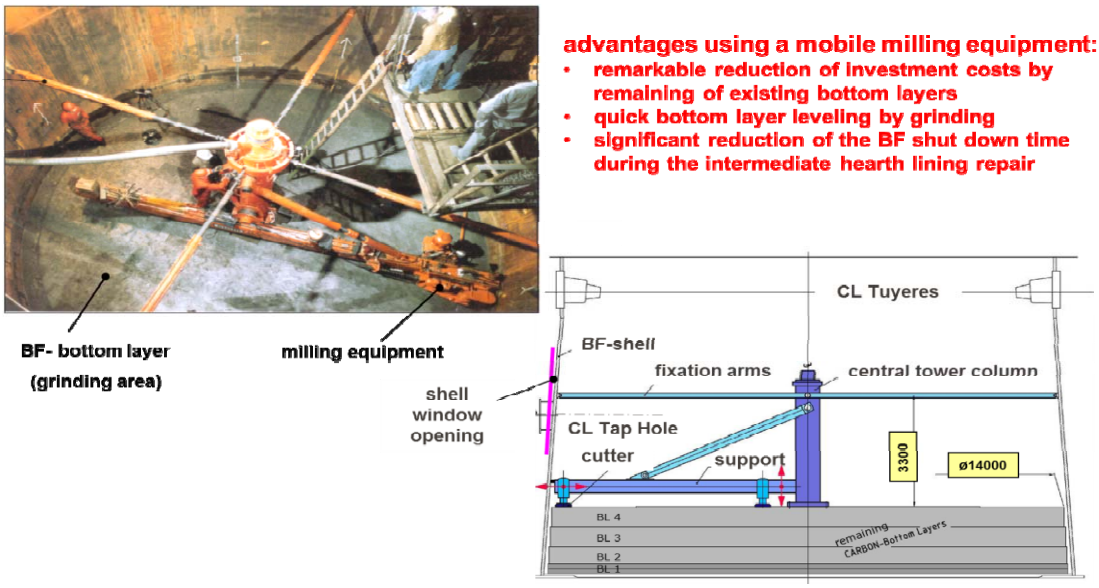

Figure 14. Hearth lining leveling by grinding with a mobile milling equipment.

9 SUMMARY

The BF-owners' main targets for a long life hearth lining campaign are significant reductions of investment, maintenance and intermediate repair costs.
The paper shows that a long hearth lining campaign can be reached if the recommended hearth lining wear observation management is implemented during the new hearth lining installation and followed during the whole BF-running campaign.
To avoid accelerated hearth lining wear, exact and true calculated wear profiles and their analyses are helpful as well as core probe extractions in cases of doubts.
BF-hearth lining life extensions are possible with different kinds of so-called hearth lining intermediate repairs, such as:

- hearth side wall lining for tap hole grouting/injecting;
- hot intermediate repair method (from outside shell);
- cold intermediate repair method (from inside pool);
- reprofiling;
- new hearth side wall lining installed on top of the remaining hearth bottom layers after leveling by grinding of a mobile milling machine;
- emergency repairs, like break out hearth side wall repair procedure a.s.o.

All of the mentioned intermediate hearth lining repair methods are well known to PW R&E, a company of the SMS-Group in Germany, which has long-standing experience in this area (reference list in Chart 1).

10 CONCLUSION

It is logical that the BF-owners want to reach their main targets regarding long life hearth lining campaign without any intermediate repairs. Therefore PW R&E recommends the BF-hearth lining observation management during the running BF-campaign.
In case of necessary hearth lining intermediate repair, the paper presented numerous different intermediate repair methods to extend the hearth lining life campaign, too.
To identify the optimal repair solution – including the right intermediate repair method as well as the necessary scope of the intermediate repair – detailed discussions with PW R&E are necessary.

11 REFERENCE LIST

Chart 1. Reference List of hot and cold hearth side wall and tap hole repairs furnished by PWR&E

Item	Costumer	Country	Year	BF.No.	Hearth Ø	with mobile milling pendulum
1	Hoesch, Westfalenhütte	Germany	1993	7	10,2	
2	Krupp Hoesch AG	Germany	1994	3	10,0	X
3	Krupp Hoesch AG	Germany	1994	4	9,7	
4	Maxhütte	Germany	1995	3	6,36	
5	Hoesch, Westfalenhütte	Germany	1995	7	10,2	
6	Rogesa, Dillingen	Germany	1996	3	8,5	
7	Maxhütte	Germany	1996	3	6,36	
8	Krupp Hoesch AG	Germany	1997	4	9,7	
9	Mannesmann Belo Horizon	Brazil	1999	1	5,1	
10	Cockerill, Ougree	Belgium	1999	B	9,75	
11	Cockerill, Sambre	Belgium	2000	6	9,75	
12	CSN, Volta Redonda	Brazil	2000	2	9,0	
13	Stahlwerke Bremen	Germany	2001	3	9,2	
14	Stahlwerke Bremen	Germany	2002	3	9,2	
15	Arcelor, Aceralia	Spain	2003	B	11,3	X
16	Arcelor, Aceralia	Spain	2004	A	11,3	X
17	Stahlwerke Bremen	Germany	2005	3	9,2	
18	ROGESA, Dillingen	Germany	2005	5	12,0	X
19	VOEST, Donawitz	Austria	2005	1	8,0	
20	VOEST, Donawitz	Austria	2006	4	8,0	
21	China Steel	Taiwan	2006	3	12,5	
22	Arcelor Steel Belgium	Belgium	2007	6	9,75	X
23	Rogesa, Dillingen	Germany	2007	3	8,5	
24	China Steel	Taiwan	2007	3	12,5	X
25	Rautaruukki Oy	Finnland	2008	1	8,0	
26	V+M Tubes	Brazil	2008	1	5,5	
27	Rogesa, Dillingen	Germany	2009	4	11,2	
28	Arcelor Mittal, Bremen	Germany	2011	3	9,2	
29	AM Eisenhüttenstadt	Germany	2012	1	7,1	
30	V+M Tubes	Brazil	2012	1	5,5	
31	SZFG	Germany	2013	A	11,2	