Higher pulverised coal injection rate and more stable blast furnace operation

The achievement of stable blast furnace operation coupled with a low fuel rate are two key objectives of plant operators. Furnace stability is improved at high coal injection rates if the coal is metered to each tuyere individually rather than metered in bulk. The AMEPA capacitive flow control system provides fully automatic operation of coal injection on an individual tuyere basis and fully compensates for all external influences.

Authors: Peter Matthes, Paul Massmann and Roland Weiser
AMEPA GmbH and F.Block

Many blast furnaces are equipped with pulverised coal injection (PCI) systems to reduce the amount of coke used, however, most of the older coal injection systems operate with a static distribution design only. This method is based on the assumption that the evenly designed pneumatic convey lines will provide equal coal distribution down each line to the blast furnace hearth, and so individual control of each line is not provided and injection rates are measured by tracking the change in weight of the hopper or storage bin. This is effective as long as injection rates are low, as unobserved line-to-line deviations have minimal influence on the operation.

However, in the last decade, the amount of PCI has been increasing in the majority of furnaces, approaching values of 200kg/tHM and higher and benchmarks for minimum coke consumption today are 480kg/tHM and lower. These values do differ between blast furnaces because of various factors such as grinding mill capacity and the quality of metallurgical coke, which limits the amount of pulverised coal to ensure proper raceway conditions if coke quality is not optimum.

The pulverised coal particles are injected in the hot air of the raceway and must be burned completely. The injection of more pulverised coal than can be burned in the raceway affects the gas flow inside the blast furnace and even the pore structure of coke can be destroyed.

Considering these boundary conditions the static distribution method without individual flow control has largely reached its limits as monitoring the weight change in the pulverised coal storage bin cannot prevent tuyere overload. A closed-loop-control of each injection line is, therefore, necessary.

UNRECOGNISED TUYERE OVERLOAD

When replacing coke by pulverised coal close to the maximum possible quantity, overload conditions in uncontrolled injection lines appear frequently. *Figure 1* shows an example for measured deviations from the average throughput in four selected injection lines over a time period of only 10 minutes. The acceptable deviation of +/- 5% from the average (white area in *Figure 1*) is exceeded for about 90% of the time. This leads to overload conditions in case of the blue and pink displayed flow rates. In the cases of the red and green flow rates, the injected amount stays below the desired average and is non-critical for the overload condition. However, this has the disadvantage that the calculated amount of reduction material is not available for the process. High deviations in both directions affect a stable furnace operation if they exist over a long time period.

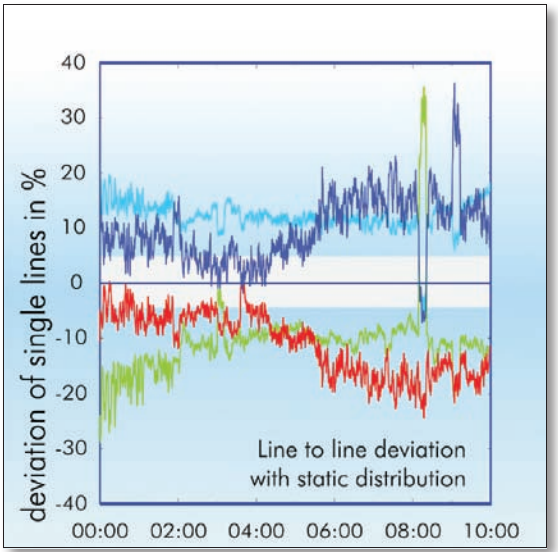

Fig 1 **Flow rate deviations in injection lines**

Figure 2 shows the measured quantity of pulverised coal injected for three consecutive days from a blast

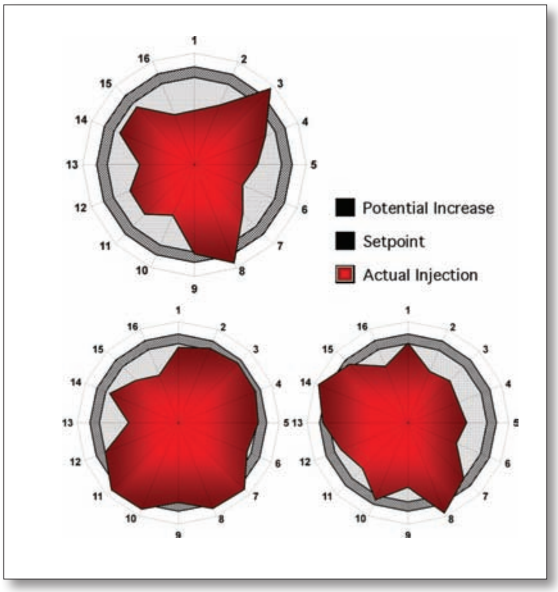

Fig 2 **Average flow rate for each injection line on three consequential days**

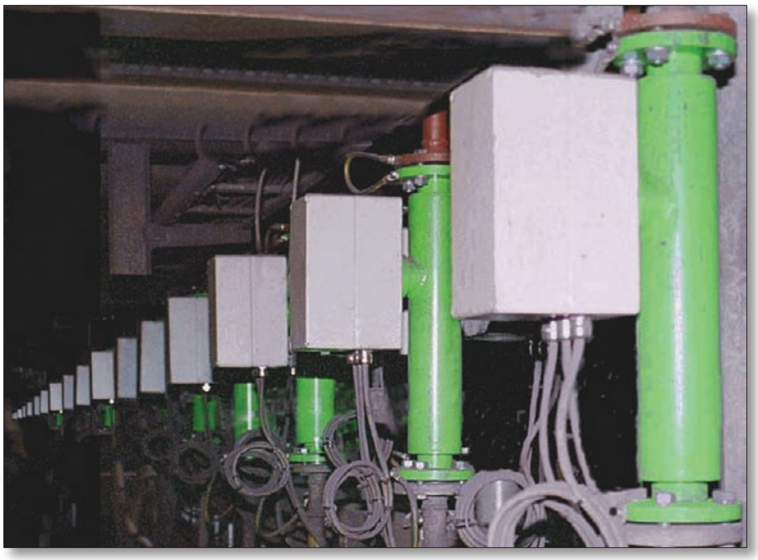

Fig 3 **CFM sensors in operation**

furnace with static distribution. A similar unfavourable behaviour of the deviations as shown in a short time interval in *Figure 1* is evident.

An analysis of this data provides the following observations:

- Overload areas exist in several tuyeres for long as well as short time periods
- Injection amounts are below optimum in many tuyeres
- Pattern of coal distribution changes unpredictably
- Average throughput as measured by changes in hopper weight is inadequate to achieve an equal distribution of pulverised coal to the blast furnace
- The concept of equal distribution in a static system is not reflected in reality

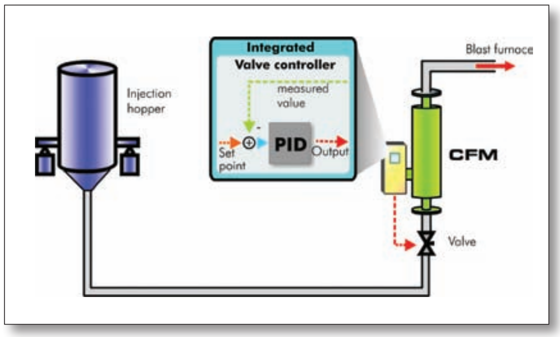

Fig 4 **Principle of closed loop control injection**

Optimisation must start with the measurement of actual flow rates in each injection line to understand the real conditions of the PCI lines. The next step is the control of each line to maintain a healthy furnace operation. Only then can injection rates be increased to higher levels. This is achievable by an upgrade of the conveying equipment from an uncontrolled to a controlled system.

CAPACITIVE FLOW MEASUREMENT (CFM)

The CFM meter was developed for the measurement of flow rate in the lines. A capacitive measuring method is used, taking advantage of the different dielectric characteristics of coal powder (ε_R) and of the conveying gas (ε_0).

Each CFM sensor consists of two sets of electrodes. The first set measures the powder coal concentration present in the injection line while the second set is needed to detect the velocity of the particles, using a capacitive-correlative method. From the product of these two values, the geometric property of the conveyor line and the material dependent calibration factors the mass flow is calculated. A microprocessor in every CFM device carries out the entire processing of the measured values and calculates the average flow rate, given by the formula:

$$\text{Flow rate [kg/h]} = \text{concentration [kg/m}^3\text{]} * \text{velocity [m/s]} * \text{pipe cross-section [m}^2\text{]} \quad (1)$$

Spiral electrodes (helix shape) around the conveying pipe deliver the most accurate measuring results for coal concentration measurement. The electrodes are integrated in an outer tube of steel, equipped with flanges for installation in conveyor lines. A microprocessor and the electronics are built into a cast aluminum housing mounted on the side of the outer tube of the CFM sensors, protecting them against mechanical damage and environmental influences, (see *Figure 3*). Thus the whole CFM sensor is a simple one piece, splash-proof (IP 66) design with customer-specific flanges. Integration and installation into an existing PCI system is easy.

CFM VALVE CONTROL

As an option each CFM unit can be equipped with an integrated PID controller. The measured flow rate signal is fed directly into this controller which compares the input signals to the set point and controls the valve in the injection line. As illustrated in *Figure 4*, the control loop is now closed.

Whether altering the flow rate by a valve or by adjusting the transport gas, the measurement system can be used in various PCI installation layouts such as a side-by-side vessel design, a stacked vessel design with locking chamber, or high pressure rotary feeders.

COMPLETE FLOW CONTROL SYSTEM

All measurement outputs and set points for the individual lines are communicated via an industrial computer network (CAN Bus) to a main digital link which interconnects the CFM system with the operator's PLC. The complete system is shown in *Figure 5*. Since all the necessary equipment is already incorporated inside the CFM no additional hardware for flow control is needed. This keeps the effort for wiring at a minimum.

By using the 'autoCAL' unit the CFM meters automatically self-calibrate to different site conditions or varying powder coal properties. This automatic calibration ensures that the flow rates are kept stable when conditions are changing, even when they happen unrecognised by the operator. The main advantages of a closed loop control with the automatic calibration are that it is independent of: powder coal qualities, coal humidity, grain size and operator.

OPERATION

A retrofit with CFM flow control provides:

- Fully automatic operation
- Complete data storage
- Data evaluation features available
- Automatic alarm when a line is blocked

RESULTS

Figure 6 shows the performance of line-to-line deviations in a controlled injection environment using this equipment in comparison to a static distribution system. One customer reports a reduction in line-to-line deviations from more than +/- 20% to less than +/- 2%, coupled with an increased PCI rate of 55kg/ tHM.

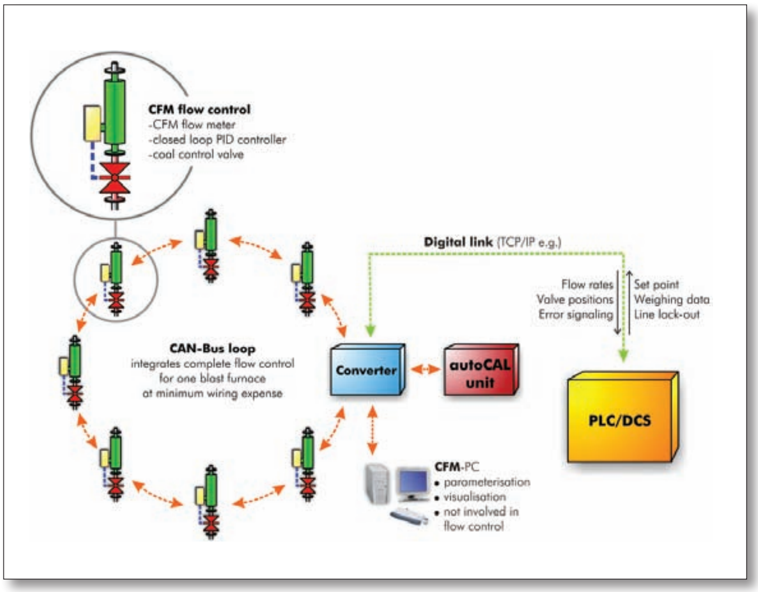

Fig 5 **Flow control system**

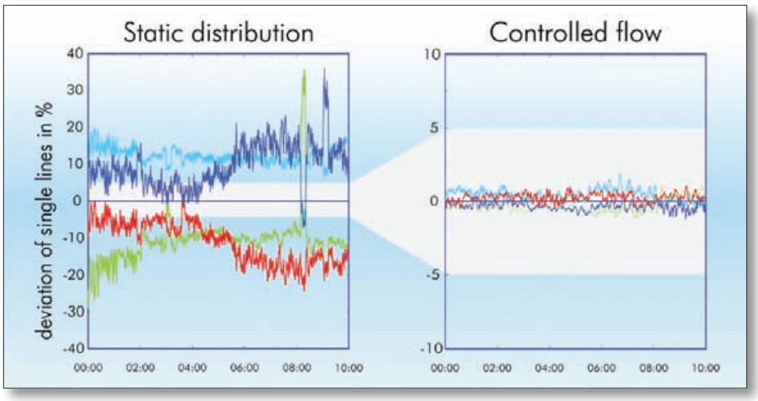

Fig 6 **Controlled flow vs static distribution flow**

CONCLUSIONS

CFM technology is proven in many installations worldwide. Its integration into existing injection systems is easy to arrange, and the system works fully automatically and compensates for all external influences. With controlled injection for each individual line and by maintaining an equal distribution between the lines, stable and higher injection rates are obtained and a healthy operation of the furnace is achieved.

In recent decades much progress has been made to minimise the consumption of reducing agents in blast furnace operation. Use of this technology significantly contributes to this trend. **MS**

Peter Matthes and Paul Massmann are with AMEPA GmbH, Wuerselen-Aachen, Germany. Roland Weiser is with F.Block, Wuerselen-Aachen, Germany.