Sonderdruck aus „Stahl und Eisen“ 128 (2008), Heft 9, Seiten 87–92
Nachdruck verboten. **Verlag Stahleisen GmbH,** Düsseldorf

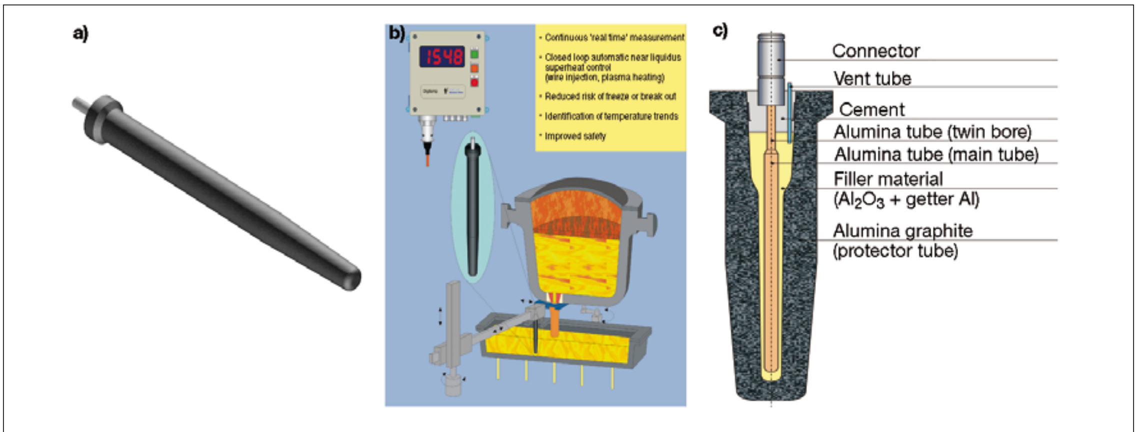
Thermocouple-based continuous temperature measurement systems in continuous casting operations

Techniken der kontinuierlichen Temperaturmessung auf Thermoelementbasis beim Stranggießen

Wolfgang Glitscher and Martin Kendall

Temperature control in continuous casting comes in basically two different ways: either by disposable temperature sensor or continuous. Modern casters of all types are today widely automated and have replaced manual measurement action by automated on demand or continuous techniques. Semi-permanent continuous sensors are the industrial standard in continuous casting. Most common is the thermocouple-based measurement, with over 95 %. Thermocouple reliability and accuracy are still unmatched and require almost zero maintenance. This paper gives a system comparison of today's industrial systems in respect to cost and technical performance.

Grundsätzlich gibt es zwei Wege der Temperaturmessung beim Stranggießen, entweder mittels Tauchmesskopf zur Einmalmessung oder mit kontinuierlichen Sonden. Moderne Gießanlagen sind heute weitgehend automatisiert und haben die manuelle Messtätigkeit durch vollautomatische Roboter oder Halbautomaten ersetzt. Entsprechende Langzeitsonden mit quasikontinuierlicher Technik sind schon Stand der Technik. Mit über 95 % vertreten ist die auf dem Thermoelement basierende Messtechnik. Bei Verlässlichkeit und Präzision ist diese noch unerreicht, der Instandhaltungsaufwand gering. Nachfolgend werden verschiedene Anwendungen der kontinuierlichen Temperaturmessung technisch/kommerziell verglichen.



1
Sensor, application sketch and inner construction
Sensor, Anwendung und innere Konstruktion

Since Charles Darwin's “On the origin of Species” we know that the strongest, the fastest, the most resistant etc survive in the chain of evolution. If this is true for the cleverest as well, the Homo erectus, we do not know yet, and we may have our doubts when looking at the recent rapid change of the world climate threatening mankind with storms, flooding, expansion of deserts etc. And what about this in the metallurgical world? Till the early 60's, the eye of the experienced foreman read the temperature of the liquid steel from the color of the steel flames and the carbon content

Revised version of a paper presented at 6th European Conference on Continuous Casting (ECCC) 2008 on 4 – 6 June 2008 in Riccione, Italy.
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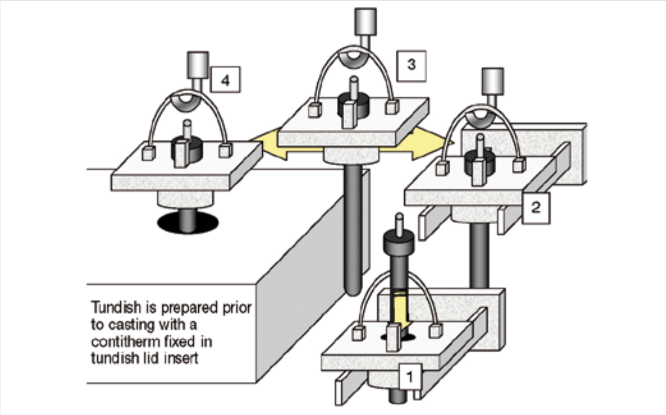
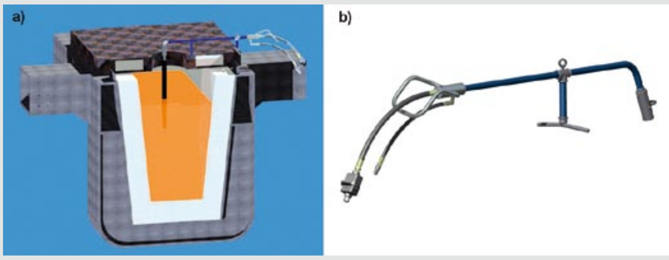


2

Pre-fixed arrangement of sensor

Vorbereitetes Einlegeset



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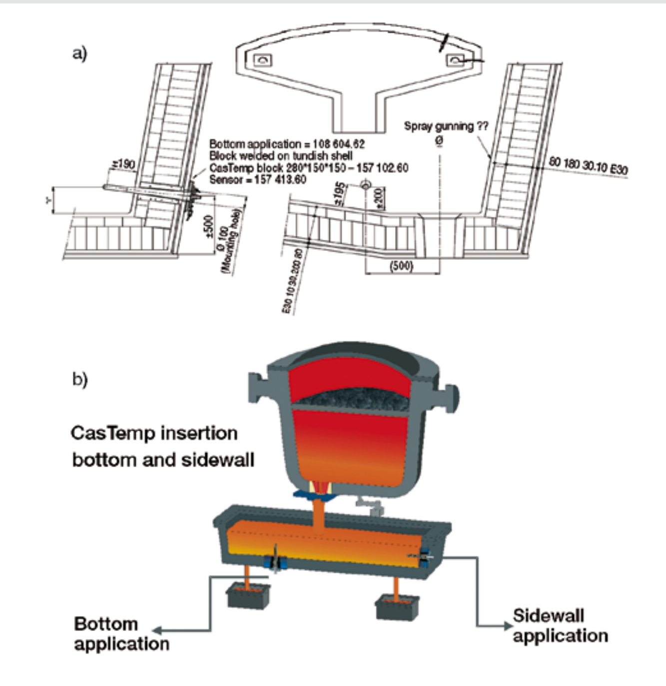
Contilance lance scheme

Contilance-Lanzenschema



4

The location of the through-the-wall sensor (CasTemp) in relation to the outlet ports and the ladle shroud

Position des CasTemp-Sensors bezüglich der Ausgüsse und des Schattenrohrs

from the sample sparks. This species of metallurgist has (almost) faded away from our steel shops. Their brilliant knowledge is not needed any more; time swept them away and replaced them with a new graven image, a new idol named sensing technology. In continuous casting operations, continuous sensors have taken over leaving human experts and disposable thermocouples by far in the shade in terms of precision and cost effectiveness. Let us have a look at various systems for making better steel.

Top immersion type

This version of continuous measuring thermocouple combines cost, fit and function in a way that makes it today's standard. Broadly independent from continuous casting operations it features precision and good flexibility. Its reusability for the next sequence of casting ladles and a long service life of typically 24 h makes it very economic for most caster applications. Thermal shock is no issue with the black refractory protector tubes used, and thus the sensor may be immersed directly without preheating.

Figure 1 shows a typical application and the schematic diagram of the sensor construction. It is common to use tundish pantographs or pre-fixed arrangements to immerse and park the sensor, figure 2.

Contilance type

A recent innovation for continuous temperature measurement is a reduced weight continuous sensor system, which enables a truly mobile system for the first time. There are a few aspects that make a Contilance attractive:

- familiarity: the method for applying the lance is virtually the same as for traditional spot measurements;
- mobility: move the continuous measurement from here to there;
- easy access: a lance is most flexible and may reach a measurement place that is difficult to access by a fix installation;
- fast thermal response;
- low investment cost;
- easy and low cost maintenance;
- improved operator safety compared to spot measurements and heavier continuous sensor types.

Figure 3 shows both, application scheme and immersion lance.

This system is most attractive for short sequence casters. The air-cooled lance is self-positioning and keeps the sensor floating even with changing steel level in the tundish. This ensures an optimised constant immersion depth, and avoids shallow immersion or even immersion loss with erratic reading.

The lance rest system is adjustable in position, and adaptable, enabling plant specific solutions to be decided locally.

Through-the-wall system

A continuous thermocouple installed through the wall or the bottom of the tundish is already an old concept but offers, if engineered in the right way, an enormous potential and customer benefits. Figure 4 shows the arrangement. This chapter describes the industrial implementation of a new approach, a very accurate real time continuous temperature measurement of the steel close to the tundish outlet nozzle.

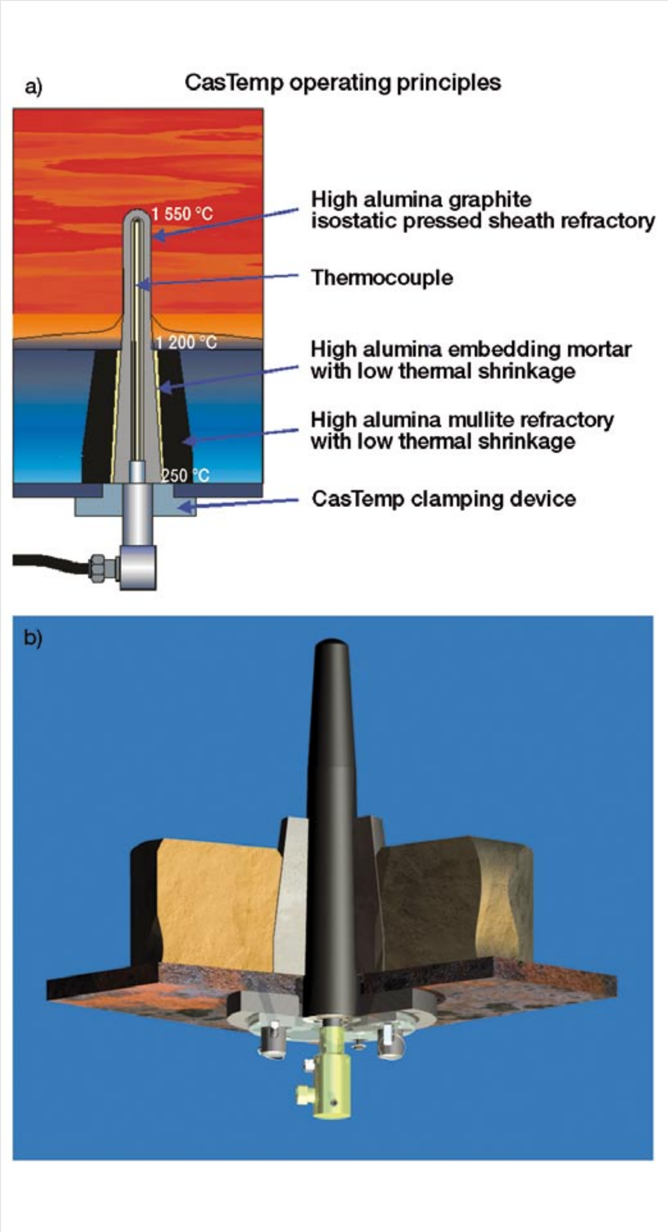
The measuring system consists of a disposable sensor which is replaced every tundish sequence and a reusable well block which is permanently mounted in the tundish lasting the lining campaign, plus instrumentation hardware. So the measured temperature relates to the steel that is exiting the tundish. Figure 5 shows the temperatures as measured through the refractory lining cross-section during a typical tundish sequence. The CasTemp and its Well Block are manufactured from materials which can be termed "technical refractories" and as such are much more refractory than the surrounding standard tundish lining materials.

Experience with the CasTemp system at Corus, IJmuiden has shown that the developed system allowed the plant to achieve the desired measurement as well as bringing the following advantages:

- A tundish temperature measuring system where the sensor measures close to the tundish outlet nozzles.
- A sensor, which measures the tundish pre-heat temperatures.
- A temperature measuring system, which requires minimal casting plant operator involvement saving manpower and ensuring safety.
- An applied measuring system requiring minimal changes to the existing plant.
- An accurate temperature signal within 90 s of opening the ladle.
- A temperature measuring system where the connection cables are located in a cool well protected area ensuring minimum damage and resulting in extended life.

The sensor measuring point should be as close as possible at the tundish outlet nozzle, so that the measured temperature relates to the steel that is exiting the tundish.

Figure 6 shows the sensor prior to and after 12 h sequence casting. Interesting is the very low sensor erosion and absolutely zero erosion around the sensor at the tundish wall spray gunning layer.



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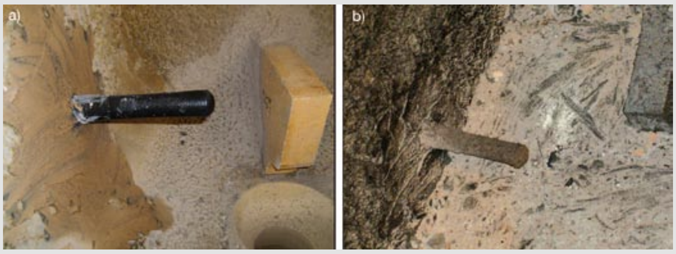
CasTemp sensor: a) surrounding refractory components, b) safty flange

CasTemp-Sonde: a) feuerfeste Umgebung, b) Sicherheitsverschluss



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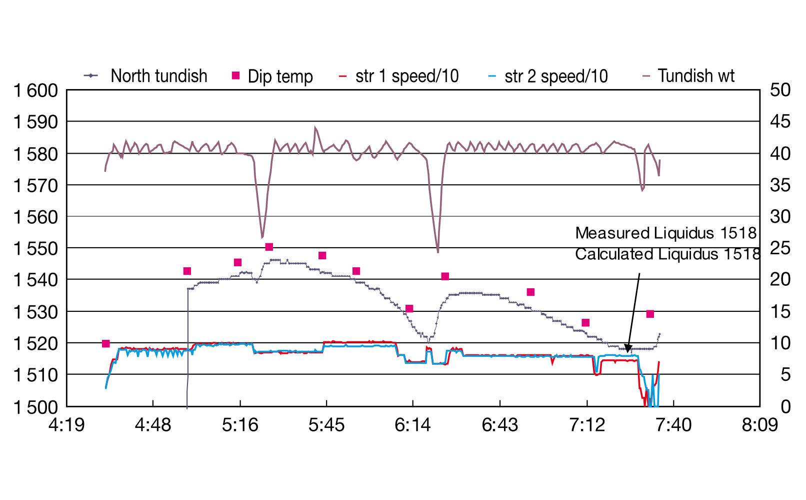
Sensor a) prior to and b) after 12 h sequence casting

Sensor a) vor und b) nach einer 12-stündigen Gießsequenz



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CasTemp and dip measurements

CasTemp-Kurve und Tauchmessungen im Vergleich

CasTemp is not a new temperature measurement. Under ideal circumstances it nicely coincides with the top immersed continuous and dip measurements. The overall advantage is that it eliminates human mistakes and corrects the assumption that the tundish temperature is homogeneous over its 3D dimensions. The "through-the-wall" system is foolproof and allows immediate, unquestioned accuracy, even during preheating, casting start-up and ladle changeover periods. In the upper chart the continuous trend of the CasTemp sensor indicates a potential risk of freezing already 30 min prior to ladle change, see middle blue line, whereas the dip measurement trend is less pronounced (pink squares). Liquidus temperature is shown (plateau) at the steel's freezing point at end of casting, figure 7. There are no handling, manipulation and exchange problems.

These characteristics make the through-the-wall system for many caster applications especially interesting particularly where there is high-speed casting, and casting different strand sizes from one tundish. Whenever it comes to "mixed" casting with different mould sizes or higher casting speed (e.g. thin slab), the tundish may no longer be regarded as a homogeneous vessel where an identical temperature prevails. The faster flow from ladle shroud through the lower tundish level to the moulds with high casting speed, and in case of "mixed" casting the preferential flow of fresh steel to the higher consuming, bigger mould creates a temperature difference either in respect to tundish level or tundish section. The through-the-wall measurement can play its advantage here, as it measures the temperature where it counts, i.e. at the tundish nozzle. This up to now widely unknown (or at least unmeasured) effect gives chance to avoid mould breakouts, and on the other side enables caster speed optimization. A major integrated steel shop of the ArcelorMittal group in the USA calculated an extra caster output of plus 100 000 t/a with this new technology.

A general view to this system comparison shows the Pro's and Con's of each one, figure 8. Highest technical standard has its price. However the savings of each individual caster may by far justify this. The data assumes a scenario with casting sequence of 10 · 200 t ladles. The cost reflects the relevant sensor prices and service lives.

Summary

Modern thermocouple-based continuous temperature measurement systems are the industrial standard of today combining accuracy and economy. Reaching from a highly economic reusable, through most flexible to top accurate systems, continuous temperature measurement has found its way to many continuous casting machines. They fulfill all the modern demands on automation, safety and maximized caster output. Continuous control for a continuous process, whereas the batch processes of primary and secondary steelmaking do not have a problem with a spot measurement on demand. Optical systems continue to be on the move, but still suffer from the one or the other drawback to be solved.

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System type	Response time from RT to 1 550 °C	Accuracy	Investment cost	Operational cost per t of steel cast
Contitherm	4.5 min	2°	3 000 – 30 000 € *	0,05 €
Contilance	1.5 min	2°	2 000 €	0,06 €
CasTemp	1.5 min	1°	1 000 €	0,09 €

* The wide range of investment cost for Contitherm is due to cost variation for installed immersion system (manual, automated)

8

Data comparison of thermocouple-based continuous measuring systems

Typische Betriebsdaten der verschiedenen kontinuierlichen Messsysteme