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A NOVEL METHOD OF ONLINE MEASUREMENT TO DEVELOP SPECIFIC HEATING-UP PROCEDURES FOR INDUSTRIAL FURNACES

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Abstract

The proper drying and initial heating-up of monolithic furnace linings is a task that has to be accomplished by the refractory producer, the aluminium producer and not the least by the heating-up service team. A too quick dry-out procedure of the refractory lining can cause critical vapour pressures within the refractories that exceed their tensile strength. As a result typical explosions, spalling or cracks can occur. On the other hand a very slow and cautious procedure causes a loss of aluminium production and consequently a loss of money. To consider both arguments most of the plants are working with a compromised heating-up program. In the given paper a new online steam pressure measuring method is presented, that allows a safe, fast and economical heating-up of industrial furnaces. Based on laboratory setups and by the help of an industrial test this novel method will be explained and discussed.

Introduction

All industrial furnaces lined with a monolithic refractory material need special and certain drying and heating procedures before they are available for the production. Finding the perfect initial heating-up sequence is a task for the producer of the refractory material, for the aluminium plant and not the least for the service team that has to carry out the dry-out and the heating-up. A too quick dry-out procedure of the refractory lining can cause critical vapour pressures within the refractories that exceed their tensile strength. As a result typically explosions, spalling or cracks can occur. [1] On the other hand a very slow and cautious procedure causes a loss of aluminium production and consequently a loss of money. Whereas the refractory producer usually strives for a rather slow procedure, many furnace operators are trying to push the service team for a faster drying process. To counterbalance all factors most of the industrial furnaces are dried based on a procedure that has proven itself for years. But nobody, neither the refractory supplier nor the aluminium producer know the exact safeties and risks of this procedure.

The idea of this given paper was to introduce a patented novel method that is able to provide an online steam pressure measurement. Therefore special pressure sensors are placed into the monolithic lining. Typically, such sensors are installed in critical areas like corners, thicker wall parts or areas that are hidden from or that are in direct contact to the hot air or a flame that is used for heating-up. Based on such an online stress measurement the service team would be able to react on the real drying conditions in the industrial furnace and inside of the refractory lining.

Sample selection and preparation

In order to investigate the drying behaviour of different monolithic refractory materials, the following materials have been selected. As stated in Table 1 two typical medium cement castables (self-flowing and vibrating type) and a novel no cement castable have been used. The novel and Nanobond-bonding system is typically free of cement and water. It is a dry refractory mix that comes with a special liquid binder. In contrast to all cement containing castables no hydraulic water has to be removed during the initial heating-up procedure. Therefore such Nanobond materials provide a fast and very secure heating-up. [2]

Table 1: monolithic refractories used for the experiments

	A	B	C
Main raw material	corundum		
Bonding system	hydraulic, MCC*	hydraulic, MCC	inorganic, no cement castable Nanobond
Installation method	casting, self-flowing	casting, vibrating	casting, vibrating
Mixing liquid	water	water	special liquid binder
Maximum service temp. [°C]	1250	1250	1400
App. porosity [%]	18.0	18.0	15.0
Cold crushing strength [N/mm²] After curing			
at 110 °C	140	40	40
500 °C	130	120	50
800 °C	120	90	100
1000 °C	60	90	120
1200 °C	65	90	120

* medium cement castable

The given monolithic materials have been mixed and casted in accordance to their preparation recommendations. The monolithic blocks of the size 250x400x400 mm were equipped with different sensors to allow an online measurement of temperature, humidity and vapour pressure during the heating-up. Figure 1 shows the blocks and the sensors. The different prepared refractory blocks were placed into a shuttle furnace and heated-up according to the given recommendation. For every experiment three identical blocks of the material A, B or C and one block of the two remaining materials were put into the furnace (Figure 2). The testing plan and the used heating-up regime are given in Table 2.

Figure 1: casted monolithic blocks equipped with different sensors

Table 2: testing plan

	Trial no. 1	Trial no. 2	Trial no. 3
Monolithic blocks	3x material A 1x material B 1x material C	3x material B 1x material A 1x material C	3x material C 1x material A 1x material B
Heating-up time	26h to 500°C	30h to 500°C	22h to 500°C

Figure 2: samples of material B right before heating-up

Results and discussion

The diagram given in Figure 3 represents the development of the vapor pressure during heating three samples of the material B. The data of the three different blocks are comparable and are showing maximum pressures of 20-23 bar. It can be seen that the highest pressures and the highest humidity occur at temperatures of ~ 320°C. This temperature corresponds with the practical experience that most of the dreaded steam explosions occur at furnace temperatures of 250-300°C. Of note is as well is that the rather rapid rise and fall of the pressure is followed by a second and smaller pressure peak at ~430°C. In principle, the curve progression of the pressure is more or less the same for all investigated materials. Only the maximum pressure values differs significantly (Table 3).

Table 3: results of the vapour pressure measurement

	Material A	Material B	Material C
Maximum pressure [bar]	12	23	6
Temperature of max. pressure [°C]	290	320	330

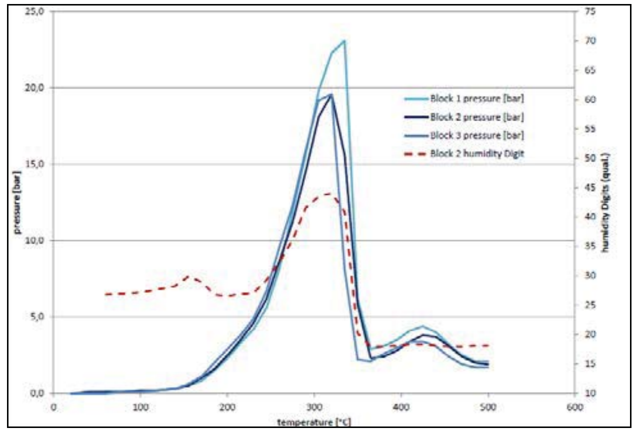

Figure 3: vapour pressure of three blocks material B during heating-up

The following diagram in Figure 4 gives a comparison of the measured vapour pressures during trial no. 1. It can be easily seen that the inner pressure of material C is far of the lowest for the three analyzed materials. This massive difference is caused by the different bonding systems. Due to the sol-gel-bonding of material C no chemical bonded water is trapped in the bonding system that has to be removed slowly and cautiously. As soon as the physical water of the Nanobond material C is removed the system is free of any water.

Figure 4 is clearly pointing out the boundaries of cement bonded monolithic refractories concerning the maximum possible heating-up procedure. By exceeding the recommended drying speed very high mechanical stress is formed that can surpass the mechanical strength of any material easily. But Figure 4 gives also an impression of the potential of the Nanobond material C. Even at very high heating-up rates of >70 K/h are possible without taking any risk. At the end of the day such materials are the perfect choice for a fast and safe lining or repairing of aluminium- and many other industrial furnaces.

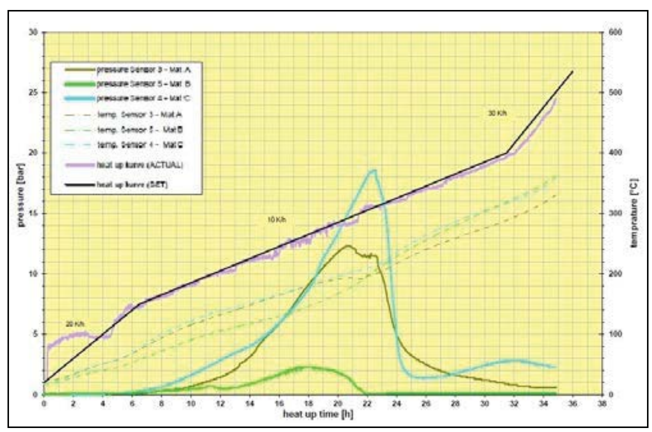

Figure 4: vapour pressure of the materials A, B and C

Conclusion

These experiments and tests open new perspectives of an online vapor pressure measurement to develop specific heating-up procedures. The idea is to implement such pressure sensors in industrial furnaces to measure the water steam pressure in different parts of the refractory lining. As a result specific initial heatings can be realized that combine both in the same time, economical and safety issues. Furthermore, the experiments show a clear relation of the monolithic refractory type to the resulting vapour pressures. The highest pressures of up to 23 bar have been measured for the two medium cement castables. In contrast the no cement castable and Nanobond-bonded material shows significantly lower pressures of 6 bar. By choosing such accomodating refractories and by using the presented online pressure measurement the dilemma of a fast and safe heating-up can be overcome.

Several industrial tests are planned in the near future to confirm the laboratory and the field trials.

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