Informed process optimisation

Successfully operating cement kilns with high rates of alternative fuel is essential in the transition to sustainable cement production. To ensure stable process conditions, detailed monitoring is necessary. Infrared cameras and analysis systems provide reliable tools to supervise the process and, in addition, extract parameters for advanced process control via automatic image and data processing.

■ *by **ci-tec**, Germany*

Unfolding the full potential of thermography to optimise industrial combustion processes is the mission of ci-tec. Combining expertise in infrared technology and state-of-the-art image processing, the company has equipped plants all over the world with reliable real-time thermography systems. The functionality of the innovative sensor platform and image-processing software toolbox 'inspect pro control' is continuously extended in cooperation with practitioners as well as researchers from the Karlsruhe Institute of Technology.

For process optimisation in cement plants, the capability of monitoring alternative and fossil fuels at the kiln outlet using infrared camera technology has a particularly beneficial effect. It enables the kiln operator to make informed decisions based on the live video from inside the kiln. Simultaneously, quantitative process characteristics can be extracted from the images and be used for automatic process control. Prompt and purposive adjustments stabilise the process conditions and hence the quality of the produced clinker. They further entail a reduction in fuel consumption, emissions and unscheduled downtime.

Challenges of kiln outlet monitoring

Steady combustion is essential to ensure optimal process conditions, eg, the appropriate temperature in the sintering zone. However, the quality and combustion properties of alternative fuels (AFs) fluctuate strongly, which may hinder the safe and successful usage of high rates of AFs. Detailed monitoring is essential here but poses a challenge due to the rough process conditions at the kiln outlet. Conventional sensor technology can only provide indirect information about the current situation inside the kiln. Camera surveillance of the kiln outlet is a valuable addition for the kiln operator if the image quality is sufficient and a suitable position for the camera can be realised. ci-tec offers a wide range of camera technologies from the visible spectrum to the infrared as well as experience in selecting a suitable technical solution for specific applications.

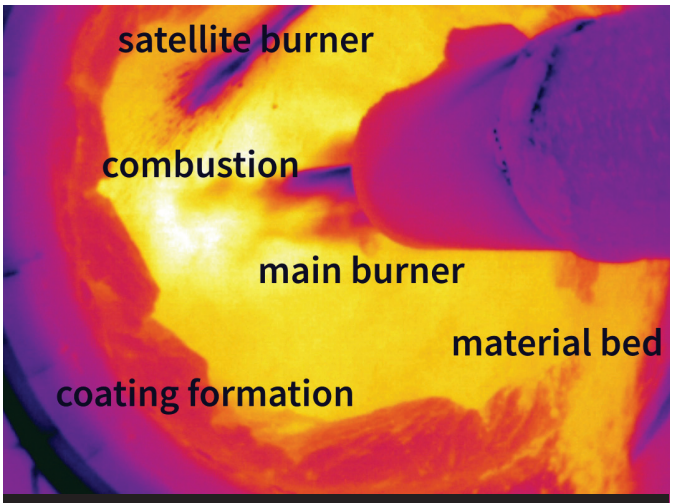

Figure 1: using infrared camera technology, fuels can be observed directly and monitored during combustion. Depending on the mounting position of the camera, multiple regions of interest are visible in the images

In cement rotary kilns, cameras operating in the thermal infrared regime have proven most useful (see Figure 1) since the transmission through the kiln atmosphere of hot combustion gases and particles such as soot, ashes and dust is higher than for wavelengths of the visible spectrum. Hence, it is possible to observe the fuels and their combustion behaviour directly. In addition, the images contain information on the temperature in all visible parts of the kiln.

Reliable temperature measurement

The camera's protective housing is built to resist the rough environmental conditions in the kiln (temperatures up to 1800˚C, high dust load) using water cooling and air purging of the lens. The camera can operate 24/7 with little maintenance since it is equipped with an automatic retraction unit triggered in case of emergency. Infrared camera images provide real-time radiometric information in each pixel at 50Hz, ie, precise temperature information from inside the kiln. The range of measurement can be customised between 400-2000˚C.

The significant advantage of cameras over pyrometers in terms of temperature measurement is the potential of automatic image processing. For instance, images (or image parts) with low visibility can be discarded, cold dust and cold lumps can be filtered out, and the region of measurement can be adjusted automatically. Figure 2 exemplifies how a pyrometer measurement would mistake a cold dust cloud for a temperature drop. An additional advantage of IR cameras is their versatility: temperatures from multiple regions inside the kiln can be selected for analysis and configured as needed.

In cement kilns the continuous temperature monitoring of the material bed in the sintering zone and at the kiln outlet is particularly useful for process control. The filtered temperature extracted by the inspect pro control system is a valuable instantaneous indicator for

the current process conditions and the produced clinker quality. Further areas that might be of interest for temperature monitoring (triggering an alarm if required) are the average temperature inside the kiln, wall temperatures, the average temperature of the fuels and the temperature of the (satellite) burner.

Extraction of process characteristics

The innovation of the inspect pro control system that distinguishes it from other established thermography solutions is the sophisticated image processing software. In addition to the live kiln image in the control room and detailed information on the temperature and its distribution inside the kiln, further process characteristics can be extracted and integrated into the plant's control system. Subtle and slow changes of the production process are objectively reflected in quantitative parameters and, therefore, can be detected more easily.

For instance, AFs can be characterised by the trajectory they take through the kiln until their complete combustion. Hence, one of the tailor-made algorithmic solutions for cement kilns from the inspect pro control toolbox is the detection of the fuel trajectory and the characterisation of its shape. The throw distance parameter is calculated in real time and can be used to optimise AF usage by, eg, adjusting the swirl air, conveying air and central air, or by means of a pneumo deflector, an additional air lance, or repositioning of the satellite burner. In addition, the incomplete burn-out of AFs can be detected early. The combined monitoring improves fuel usage and can prevent refractory damage.

All process characteristics are calculated in real time and can be combined with data recorded by other sensors throughout the plant. Therefore, the inspect pro control software system can readily provide data suitable for utilising data-driven advances in process control based on big data.

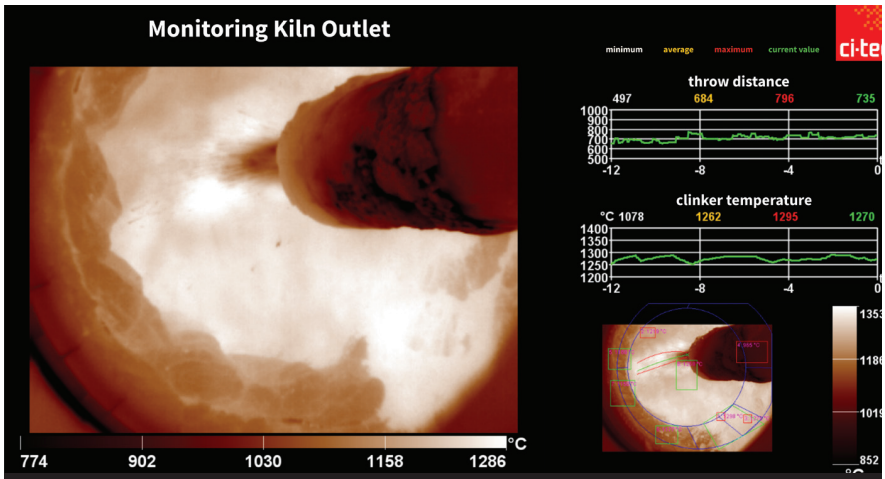

Figure 3: the camera image is displayed in the control room and the extracted process characteristics are made available to the kiln operator via the inspect software and the plant's control system

Process optimisation at OPTERRA Wössingen, Germany

The inspect pro control C system was developed for the requirements of cement kilns in close collaboration with the OPTERRA cement plant in Wössingen, researchers of the Karlsruhe Institute of Technology and the burner manufacturer Unitherm Cemcon. The system, including an infrared camera at the kiln outlet and the software including cement-specific image-analysis algorithms, was installed at the plant in 2018, where it is a vital part of kiln control.

The system is fully integrated into the plant's distributed control system and the live image of the infrared camera is displayed in the control room, where it replaced a visual camera. As shown in Figure 3, the control-room GUI of the inspect system provides an impression of the process conditions at the kiln outlet, and the operator is provided with a direct view on the fuels and information about their trajectory. This allows for immediate reactions to changes in fuel properties and optimisation of the combustion, eg, by adjusting the pneumo deflector of the main burner.

Furthermore, temperatures in different areas of the kiln are monitored continuously by the system. In particular, the material-bed temperature has been proven beneficial for process control at OPTERRA Wössingen since it is strongly correlated with clinker quality as reflected by the alite, belite and free lime content. Since temperature information provided by thermal camera monitoring is instantaneously available, it is used as an early indicator for clinker quality in the control room of the plant. Therefore, the reaction time for kiln control is significantly reduced compared to sole feedback from the results of the clinker analysis in the laboratory.

Conclusions

Infrared camera-based analysis systems are an extremely useful tool for monitoring industrial kilns. Relying on innovative image processing techniques, ci-tec enhances the usefulness of thermography: quantitative information about the current process conditions is automatically extracted from the camera images and complements the intuitively interpretable images.

By having the information in real time, the process conditions can be optimised by prompt adaptions and the rate of AFs can be increased in a controlled way. Altogether, the detailed information provided by inspect pro control is a strong basis for informed process control. The stabilisation of the process conditions leads to better product quality, decreased emissions, fewer fuel costs and reduced maintenance. ■

Figure 2: cold dust can be filtered out, which makes the temperature measurement based on infrared images very reliable