Journal of Environmental Science and Engineering B 6 (2017) 558-563
doi:10.17265/2162-5263/2017.11.003

Development and Introduction of Monitoring System of Refractory Lining Wear in Blast Furnace Hearth

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Abstract: To diagnose the lining condition of the blast furnace hearth during its campaign, are widely used methods based on the analysis of the temperature characteristics of the refractory lining. Measurement of the temperature characteristics is performed by means of a few hundred thermocouples placed inside the refractory lining. The peculiarity of proposed and used mathematical models is a fully three-dimensional assessment of the refractory lining, presence mechanisms of adaptation to the actual thermal conductivity of refractories and optimization calculations to the work in the on-line mode. The new monitoring systems of the lining wear of the blast furnace hearth are established on 5 blast furnaces of integrated iron-and-steel works of China: No.4 by volume 3,200 m^3 of "Jinan Iron & Steel Company" in Jinan (683 thermocouples), No.2 by volume 1,080 m^3 of "Henan Jiyuan Iron & Steel (Group) Company" in Jiyuan (212 thermocouples), No.4 by volume 2,500 m^3 of "Guangxi Liuzhou Iron & Steel (Group) Company" in Liuzhou (383 thermocouples), No.3 by volume 1,750 m^3 of "Jinan Iron & Steel Company" in Jinan (524 thermocouples); No.1 by volume 1,750 m^3 of "Jinan Iron & Steel Company" in Jinan (524 thermocouples).

Key words: Blast furnace, hearth, lining, diagnosis, thermocouples, mathematical model, adaptation, introduction in industry.

1. Introduction

The duration of the campaign of the blast furnace, that is the time from one major overhaul to another, occurs from 5 to 20 years. One of the causes, which can reduce considerably the campaign continuance, is the break of fluid cast iron through the lining of the lower part of the blast furnace (hearth). In recent years in the world, the searching of possibilities of the thermal state monitoring (temperature condition) of the blast furnace hearth is carried. In current Chinese metallurgical plants, the longest service life of blast furnaces generally run 21 years, but the shorter service life of blast furnaces may only last 2 years. Hence, monitoring is very important for safe production and economy of the enterprise for visualization, diagnostics, quality check and alarm systems for the lining state of the lower part of the blast furnace. In European practice, cases of campaign duration of blast furnaces lasting 28 years are known.

For performance monitoring of the hearth lining state, understanding and acceptance of the exact technical solutions is a necessary part of the information system. The similar system at the expense of an estimate of dynamics of the wall's thickness modification of the furnace will allow avoidance of the origin of such emergency situations of technogenic character on metallurgical production as break of blast furnace hearth.

Such systems should meet the following requirements: efficiency and data obtaining continuity about lining state, maximum precision of determination of residual thickness of lining and determination of scull thickness.

Various diagnostic systems of the condition of the lining of a blast furnace are applied to try to solve the problem. However, a uniform approach to the

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organisation of such systems does not exist. The basic difficulty regarding deterioration control is the fact that it is impossible to measure a residual thickness of walls immediately. Residual thickness can be defined only with indirect methods [1]. There are currently alternate systems of diagnostics of the lining based on using special probes, radioisotopes, sound waves and measurement of temperature characteristics of the furnace.

The last group of methods, in turn, is subdivided into systems based on data processing arriving from the cooling system and on the systems based on placement of special sensors in the lining.

The first two methods possess a high degree of reliance, but they demand a very cost-based engineering preparation at a stage of building of the lining, and as a rule provide diagnostics in very small, local regions of a lining. Therefore, authors will further consider a combination of methods of diagnostics leaning against the indications of thermocouples, a heat flux through a cooling system and the acoustic data. These procedures, separately, have obtained the greatest practical extension [2].

2. Materials and Methods

In 1997, the Joint-stock Company SDM (Shandong Province Metallurgical Engineering Co., Ltd., Jinan, China) together with Northeast University (Shenyang, China) began joint development of a modern system using a two-dimensional mathematical model for lining control for the hearth and flag of the blast furnace.

From 2000-2013, the SDM Company successfully developed and introduced a system of visualization, diagnostics, control and an alarm system of the blast furnace lining with the use of the mathematical model 2D-3D on a number of blast furnaces in China.

Furthermore, in 2007 and 2008, on two blast furnaces in China, the SDM Company together with other Chinese developers executed a check on compliance of calculation results for a mathematical model and actual data of geometrical measurements of the remains of the lining of a hearth and flag for the furnaces at capital repair. Results of the check provided positive results.

From 2010-2015, the SDM Company together with Institute of Metallurgy of Ural Branch of Russian Academy of Sciences (Yekaterinburg) introduced the new monitoring system using the 3D mathematical models on 5 blast furnaces in volumes from 1,080 m^3 to 3,200 m^3 in China: No.4 by volume 3,200 m^3 of "Jinan Iron & Steel Company" in Jinan (683 thermocouples), No.2 by volume 1,080 m^3 of "Henan Jiyuan Iron & Steel (Group) Company" in Jiyuan (212 thermocouples), No.4 by volume 2,500 m^3 of "Guangxi Liuzhou Iron & Steel (Group) Company" in Liuzhou (383 thermocouples), No.3 by volume 1,750 m^3 of "Jinan Iron & Steel Company" in Jinan (524 thermocouples) and No.1 by volume 1,750 m^3 of "Jinan Iron & Steel Company" in Jinan (524 thermocouples) [3].

3. Results and Discussion

Advantages of this system consist in the following [4]:

The calculation is led by the solution of the heat conductivity equations with use of the large number indications of the temperature sensing transducer (to 700), built in the oven lining between the fireproof blocks. The calculation algorithm was developed regarding the account of an intricate profile of blast furnace drag with the use of a Nyquist theorem. The system of gathering, processing and information transfer from the temperature transmitters to a program database is used. The continuous control of the temperature change in each point allows the definition of the remaining thickness of the firebrick lining in order to warn the furnace personnel about the beginning of the firebrick lining deterioration. The developed interface of the program allows the master of the oven to use many additional functions of control, particularly the history of indications of the transmitters and the remaining thickness of a wall, including:

(1) Direct visualization of a condition, a tendency of change of the wear, the remaining thickness of a fireproof wall, distribution of temperatures on any point in the lining on the computer monitor, including history and the current time;

(2) Alarm system of a dangerous zone;

(3) Prevention of the breaking of a hearth;

(4) Volume temperature distribution (isotherms) and tendency of their changes.

Interface language: Chinese, English and Russian. Figs. 1-5 show the examples of the interfaces of the program.

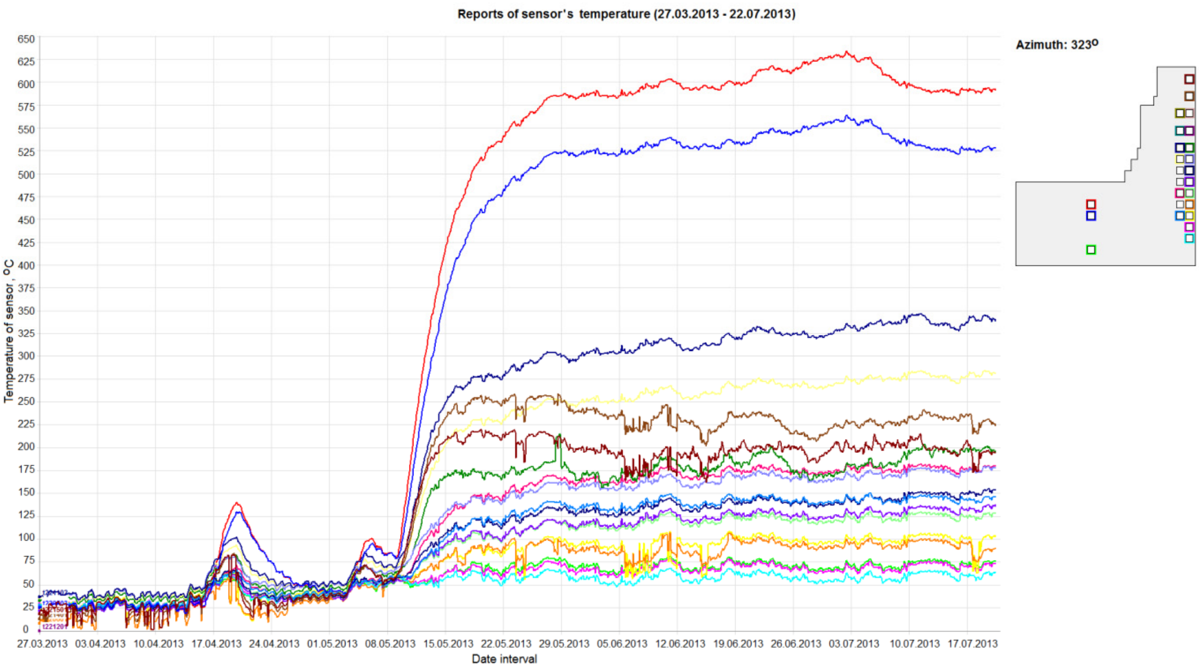

Fig. 1 The schedule of temperatures change in points of an arrangement the thermocouples for one of vertical sections.

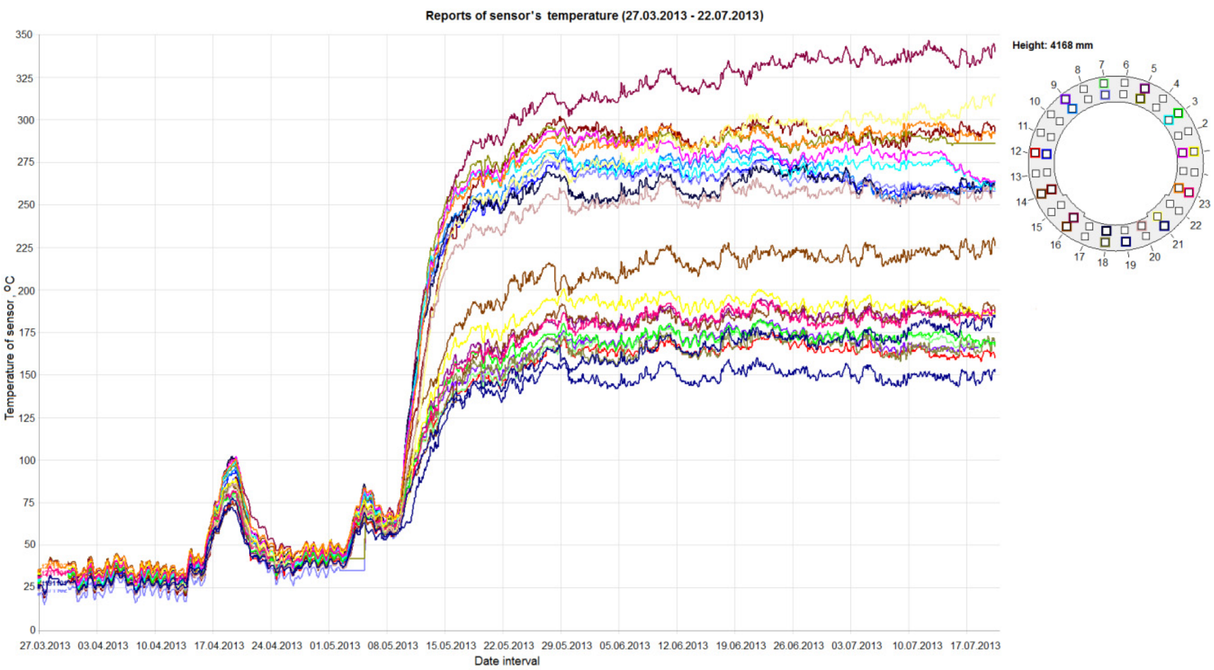

Fig. 2 The schedule of temperatures change in points of an arrangement the thermocouples for one of horizontal sections.

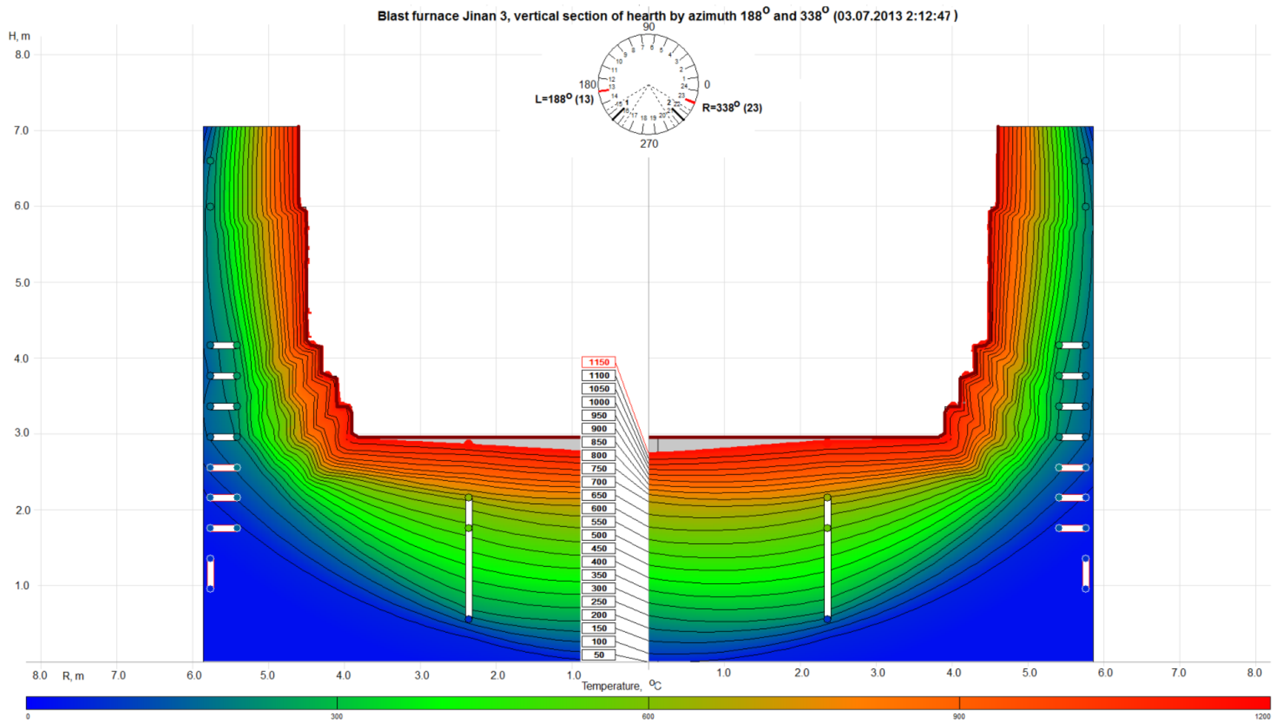

Fig. 3 A temperature field in the hearth lining (vertical section).

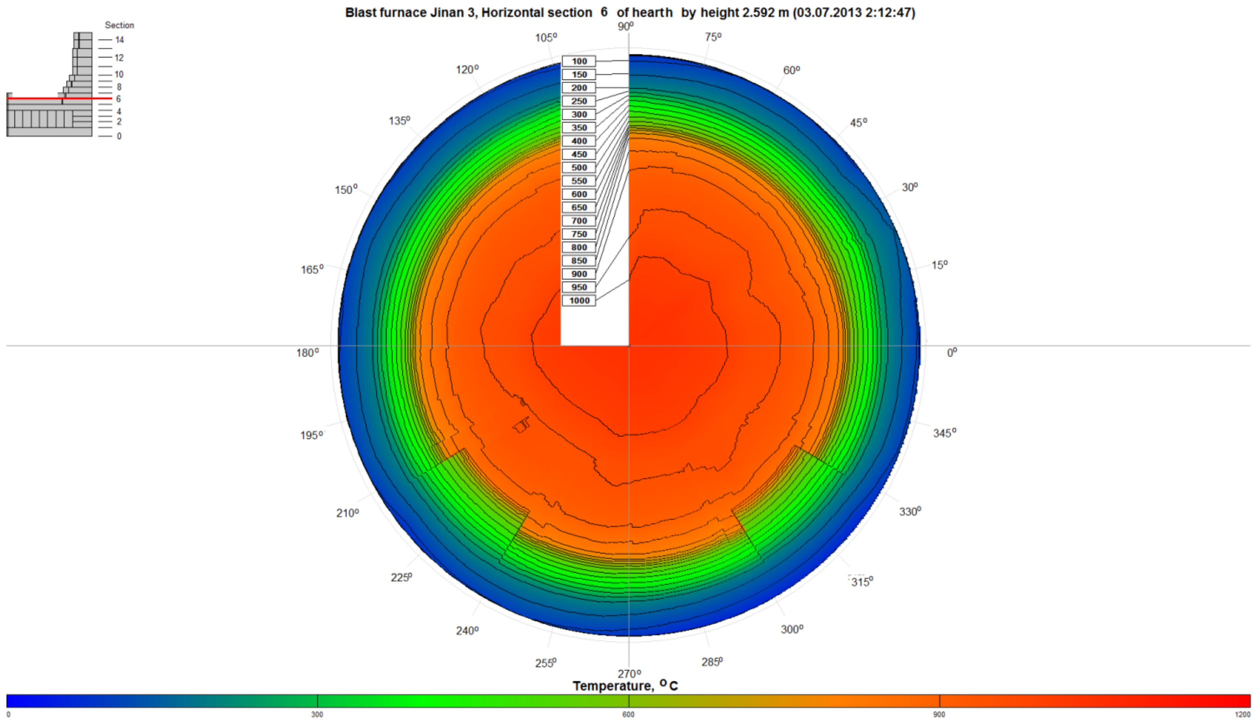

Fig. 4 A temperature field in the hearth lining (horizontal section).

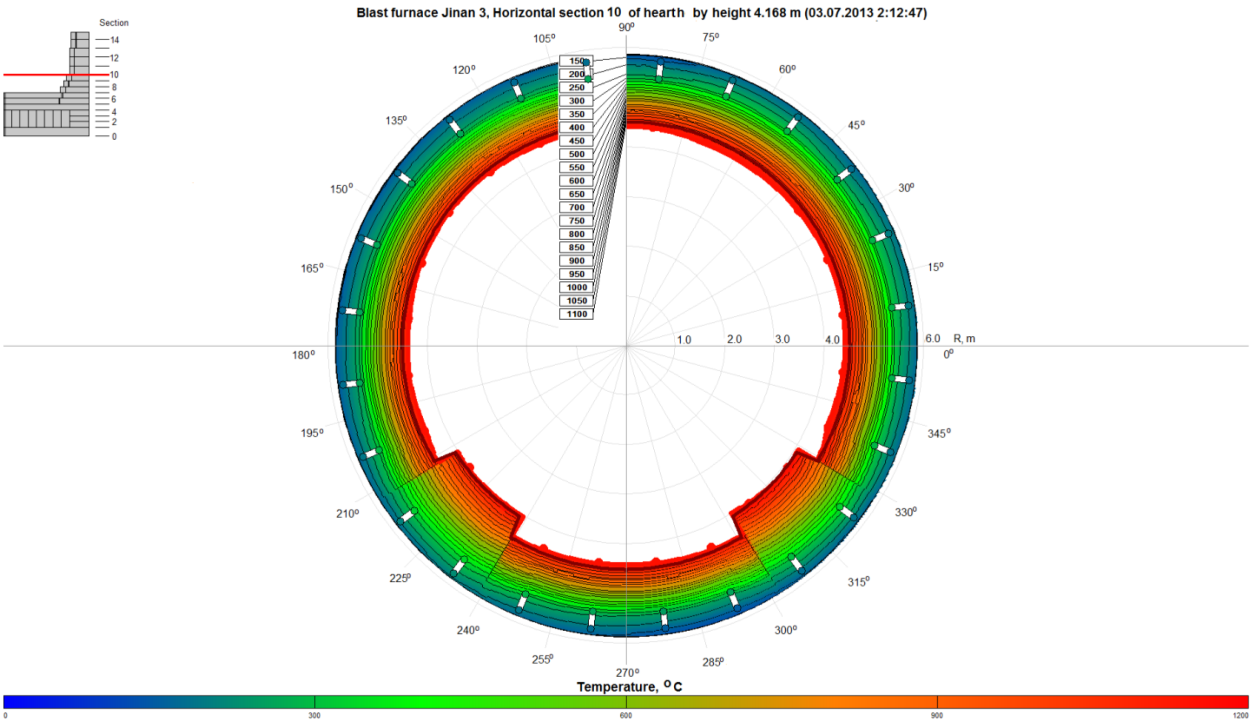

Fig. 5 A temperature field in the hearth lining (horizontal section).

The technique of definition of optimum quantity and arrangement of thermocouples in the blast furnace hearth lining is developed [5].

The technique of determination of thermal properties of flameproof materials on curves of acceleration of temperatures after the blowing-in of the blast furnace is developed [6].

4. Conclusions

The experience of the introduction of a system on real blast furnaces showed its efficiency and superiority over similar systems, caused by the features:

(1) The high speed of calculations providing the organization with monitoring in real time, in a mode 24/7;

(2) Creation of a three-dimensional model of wear with the use of methods of adaptive interpolation;

(3) Avoiding the use of pre-calculated profiles of wear which allows flexibility in the construction of the profile of a hearth wear;

(4) Little squares of separate controlled segments;

(5) Possibility of use of the software in already existing systems of data collection from thermocouples in a furnace lining;

(6) Possibility of adaptation of a mathematical model of wear to each surveyed furnace at the expense of an original analysis algorithm of the actual thermal conductivity of refractory materials is provided.

This system is expedient for using together with one of acoustic and ultrasonic technologies [7], thus the last will be used periodically, for example, once a year.

Acknowledgments

This work is executed with the financial support of the State Task of Institute of Metallurgy of the Ural Branch of the Russian Academy of Sciences, the Project No.0396-2015-0081.

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