Visualise to Optimise

Rainer Böcher, ORFEUS Combustion Engineering GmbH, Germany, describes the company's solution for non-contact optical pyrometry and thermal process analysis for optimised kiln control.

Introduction

As is well known, cement is manufactured in a series of processes where the raw material, a mixture of calcium carbonate (limestone), silica, iron (oxide) and alumina, is heated to a partial melt at 1450 °C (sintering) and transformed chemically and physically into the clinker. The clinker is finally ground and mixed with sand and gypsum and results in the product cement.

The sintering process is critical to the quality of cement and requires accurate control of the energy input. Combustion is the process needed to transform the chemical fuel energy into the heat needed to burn the clinker. Insufficient heat will cause the clinker to contain unconverted lime. Excess heat will shorten the life of the refractory bricks in the kiln and may damage the kiln shell, diminish product quality and increase process costs.

Since the ratio of energy costs to the entire production expenses in the cement industry is very high, secondary fuels are applied in a high degree to save primary fuels. Secondary fuels often have fluctuating heat values, which influence the relatively complex thermal – or rather chemical – conversions of the raw material in a negative way. Accurate process control and optimising the combustion process is the key to optimised kiln operations.

Requirements

The process control system, as well as expert systems for optimisation tasks and, perhaps most importantly, the kiln operator must be supplied with reliable online data from the sintering process to control the kiln and firing process in the best way possible. A process data measurement system for this application should gather reliable online information from the high temperature burning process, which cannot be measured with the standard process instrumentation.

The system should meet the following requirements:

- Real time and colour video presentation of the sintering zone at kiln outlet.
- Detection of flame form and position.
- Detection of burner nozzle position and condition.
- Temperature measurement from the sintering zone, flame and clinker bed.
- Temperature distribution with spatial resolution.
- Evaluation of radiation energy of the flame.
- Hard and software designed for the harsh environmental conditions of the clinker production process.

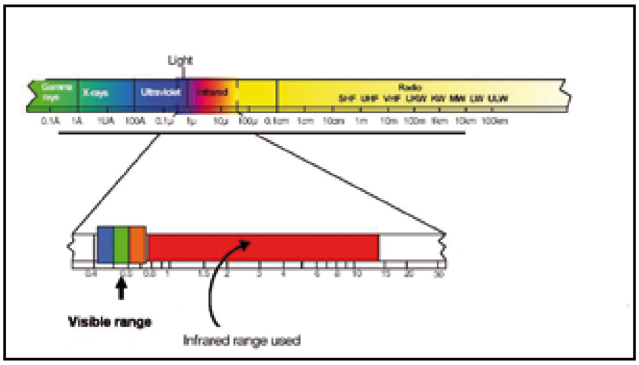

Figure 1. The visible and infrared region of the Electromagnetic spectrum.

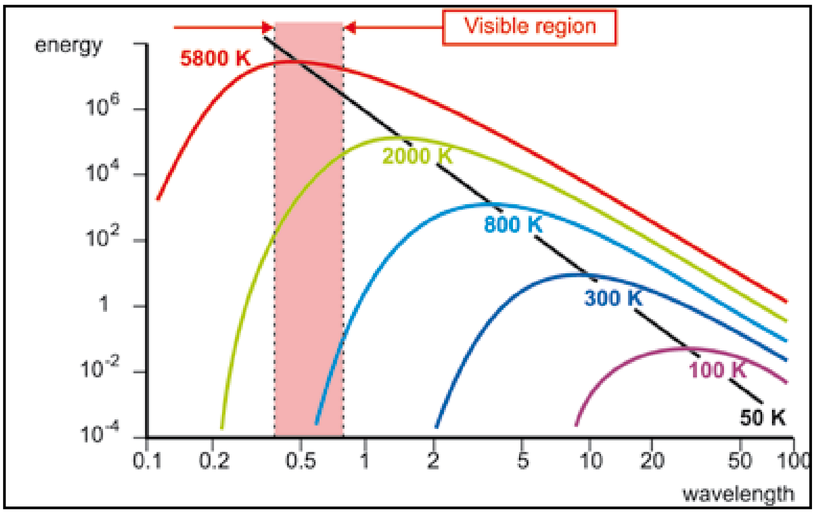

Figure 2. Infrared energy across the Electromagnetic spectrum.

Figure 3. ORFEUS Sensor with retraction unit in operating position.

Video and thermography system "FlameSightCem" with thermal imaging

The FlameSightCem System from ORFEUS Combustion Engineering is a high-temperature video imaging system with image analysis, and video data processing, in combination with an online, non-contact temperature measurement system based on optical pyrometry.

This intelligent sensor system is composed of the field-mounted sensor and pre-processing components together with the system PC normally located in the control room with video and thermal image monitors as the human machine interface. The Interface to Process Control Systems or to Expert Systems is as standard. All data gathered from the high temperature process, such as analytical data and temperature measurements, are available for the control systems.

The FlameSightCem–Sensor (Figure 3) with pneumatic operated retraction system is installed through the wall of the kiln hood or the wall of the clinker cooler. The sensor is water-cooled, air-purged and operates in the field without any moving parts. This special design is to protect the optical, video and thermography components against the harsh environmental conditions at the kiln hood or clinker cooler and to guarantee a reliable operation with minimal maintenance.

Figure 4. Video presentation from sinter zone and kiln outlet.

Non contact temperature measurement (optical pyrometry)

A controlled temperature distribution and the temperature measurement have always been the most fundamental parameters in the sintering process. These parameters can be taken as indicators for the conditions of the clinker burning process.

Every form of matter with a temperature (T) above absolute zero emits electromagnetic radiation according to its temperature. This is called characteristic radiation. The cause of this is the internal mechanical movement of molecules. The intensity of this movement depends on the temperature of the object.

Since the molecule movement represents charge displacement, electromagnetic radiation (photon particles) is emitted. The photons move at the speed of light and behave according to the known optical principles. They can be deflected, focused with lenses and reflected from reflective surfaces. Figure 1 shows various forms of radiated energy in the electromagnetic spectrum including X-rays, ultra violet, infrared and radio. The different bands are classified according to their radiation wavelength.

The spectrum of this radiation ranges from 0.4 to 1000 μm wavelength. In most industrial applications it is the energy radiated at infrared wavelengths (0.4 – 20 μm) that is used to determine the object's temperature.

However, objects at high temperatures emit, infrared radiation in the visible band of the spectrum, as shown in Figure 2. This is why objects at temperatures above 800 °C can be seen glowing somewhere from red to white. The radiation maximum moves toward ever-shorter wavelengths as the target temperature rises.

These relationships were recognised by Stefan Boltzmann in 1879 and illustrate that an unambiguous temperature can be measured from the radiation signal without physical contact by measuring the emitted energy.

Video system – video image

The real-time visual information from the sintering zone or from the clinker cooler is permanently displayed on the video monitors in the control room. The information from the video system will be an online colour insight into the kiln with presentation of flame form and position, burner nozzle position and condition and clinker bed situation (Figure 4). It also reveals any potential problem in forms of consistency, thickness, caking and ring-formation of the clinker bed and formation like "snow men" and "red rivers" in the clinker cooler.

Thermography system – thermal image

For each physical point in the optical field of view of the video sensor, the energy of the characteristic electromagnetic radiation will be measured, evaluated and the representative temperature will be calculated. For the thermal presentation the calculated temperatures are transformed to a two-dimensional colour map (thermal image).

The Thermography–System provides a method of determining the spatial distribution of heat out of the field of view of the sensor's video system from the sintering zone. The qualitative thermography measurements rely on analysis of thermal patterns to reveal the existence and position of anomalies and evaluate them. The quantitative thermography analyses use temperature measurements as criteria to determine the seriousness of anomalies in order to establish predictive maintenance priorities.

User definable lines (Line Of Interest = LOI) and user definable objects (Region Of Interest = ROI) can be defined by the user/operator inside the thermal image (optical field of view). The ROIs and LOIs are free in length, form and dimensions and can be freely positioned. The temperature distribution on these LOIs or inside of the ROIs can be measured and displayed as minimum, maximum and average temperatures (Figure 5).

With the thermography system, temperature measurement, temperature distribution presentation and thermal analysis of the process conditions are available. The thermal Imaging is the basis for an objective analysis of the process conditions. The thermal image (Figure 6) presents the operator the temperature distribution along the LOI 1 located at clinker dropping position (Figure 5). The information from this presentation is, for example, the temperature of clinker and the width and local position of the clinker dropping.

Conclusion

The ORFEUS System "FlameSightCem" is an intelligent sensor system for the cement industries. The optical online analysis of the sintering process provides a number of qualitative assessments, such as clinker size, flame conditions, turbidity and kiln dust level as well as "snowmen" and "red river" formations in the clinker cooler entry. This video imaging gives the operator the opportunity to form his subjective opinion concerning the current process conditions.

The thermal online analysis of the sintering process with the thermography system and the thermal imaging provides precise data and information from the sintering process. This data is a real-time basis for the automatic process control and a basis for the operator to take objective appraisals concerning the process and product quality. ◆

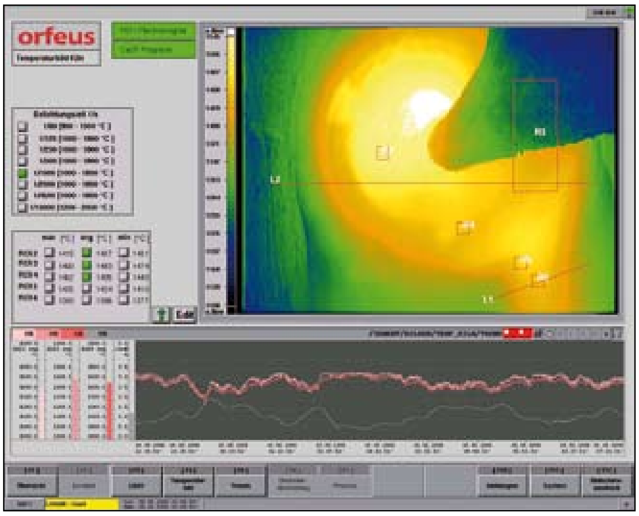

Figure 5. Thermal image with LOIs and ROIs and temperature-trend-indicator.

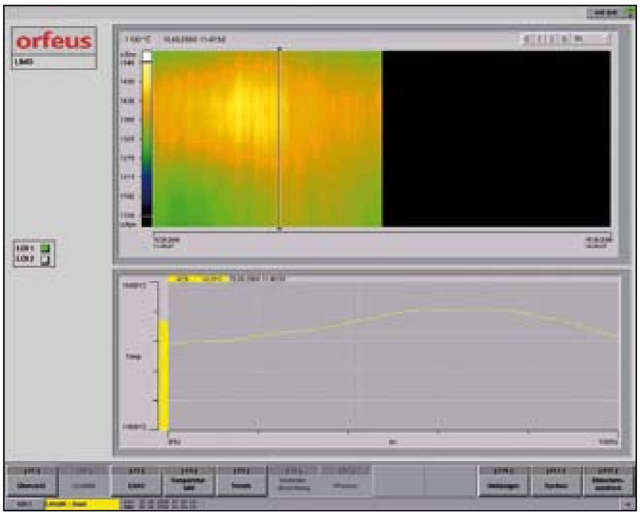

Figure 6. Temperature distribution history from LOI 1.