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New strategies for blast furnace raceway monitoring

Operating a blast furnace (BF) at maximum rates of pulverized coal injection (PCI) requires a sophisticated process control to ensure stable BF operation. One key factor is a reliable system for raceway monitoring which can trigger the shutdown of PCI branches if the corresponding raceway is blocked. Such blockages occur on a frequent basis, but the absolute number may vary strongly between different furnaces and operating conditions. Work Package 1 of project 2.1 evaluates different approaches for raceway blockage detection based on tuyere images and hot blast pressure data.

Optical blockage detection based on tuyere image processing

The raceway region is mainly characterized by a dilute coke particle distribution in comparison to the burden in the rest of the blast furnace. High-speed video recordings have shown a highly turbulent motion of coke particles driven by the high inertia of the hot wind. Under certain conditions this dilute area can be blocked due to the downwards movement of the burden.

This movement of the burden excites a force on the raceway which is counter-balanced by the inertia of the hot wind. However, the descent of the burden is not always smooth but can also show unsteady motion of larger areas caused by e.g. wall friction effects or bridge building and collapsing inside the burden (also known as 'hanging' and 'slips'). In the case of such an unsteady movement close to a raceway area the inertia of the blast might not be high enough to keep the raceway in its usual extension. This can be visually observed as a complete or partly blocked tuyere. A second reason for blockages is the formation of low porosity zones at the borders of the raceway by unburnt coal particles sticking to the coke. These zones are also termed 'bird's nest'. Occasionally these shell-type structures will also break and block the raceway for some time.

The left image in Fig.1 is an example for normal raceway operation. One can see the tip of the PCI lance, part of the coal plume and freely moving coke particles. The bright area in the central right part of the image indicates a void area in the raceway where the high background heat radiation saturates the camera chip to the maximum white level. In contrast the picture on the right shows a complete blockage of the raceway. The image gives the impression of a large lump of agglomerated material right in front of the tuyere.

At the first glance, visual blockage detection seems easy to implement, as the examples in Fig.1 can be clearly distinguished from each other. Nevertheless, the transition from ordinary operation to a blocked raceway is not so obvious and blockages might cover only a part of the raceway or occur at a further distance from the tuyere deeper inside the raceway. Most of the tested image processing algorithms have problems in detecting all kinds of blockage events with the same reliability.

bmwfw
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Blockage detection based on signal processing of blast pressure data

Figure 2 gives an example of a tuyere pressure signal (blue line) which is directly related to the hot blast flow rate on that specific tuyere. In addition, the overall blast pressure is depicted (black line) which shows significant dips at the instances when the hot wind stove is switched. The marked areas in the pressure signal correspond to two major blockages (event 2 and 3) and two minor blockages (event 1 and 4). As the average signal level is not constant over time, a simple thresholding method is not capable of detecting blockages reliably. Currently signal processing algorithms based on signal correlation, filtering and wavelet transform are under test. In general, all of the signal processing algorithms have a better detection rate than the image processing algorithms.

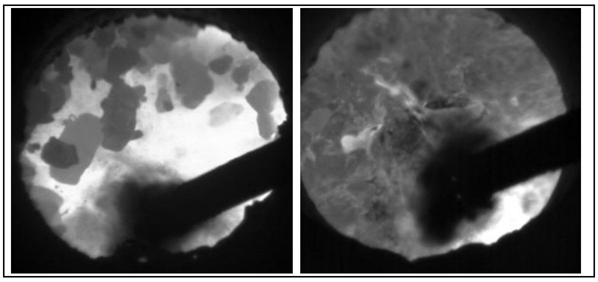

Fig. 1: The left image shows ordinary raceway operation. The right image shows a complete blockage of the raceway.

Impact and effects

The tested algorithms using image processing and signal processing have shown the difficulties for fully automated raceway blockage detection. A system based on tuyere cameras alone cannot deliver a reliable blockage detection.

However, signal processing of hot blast pressure data unveiled the potential of using already available plant data for the detection of raceway anomalies.

On optimal solution for process control could be to combine both methods. Due to its computational efficiency, a blockage detection based on hot wind data can be run constantly online for a whole blast furnace. As soon as this system detects a raceway blockage, cameras on this specific tuyere and its neighbour could be triggered to provide a visual check in the control room and record data for correlation with other BF operating conditions.

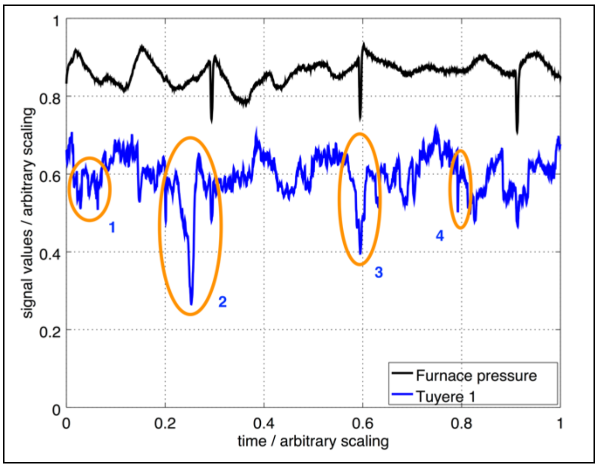

Fig. 2: Example of blast flow rate signal covering a time span of approx. 2h45m. The signal dips represent minor and major raceway blockages.

Such a combined raceway monitoring system will lead to a better understanding of the raceway behaviour and can improve the process control of a blast due to a more reliable shutdown of PCI branches.

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