Infrared temperature measurement for sustainable production and processing of liquid iron and steel

by Albert Book

The goal of sustainability is to leave an intact living space for future generations. Sustainability is therefore not only the basis for political decisions, but it should also raise the personal awareness of each individual for ecologically sustainable and economically efficient action in order to use resources wisely. The production and processing of liquid iron and steel in particular requires large quantities of raw material resources such as coke and iron ore as well as fuel for energy production. It is encouraging that, according to figures from the German Raw Materials Agency, 45 % of steel in Germany is already produced from secondary raw materials. But heating the air in the stove dome for the blast furnace to 1,300 °C or melting the iron and steel for casting to up to 1,500 °C requires large amounts of energy.

For a resource-saving process in the iron and steel industry, it is therefore of great importance to precisely record and maintain the temperature in the various production processes. In the following, we will present the state-of-the-art infrared temperature measurement technology of the respective production plants.

Classic temperature measurement using thermocouples

A common method for measuring the high temperatures is contact measurement using thermocouples. The thermocouples are permanently installed in the furnaces and pipelines. Besides mechanical susceptibility, diffusion effects are a well-known physical problem of thermocouples. Over time, the thermoelectric voltage decreases. Due to the so-called ageing, the measured value drifts. Changes are not immediately recognisable and lead to unintentional measurement errors. As a countermeasure, the thermocouples are regularly checked for measurement deviations and replaced.

When measuring the temperature of the liquid metal in the channel of a blast furnace or in the crucible of an automatic casting machine, measuring lances with attached thermocouples are immersed in the melt. In addition to the disadvantage of high consumption costs, the manual, sporadic measurement does not allow continuous recording and thus a constant temperature profile and therefore an energy-saving operation of the plant.

Infrared temperature measurement

Unlike thermocouples, infrared thermometers or pyrometers optically detect the temperature of the measuring object. A lens detects heat radiation, which is fed to the infrared sensor. Based on Planck’s law of radiation, the temperature is then calculated.

A decisive advantage of this measuring method is the non-contact measurement from a large and safe distance of several metres. The measured value acquisition and process-

Fig. 1 *Pyrometers measure the temperature of the checker bricks in the stove dome from the cupola.*

ing takes place in a few milliseconds and therefore offers the possibility of a fast reaction time in the event of an inadmissible temperature deviation. The wear-free measuring method also means that there are no permanent consumption costs.

Temperature measurement of the checker bricks in a stove dome

In a stove dome, the air is heated to approx. 1,300 °C before being fed into the blast furnace. For this purpose, cold fresh air flows from bottom to top through preheated checker bricks. The temperature of these checker brick is determined by a pyrometer mounted on the cupola of the stove dome (**Fig. 1**). The basis for a reliable measurement are pyrometers with a high optical resolution and a narrow sight cone in order to detect the infrared radiation from a great distance of several metres through the sight tube.

The plug and play measuring system developed by KELLER ITS includes the pyrometer, a protective fitting for outdoor installation with mechanical and pneumatic ball valve, and a switch box for the electrical connection and for the supply of the cooling and purging gas (**Fig. 2**). The special feature of the measuring system is the use of a perforated screen coupled with a dynamic adjustment of the gas quantity depending on the operating state of the stove dome. Compared to previous measurement systems, the amount of gas required to keep the field of view clean is reduced by up to 80 %. This measure contributes significantly to resource conservation and thus sustainability.

Temperature measurement of the melt in the casting channel of the blast and cupola furnace

Pyrometers are used to measure the temperature of the melt in the casting channel of the blast furnace and cupola furnace from up to 20 m away. Slag and oxides on the surface of the liquid metal are problematic at this measuring point (**Fig. 3**).

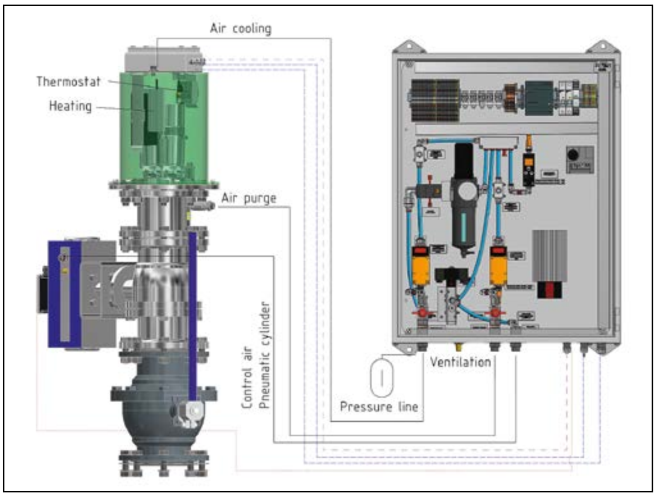

Fig. 2 *Plug and play measuring system for stove dome.*

Fig. 3 *Measuring point casting channel with slag and oxides on the flowing melt.*

Unlike the clean melt, these have different radiation properties. In order to be able to precisely measure the temperature in the casting channel despite the impurities, pyrometers were developed that are equipped with very high-resolution lens and thus a measuring field of only a few millimetres. In combination with a short measuring time in the millisecond range and a CSD (Clean Surface Detection) function, the devices are able to filter out the temperature of the flowing melt at the oxide- and slag-free points. Equipped with an integrated video camera, the measuring field including the temperature is displayed on a monitor in the control room. Thanks to the continuous recording of measured values, it is possible to react immediately in the event of temperature deviations. The wear-free measuring method also saves enormous resources and consumption costs by eliminating the need for immersion thermocouples.

Temperature measurement of the pouring stream at the automatic casting machine

At the automatic casting machine, the temperature of the liquid metal has a decisive influence on the flow behaviour and the uniform distribution in the mould. In addition, the casting temperature determines the processing properties of the semi-finished and finished products and is largely responsible for the quality of the castings and the amount of rejects. Avoiding the production of defective parts is the most efficient way to preserve raw material resources.

With immersion lances, it is only possible to determine the temperature in the ladle before the actual casting process and thus never the production-critical temperature of the pouring stream. The user-dependent position and immersion depth of the measuring lance also affect the measurement uncertainty of the lance measurement. Only by precisely recording and monitoring the pouring stream temperature is it possible to achieve consistent quality with a minimum reject rate and thus save material and energy resources.

The CellaCast PA 83 panorama pyrometer was developed for measuring the temperature of the pouring stream on the automatic casting machine. Thanks to the rectangular measuring field, a reliable measured value is determined even with different stream diameters and fluctuating position of the pouring stream. Furthermore, the measuring system has an intelligent ATD (Automatic Temperature Detection) function. This automatically records the temperature of each individual cast. The measured value is shown on the display of the unit and is available for further processing via the analogue output and the serial interface. The pyrometer has either a through-the-lens sighting or a colour video camera. The monitor in the control room displays the pouring stream with the measuring field, the measured temperature and the measuring point number (**Fig. 4**).

Analysis and archiving of the measured values

The CellaView software is included with the CellaCast PA pyrometer series. This makes it very easy to set up a self-sufficient, PC-based data acquisition system. The software graphically displays the measured values in real time. Thanks to the modern MDI interface, any number of diagrams can be opened simultaneously and the measurement series of up to 31 devices can be recorded in parallel. In the CellaCast mode of the software, the number of castings including the reject rate is displayed for each production batch and documented in a metrological report (**Fig. 5**).

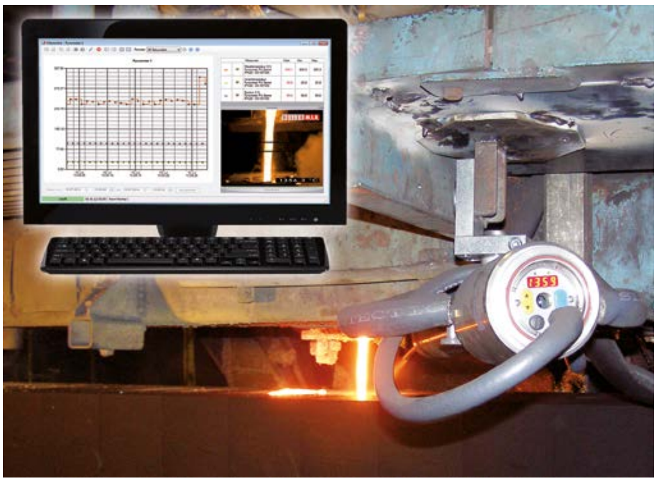

Fig. 4 *Measuring point at the automatic casting machine and monitor for displaying the casting temperature and the video image.*

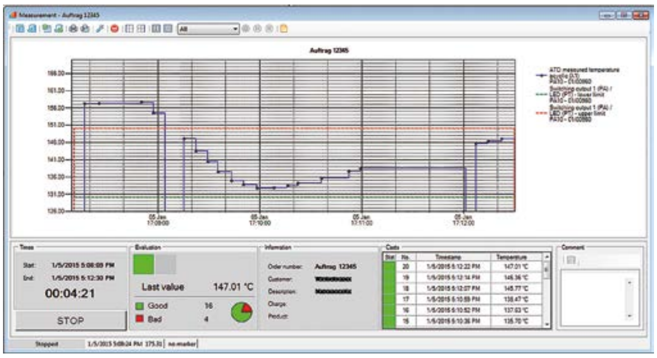

Fig. 5 *Documentation of the temperature per cast part and of the reject rate per production batch.*

Both the data from the serial interface and the video signal can be integrated into an Ethernet network. This means that the measured values as well as the video image can be viewed at any workplace, regardless of location.

Connection to a central control system

The topic of Industry 4.0 for the recording and verification of production-relevant measured variables is also being discussed intensively, especially in the manufacture of foundry products. The pyrometers of the CellaCast PX series are equipped with the modern IO-Link interface technology. This makes the integration of the measuring system into the plant control system very simple (**Fig. 6**). This is because when specifying the IO-Link interface according to IEC 61131-9, particular emphasis was placed on standardisation, operational safety and simple cabling and commissioning in terms of hardware and software. Several measured values, diagnostic information for demand-oriented maintenance, information on operating states or fault messages can be transmitted in parallel via the digital interface.

Conclusion

Both in terms of the sustainability of resource-saving production through precise temperature measurement and for the continuous documentation of the casting temperature and, last but not least, to save permanent consumption costs, the use of pyrometers on the temperature-relevant processes in the production and processing of liquid iron and steel is a future-oriented and worthwhile investment.

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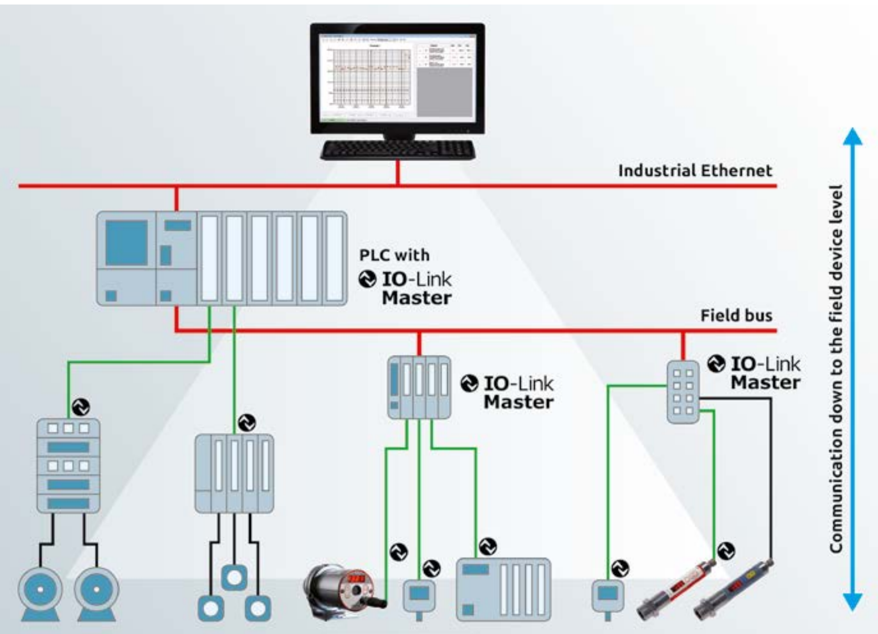

Fig. 6 *Integration of the pyrometer with IO-Link interface into the plant system control.*