Advanced sensoring systems for improved control of casting operation

Kersten Marx
VDEh-Betriebsforschungsinstitut GmbH
Sohnstraße 65
40237 Düsseldorf
Germany

Research Fund for Coal & Steel

Sensoring for improved process control

General Aim

Evolution of measuring instrumentation and control system tools to increase the performance of the continuous casting process in terms of:

- Safety
- Energy and raw material savings
- Reduction of defect occurence on the final product

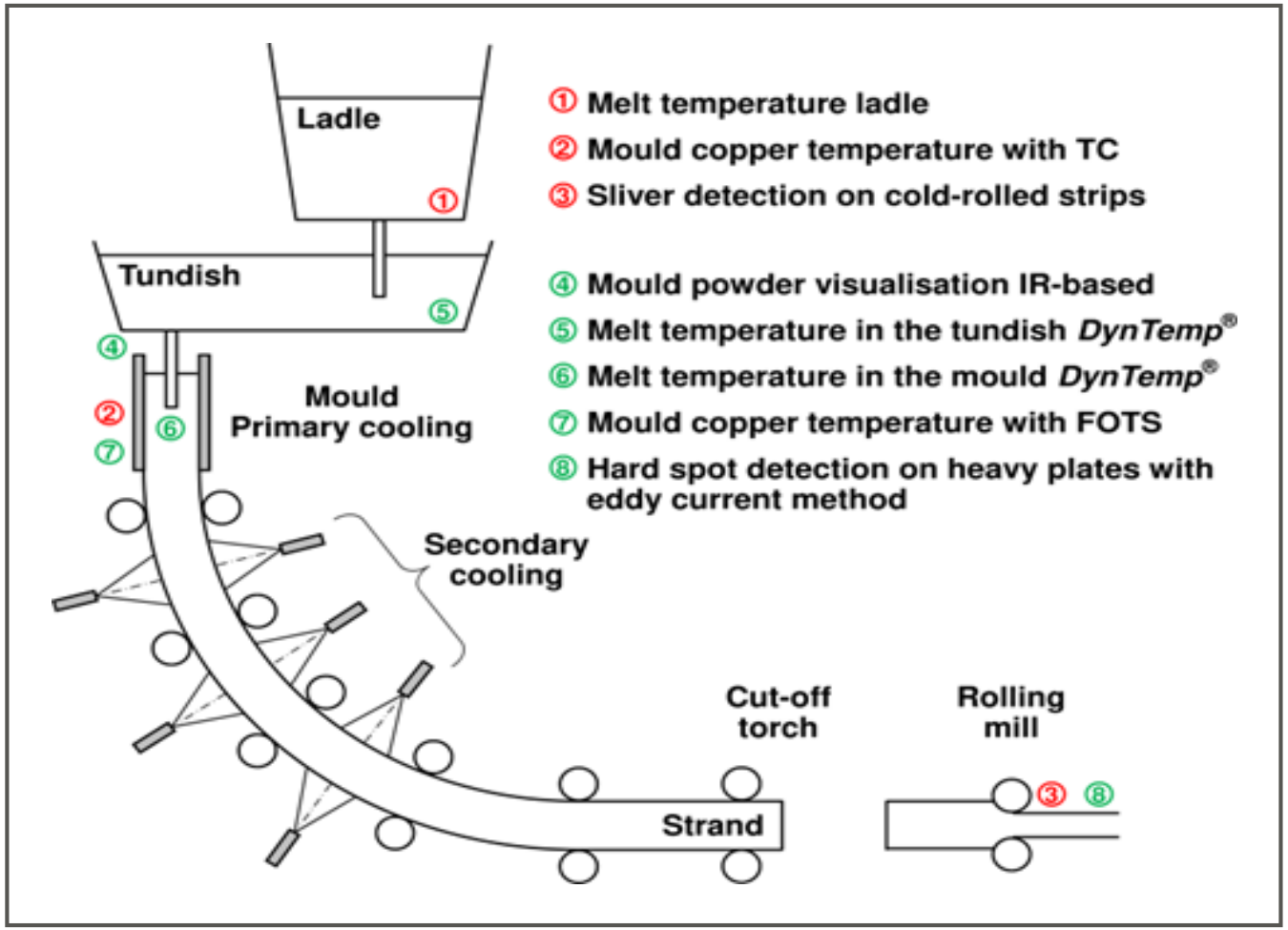
Sensoring for improved process control

New tools to optimize process control

- Temperature measurements in the mould copper and in the melt
- Continuous observation of the mould powder surface and derivation of its influence on melt temperature as well as lubrication and with it on surface quality
- Innovative measuring techniques for the detection of defects
- Enhanced data processing based on Big Data technologies to exploit various and heterogeneous existing and new data from ladles down to quality supervision in real-time

Sensoring for improved process control

Measuring locations RFCS-project RealTimeCastSupport



Sensoring for improved process control

Possible outcome RealTimeCastSupport

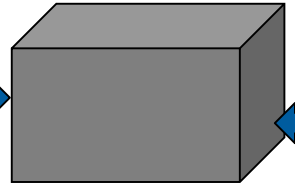
- Track the thermal field at top of the mould, mould steel level and mould powder layer thickness
- Effect of manual powder feeding and meniscus level oscillation on the mould temperature
- Identification of irregular casting conditions with particular reference to mould powder feeding, slag rim formation and irregularities in initial solidification
- Development and operation of a better control of the initial solidification at meniscus level to enhance surface quality of as-cast products

Mould powder monitoring

IR Camera Measurement of mould powder cover

Image analysis system

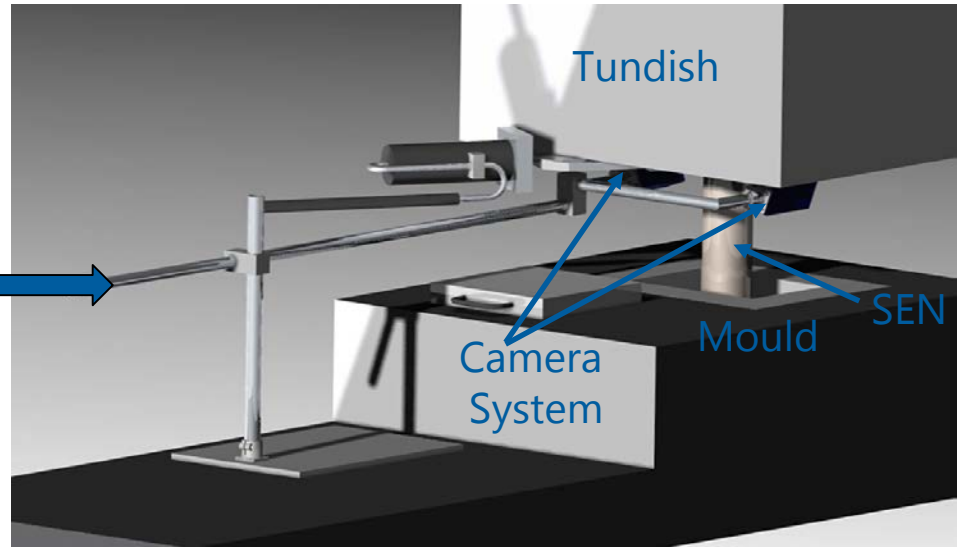
Supply box



- Image acquisition from camera
- Analysis of images
- Extraction of important information, e.g. starting point, frequency and intensity of mould powder break-up
- Display of results on screen
- Transfer of results to the project data base

› Supply of:
  - › Data transfer
  - › Power to cameras
  - › Cooling gas

Monitoring system for casting powder cover

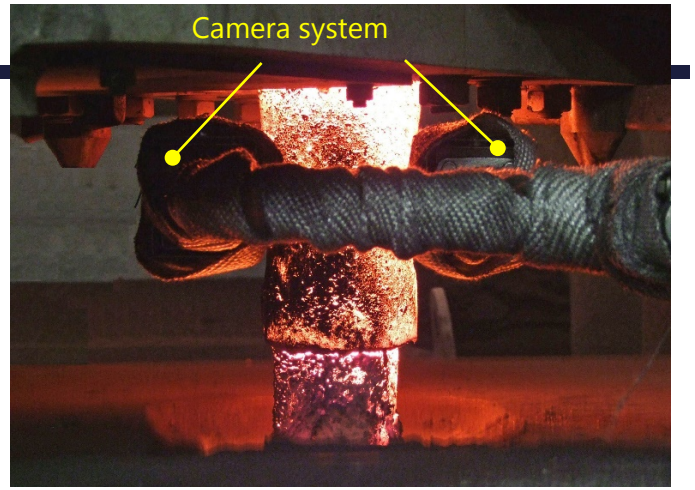


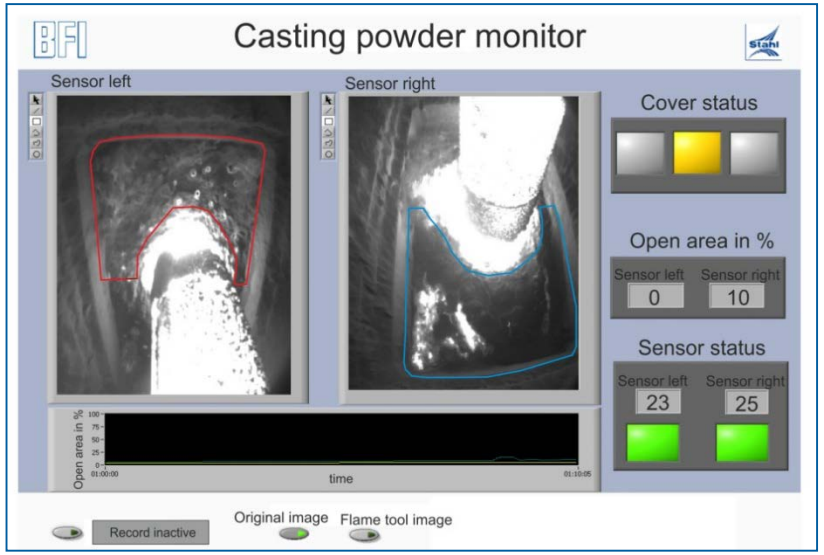
- › Camera with IR sensor to monitor the thermal radiation of the mould powder surface
- › Protective housing to protect camera against harsh environment

Mould powder monitoring

Description of mould powder monitoring system

- Camera system:
  - Two IR cameras suggested for optimum view due to SEN
  - Selection of camera based on requirements, e.g. resolution, connections (reduce amount of cables), size
- Supply box:
  - Can be equipped with automatic control of cooling gas flow depending on T in camera protection housing
- Image analysis:
  - Mould powder coverage is analysed continuously
  - A warning system automatically identifies insufficient mould powder coverage and instantly informs the operator via optical traffic light signals





Images taken from a previous project (Transient, RFSR-CT-2009-00005)

FOTS measurements in mould copper

Features of Fibre-Optical-Temperature-Sensors (FOTS)

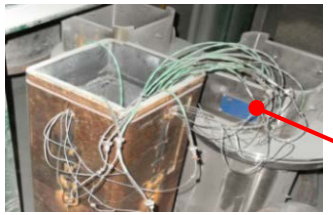
FOTS

- Not influenced by electro-magnetic fields
- Less influence of water flow
- Less access points per mould plate
- Geometrically free positioning of up to 20 temperature sensors in one fibre
- Multiple usage possible

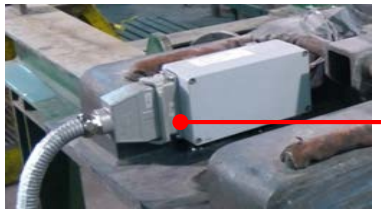
Mould instrumentation

Possible use

- Early detection of disturbances in strand shell formation
- Evaluation of the homogeneity of heat transfer
- Avoidance of breakthroughs
- Control of the meniscus level



Cable bundle
15 thermocouple



FOTS application with
40 measuring points.

FOTS measurements in mould

Example: Fixed installation at the billet mould

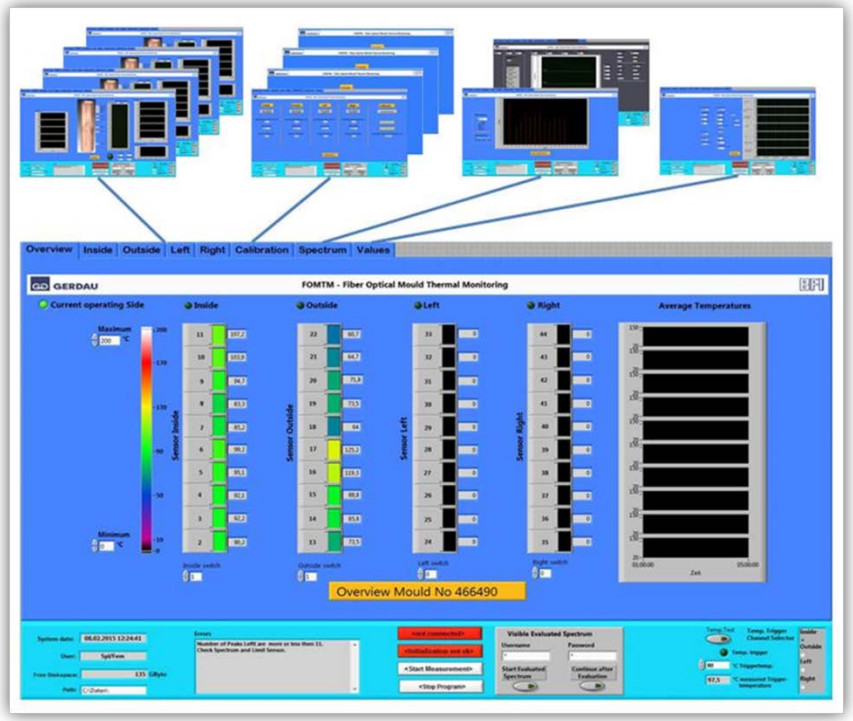
Mould tube, grooves at all four faces

Sealed FOTS in the meniscus region

4-channel feed through, pressure-proof

Instrumented mould ready for casting

Industrial plug, 4-channel, each 10 FOTS



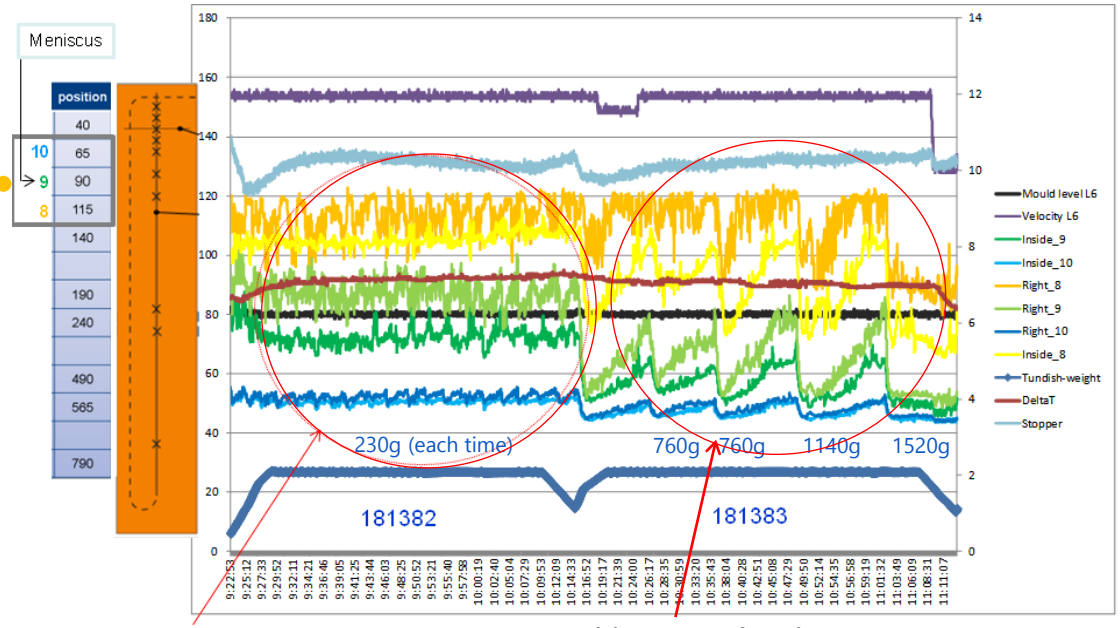
Graphic user interface

FOTS measurements in mould copper

Examples:

› Variation of mould powder amount

- Measurements at the meniscus area (point 8-10, inside and right face)



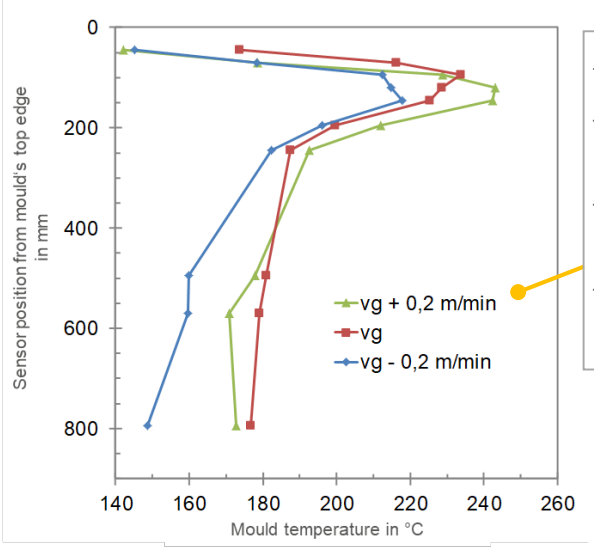
Higher frequency of additions

- Temperatures nearly steady
- Saw tooth structure - less

Higher amount of powder

- Temperatures oscillating
- Saw tooth structure – strong
- Meniscus moves up and down

› Effects of changes in casting speed



- Meniscus level 90 mm below top edge of mould
- Correlation between temperature maximum and casting speed (vg)
- Strand shell detachment at a casting speed decrease of 0.2 m/min
- Marginal influence of increase of casting speed to the heat balance in the lower mould area

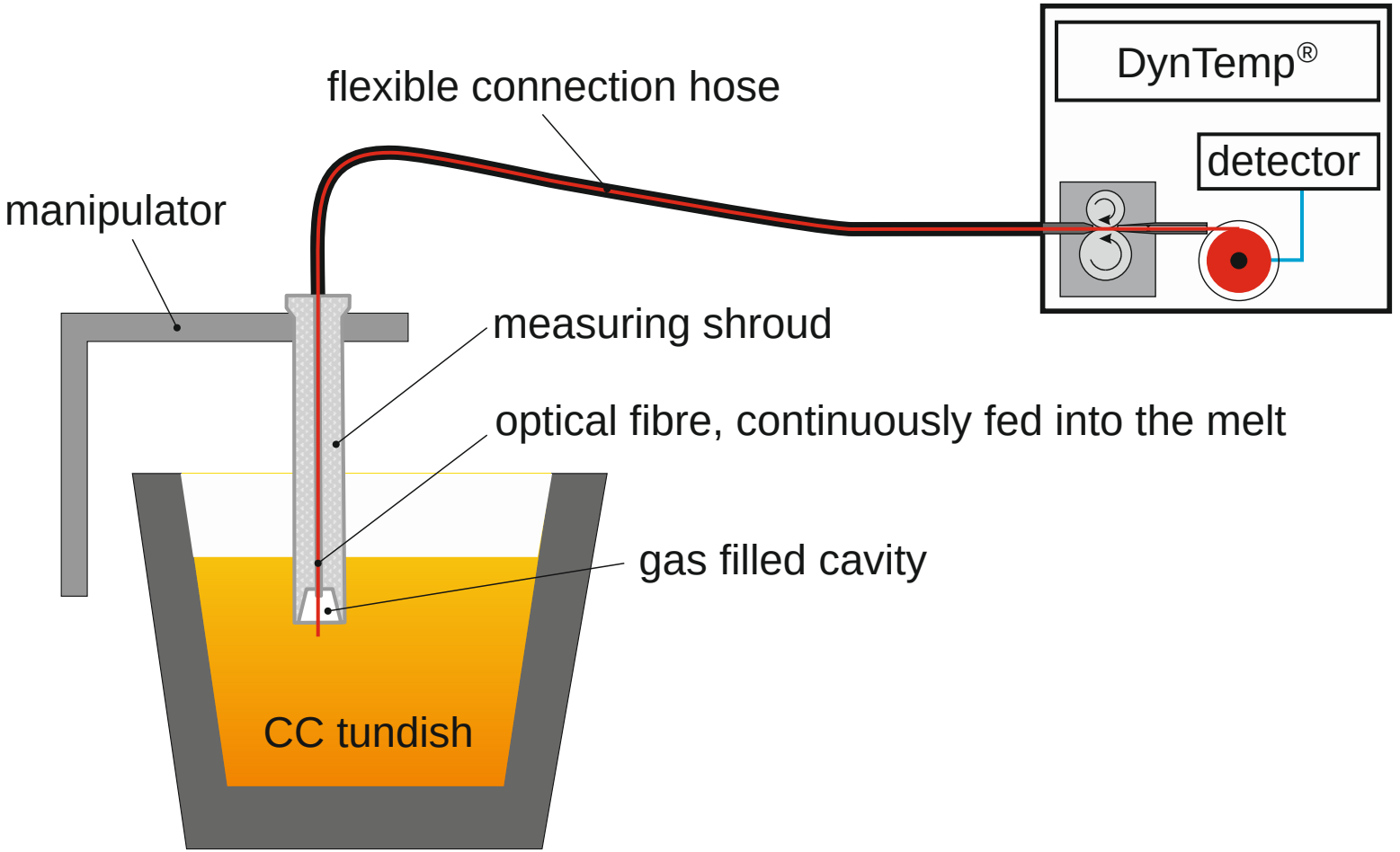
Fibre Optical Temperature Sensors

Results RFCS-project FOMTM

- FOTS pilot installation has demonstrated that this technolgy can survive under the harsh environment conditions of a caster and withstand the revamping procedure.
- Relationship between events and the surface quality of the product has been observed.
- Strategies for optimized casting powder addition and corrective actions for assurance of a better quality of as-cast products were derived.

DynTemp®

Continuous Temperature Measurement in the Melt



Detection of surface defects

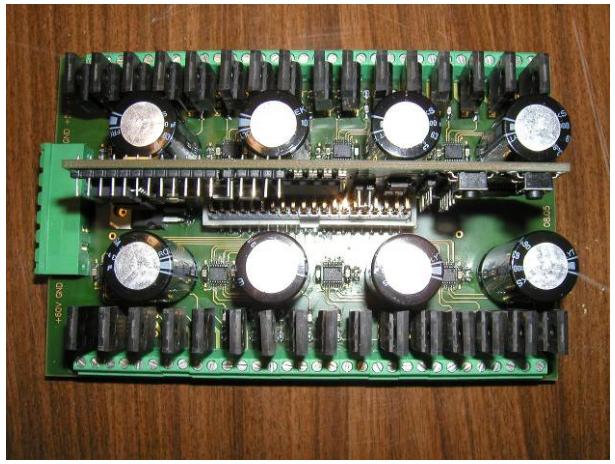
Objectives RFCS-Project NDTCasting

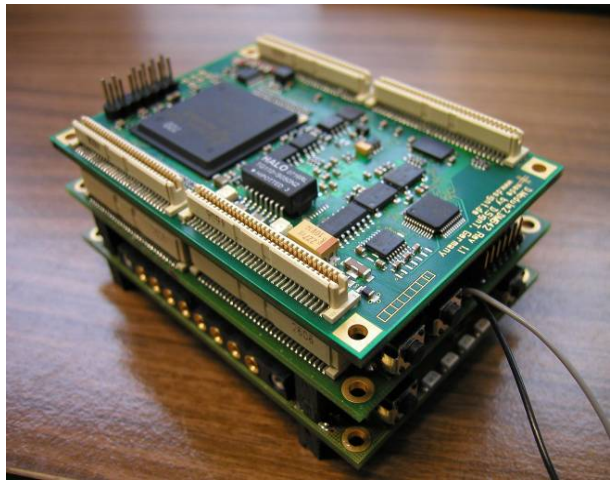
- Development of the **EMAT-EMAT system** for generating and receiving ultrasound designed as Phased-Array-probes.
- Development of the **Laser-EMAT** technology to inspect steel above the Curie point.
- Development of the **Conoscopic Holography** (CH) system to be extended to cover 100% of both top and bottom faces of the slab, at high temperatures in the production line.
- Development of ultrasound signal processing and software for B-scan interpretation.

EMAT = **E**lectro**m**agnetic **A**coustic **T**ransducer

Detection of surface defects

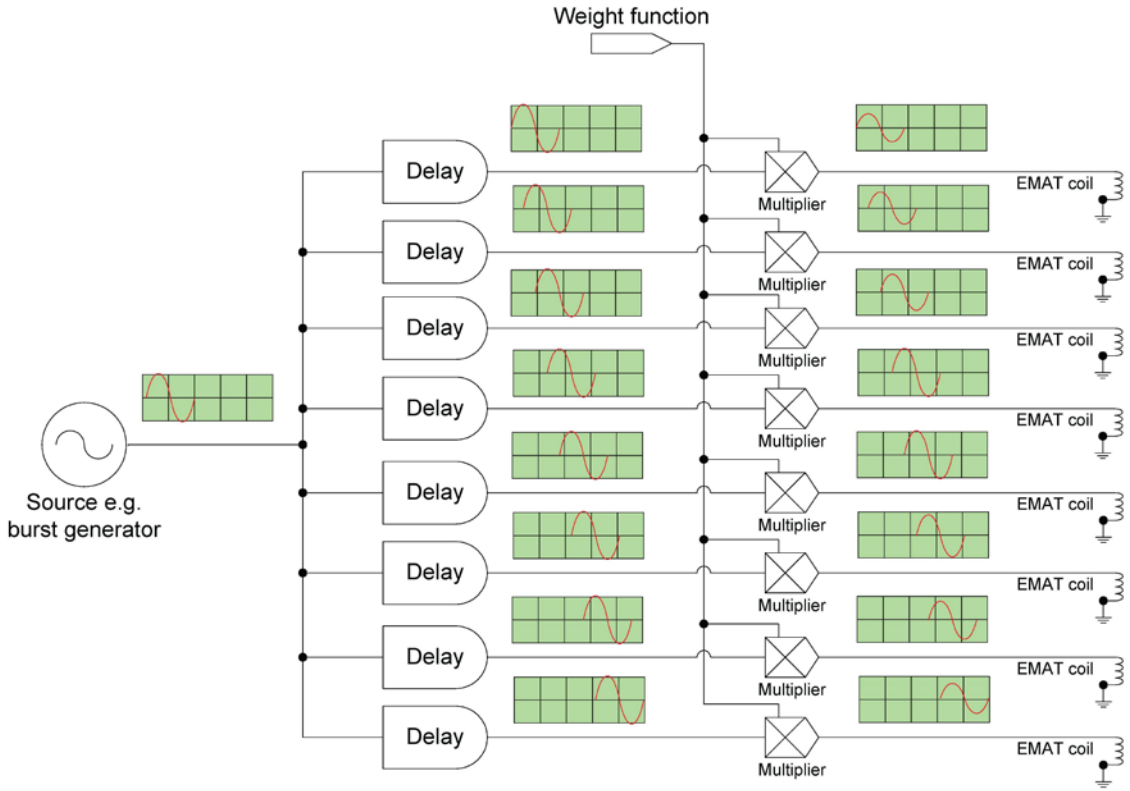
Phased-Array EMAT-EMAT System





Transmitter and receiver unit

The Phased-Array transmitter probe consists of many small elements, which can be pulsed separately and emit pressure waves which interfere.

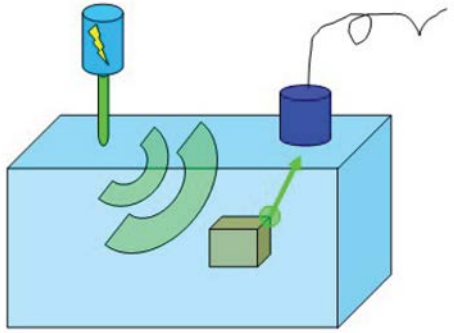


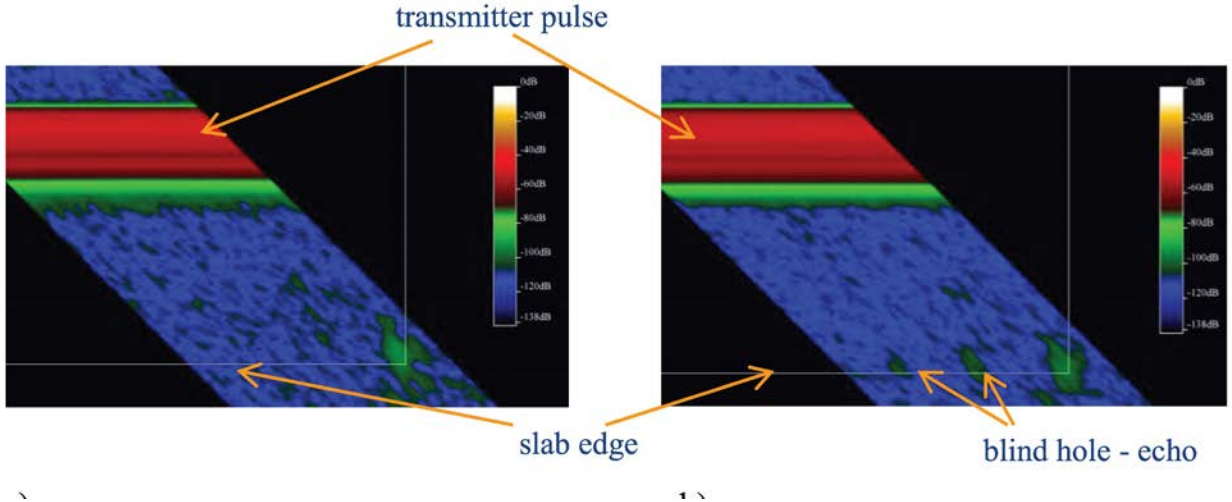
Principle of Phased-Array EMAT transmitter

Detection of surface defects

Phased-Array EMAT-EMAT System

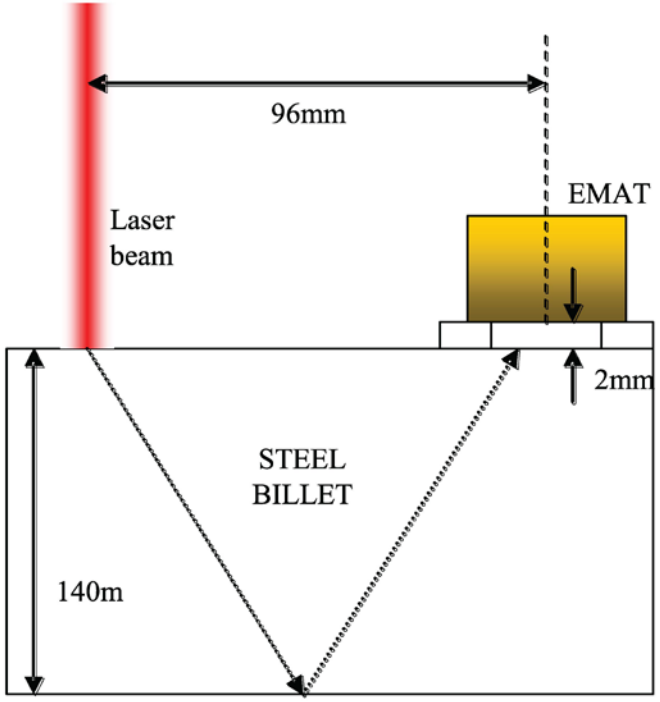
With the EMAT-EMAT-technique it is possible to detect surface and subsurface defects on-line at high temperatures (below the Curie point) with a high sensitivity for a relative low price under harsh industrial conditions



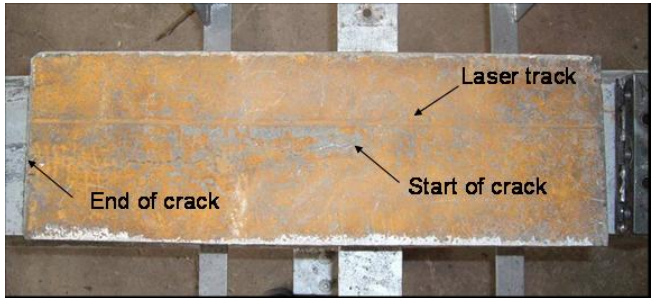


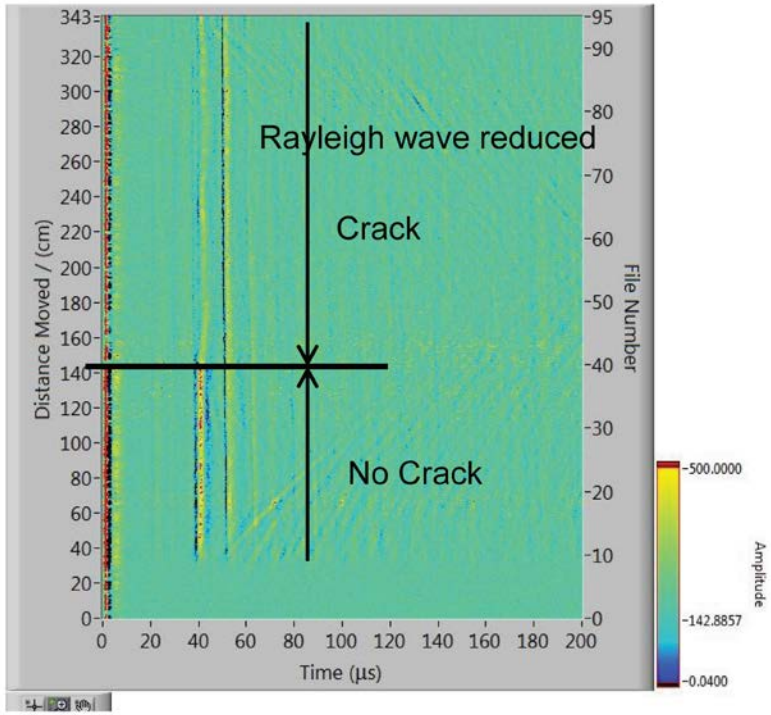
Detection of surface defects

Laser-EMAT



A prototype was developed. The system has been proved in the lab on cold samples. Hot trials have been of limited success.

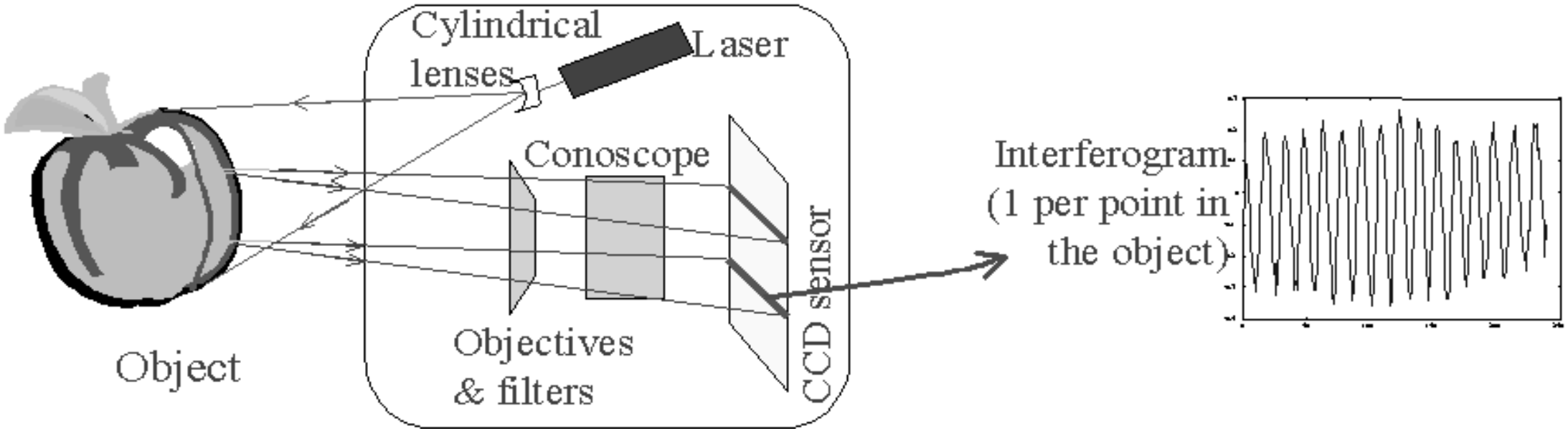




Principle of Laser-EMAT
Laser is used as a broadband US source.

Detection of surface defects

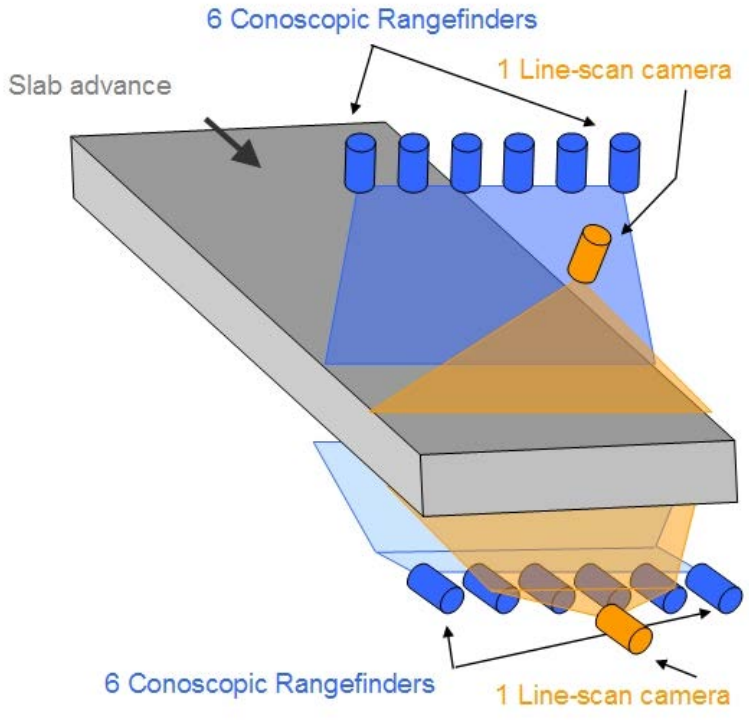
Conoscopic Holography

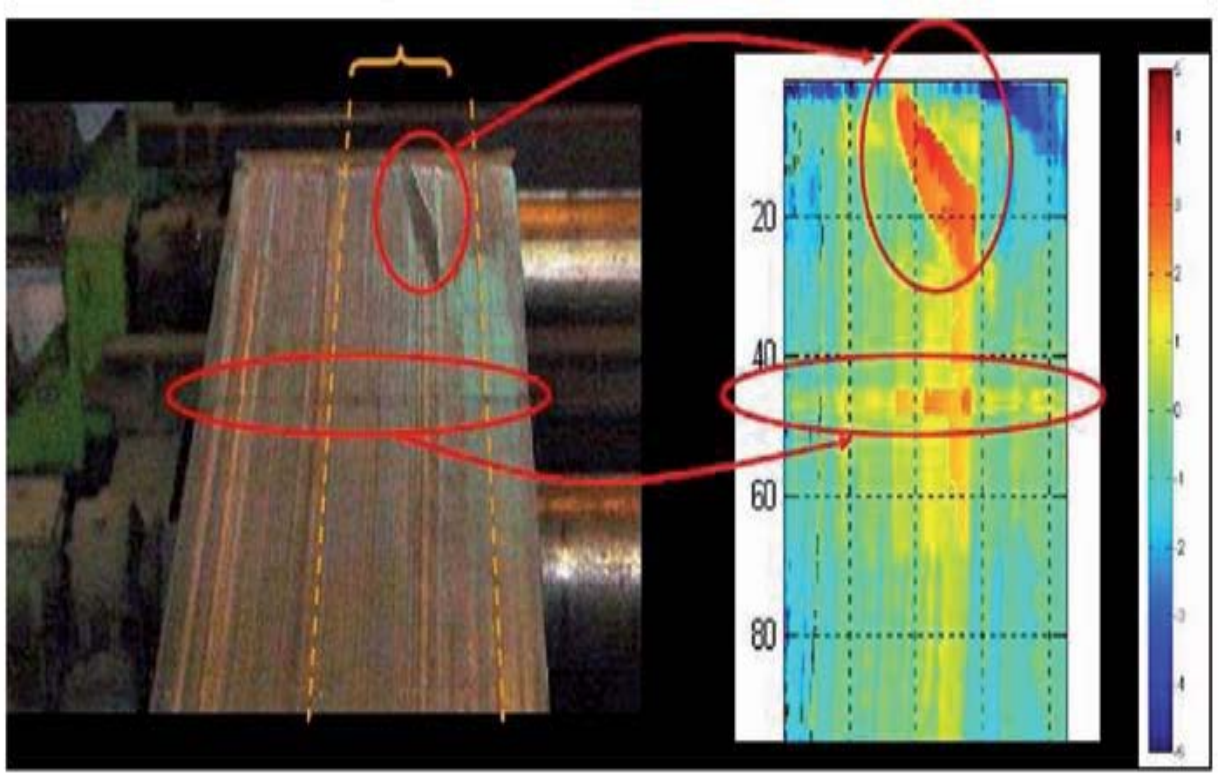


Principle of Conoscopic Holography:
Incoherent light interferometry,
Interference pattern is captured by a CCD camera

Detection of surface defects

Conoscopic Holography



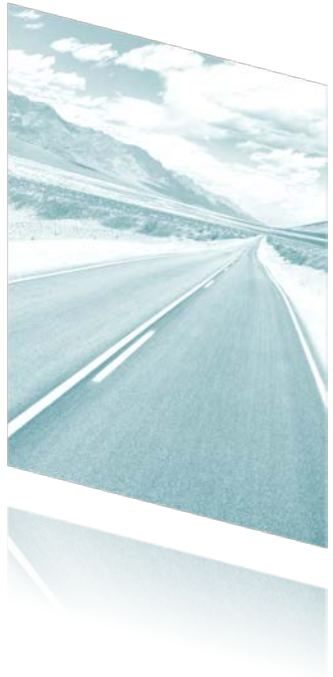


Very thin and zigzag cracks can be reliably detected. Internal defects cannot be found.

Conclusion

These innovative measuring techniques should be further developed:

- Continuous temperature measurement in tundish and mould
- Control of melt flows
- Monitoring of mould powder layer
- Measuring of temperature in mould copper walls
- Monitoring of spray cooling
- Measuring the temperature of the strand surface
- Detection of defects



Thank you for your attention!

Questions?

Contact: kersten.marx@bfi.de