Application report

Non-contact temperature measurement of molten metal

Temperature is one of the most crucial process parameters in the casting process. Monitoring and controlling molten metal temperature is essential to yielding foundry products which feature desired physical properties such as tensile strength. CellaCast, a newly developed non-contact temperature measurement system, captures the precise in-stream temperature of each pour, providing full traceability for each cast product and documented evidence of conformity to the tolerance requirements. The reduced amount of process scrap and a decrease in the number of required thermocoupler lead to reduction in operating cost.

The effect of temperature on the work-piece

In metal casting, maintaining the correct process temperature is a decisive factor in producing high-quality castings. Molten metal which is too hot will damage the sand moulds. A temperature which is too low will result in low fluidity. Especially cast metal parts with detailed features demand precisely controlled casting temperatures. A molten mass which is not hot enough will exhibit poor metal flow within the complex passages of the mould and may result in bubbles or cavities. The pour temperature also has an impact on the physical properties of the resulting workpiece. Problems often arise during subsequent welding or machining. Even worse is when flaws are not identified until after the cast parts have been integrated into other products. Incorrect process temperatures will yield parts that break or wear out prematurely due to material fatigue.

Strict compliance with process parameters is therefore of utmost importance –and this requires precise temperature monitoring and control. This is the only way to ensure that required material properties are achieved. Reducing the number of rejects and defective products will save costs up front and prevent liability claims later.

Temperature measurement using a thermocouple

The temperature of molten metal is most commonly measured using immersion probes or thermocouples (Photo 1). The probe is dipped into the liquid metal after the ladle is filled, that is, before casting even begins. Data accuracy is subject to the precision with which the foundry operator performs the measurement. Depending on the immersion depth and the position of the probe, temperature readings can deviate by approximately 20 °C. The development of a slag deposit on the sensor element may also lead to false temperature readings. Another potential source of error is the fact that molten iron in the ladle cools at about 10 °C per minute, depending on the condition of the ladle insulation. The permissible temperature range at which the melt can be poured is precisely specified for the particular process. For most molten alloys, this span is about 50 °C. If the temperature of the molten metal in the ladle is higher than specification, production will either be interrupted to allow time for the material to cool, or scrap will be added to the ladle with the same effect.

The pouring process must begin almost immediately once the desired molten metal temperature has been detected within the ladle. Interferences at the casting line (which occur quite frequently) cause unscheduled interruptions

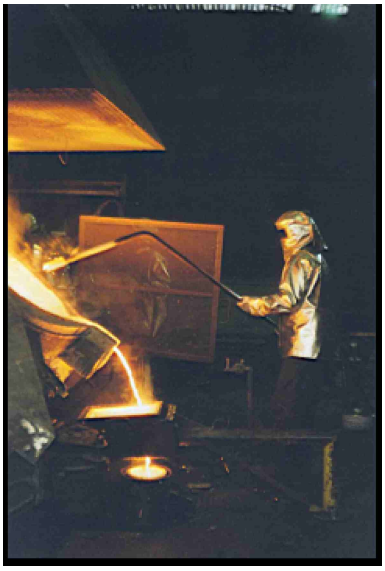

Fig. 1: Temperature measure-ment using a thermocouple

and delays.

The foundry operator performs a quick visual check and then decides whether to continue pouring from the same ladle or not. Based on the colour and flow characteristics, the rema-ining molten metal in the ladle will be either reheated in the furnace or the products poured from that mass will be designated as potential rejects or scrap.

At fully automated casting lines, the process cannot be simply stopped. When a disturbance occurs, the subsequent castings pou-red from that inter-rupted ladle will also be marked so that the products can be inspected later to assess their properties and usability.

Due to the lapse in time between an immersion measurement and the instant of time when a mould is filled, a foundry will have no proof of the exact molten metal tem-perature at the actual time of pouring.

Advantages of non-contact temperature measurement

A pyrometer detects the infrared radiation emitted by an object's surface and produces a temperature reading. Similar to a camera, the pyrometer's precision optics focuses on the object to be measured and indicates the exact position and size of the target spot. The pyrometer can thus be installed at a safe distance to the hot target.

Fig. 2: The pyrometer detects the temperature at the moment the metal stream

A pyrometer has no parts subject to wear, therefore a foundry does not incur any operating costs for expendable parts. The immersion method, on the other hand, uses thermo-couple tips which require frequent replacement. A pyrometer based on a two-colour (ratio) tech-nique yields highly reliable measu-rement results, even when dust or smoke obstruct the pyrometer's field of view. A pyrometer detects infrared energy at two different wavelengths and produces temperature readings based on the ratio of these two inten-sities. The ratio method produces accurate tempe-rature data even at signal attenuation of up to 90%. The temperature of molten iron is measured at a crucial point in the casting process: just as the iron is poured into the mould (photo 2).

A pyrometer functions independently, thus the accuracy of the tempe-rature data is not subject to the attentiveness or precision of the employee performing the measu-

rement. For all of these reasons, a pyrometer is more than just an alternative to an immersion sensor.

New system with rectangular measurement area.

For more than 40 years, the MSR Division of KELLER HCW GmbH has been engineering and manufacturing instruments for non-contact temperature measurement. Conventional pyrometers usually detect the temperature at one specific spot. At a foundry, the stream position will vary as the molten metal is poured into a mould. Especially when poured from a ladle, the liquid metal stream will fluctuate, depending on the tilt angle of the ladle. At automated casting lines, a clogged siphon will also alter the position of the pour stream.

wide-angle) to perfectly suit the application. The lens requirement will depend on the stream diameter and the distance between sensor and target. With the help of the rectangular target indicator in the field of view, it is easy to capture the pour stream.

signal or impair the measurement. After each pour, a temperature reading is displayed for each cast mould. This system ensures that temperatures are continuously detected and data is saved for each poured metal part.

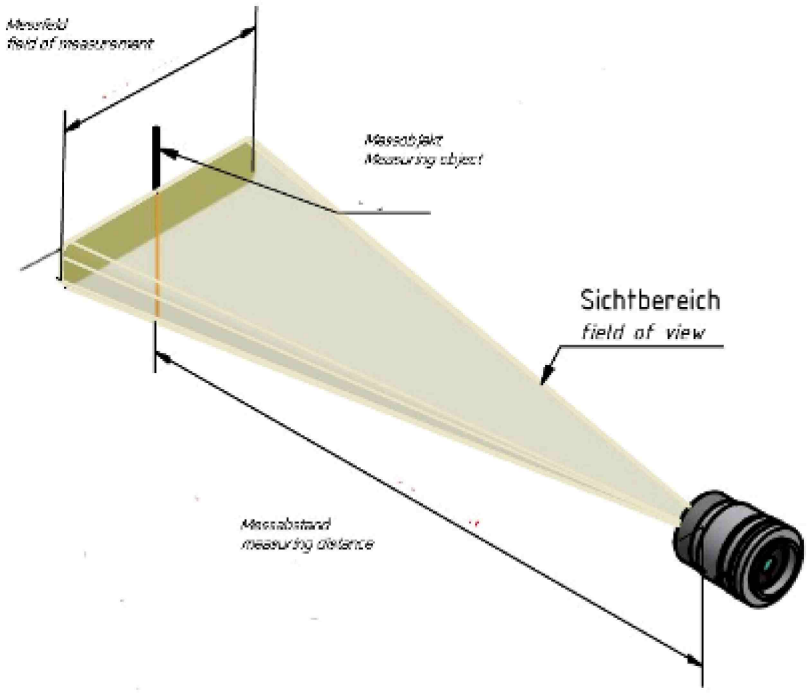

Fig. 3: The position of th emolten metal stream may vary within the pyrometer`s field of view

The CellaCast system is based on a newly designed two-colour pyrometer, the CellaTemp PA 83. This pyrometer features a unique optical system with a rectangular measurement area rather than a round target spot. The molten metal stream may move within the measurement area (photo 3). CellaTemp PA 83 can be equipped with one of three lens options (standard, telephoto or

The intelligent ATD function (automatic temperature detection) enables the CellaTemp PA 83 to detect the correct temperature regardless of the pour stream position. ATD automatically identifies when the pour begins and starts measuring at that moment. Thanks to ATD, interferences such as flames or molten metal drip will not impede the

view temperature readings instantly at a large external digital display unit and/or from a monitor within the control room. As an option, a visual alarm signal can indicate temperature threshold violations. The CellaCast system can be augmented by a control panel which can be custom-configured with specific parameters for various molten metal alloys.

When the lowest permissible temperature is reached, the operator can immediately stop the casting process. In this way, the foundry minimises the amount of scrap, rejects and cold shut parts. The pyrometer features a serial interface, enabling temperature data to be saved at a PC or recorded via a data acquisition system. The scope of supply includes CellaMevis PC software which provides online graphic images of measurement data at a PC. An autosave function stores data at periodic intervals with a timestamp. (Photo 5). CellaCast also comes with an extremely rugged protective mounting assembly to enable installation in harsh environments. (Photo 6).

Points of non-contact measurement

The most common application for CellaCast is temperature detection as the mould is being filled, whether poured from the ladle or at a fully automated casting line (Photo 7). Another frequent use is continuous temperature monitoring at a cupola furnace. In contrast, immersion measurement in the casting channel is usually performed at great intervals which makes it impossible for a foundry

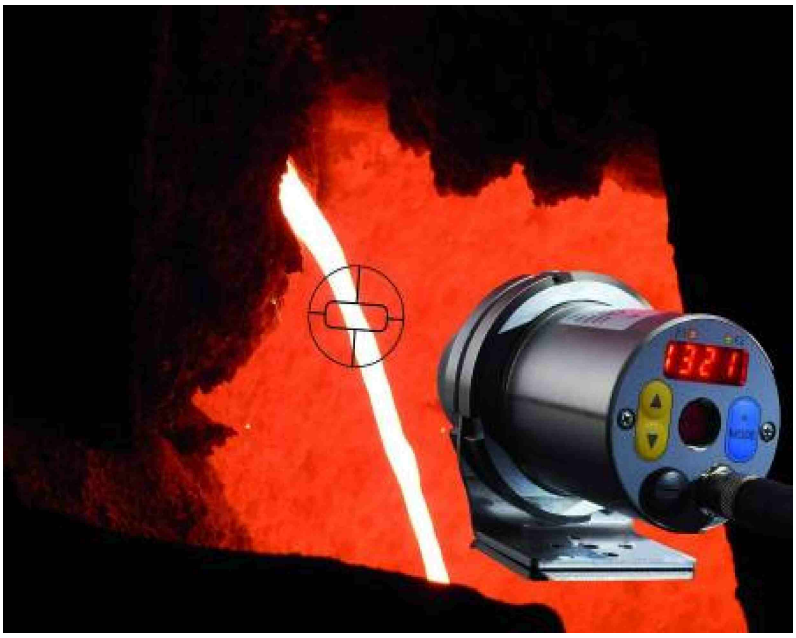

Fig. 4: CellaTemp PA 83 captures with through-the-lens sighting

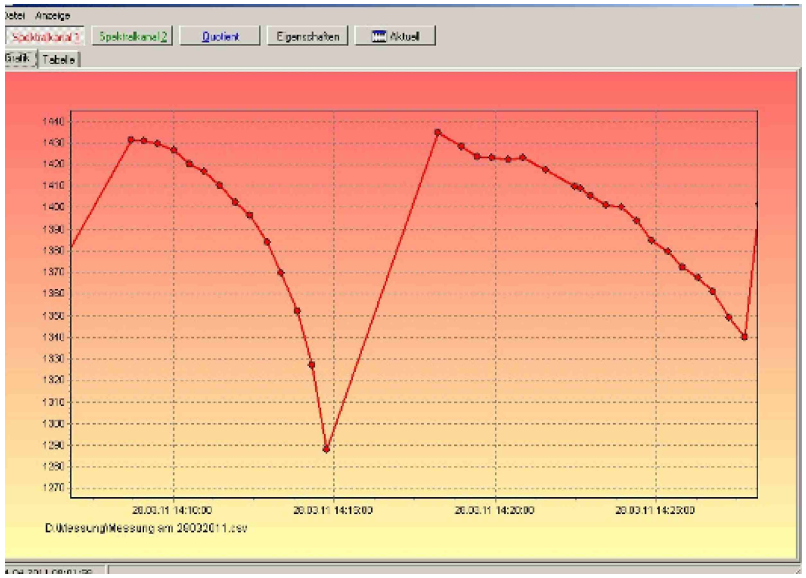

Fig. 5: Graphic display of measurement data for two foundry ladles; each point represents a mould.

Fig. 6: Protective mounting assembly for the CellaCast System

worker to react to unwanted changes in temperature just as they occur. A pyrometer measures continuously without interruption, enabling an operator to intervene immediately if necessary. Thus, with pyrometer use, great temperature fluctuations can be prevented and uniform results can be achieved and verified. For foundries using induction melting furnaces, temperature is a crucial parameter which determines the exact point in time for transferring molten iron into the transfer ladle. The use of immersion sensors with this application presents a challenge: during measurement, induction heating must be switched off in order to protect the operator from electrical shock.
A pyrometer, on the other hand, continuously monitors the temperature of the molten metal in the furnace du-ring the heating process from a safe distance.

At a steel mill, pyrometers are employed to check tapping temperatures at blast furnaces. Using high-resolution telephoto optics, the CellaTemp PA 83 can detect temperatures from a distance of up to 20 meters.

Conclusion:

CellaCast is a state-of-the-art measuring system which provides foundries the ability to continuously monitor and document process temperatures. CellaCast not only saves operational costs as a non-expendable system, it improves and facilitates quality assurance so that foundries can keep pace with increasing demands on product quality.