Development of caster instrumentation at the Materials Processing Institute

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Introduction

A number of techniques have been developed by the Materials Processing Institute as part of European supported projects:

- Surface profile measurements
  - Off-line in slab yard
  - On-line in slab top-zone
- End-plate inclinometers for measuring mould taper
- Strand speed measurements
- Movements of caster structure
  - Caster back bone
  - Segments
- Steel flow visualisation

Surface profile measurements

As-cast product surface is variable

- Steel grade
- In-mould conditions
- Machine condition

Measurements of surface profile can give quantitative information about surface quality

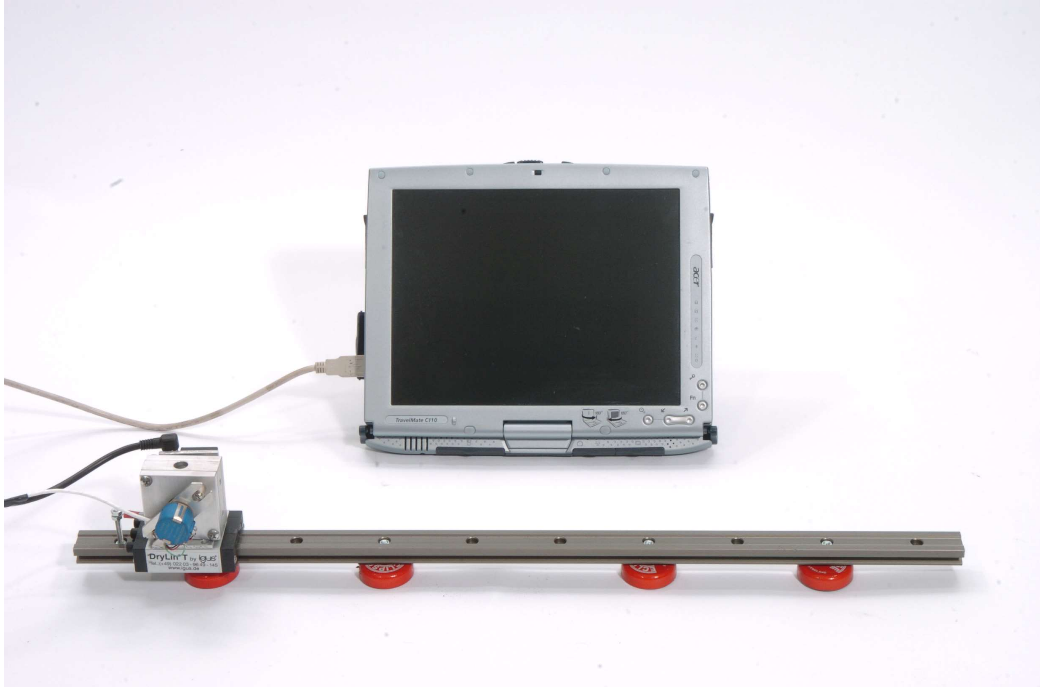
Devices developed to measure surface off-line

- Automated with motorised stages – heavy, difficult to use
- Manual lightweight system for fast data acquisition

Off-line profile measurements

Measurement device

- Simple, easy to use, manual measurement device
- Laser rangefinder mounted on slide mechanism
- Wire-pull potentiometer to measure horizontal distance
- Magnetically fixed to product
- Data recorded to tablet PC
- Stores surface profile and measures oscillation marks



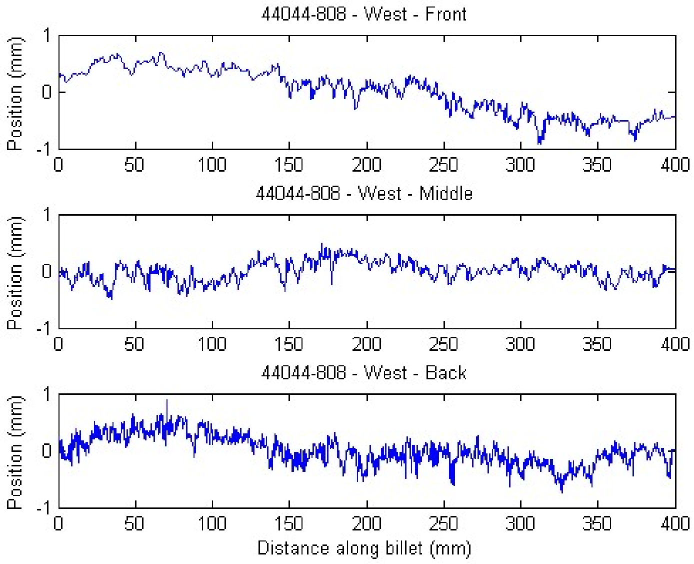
Off-line profile measurements

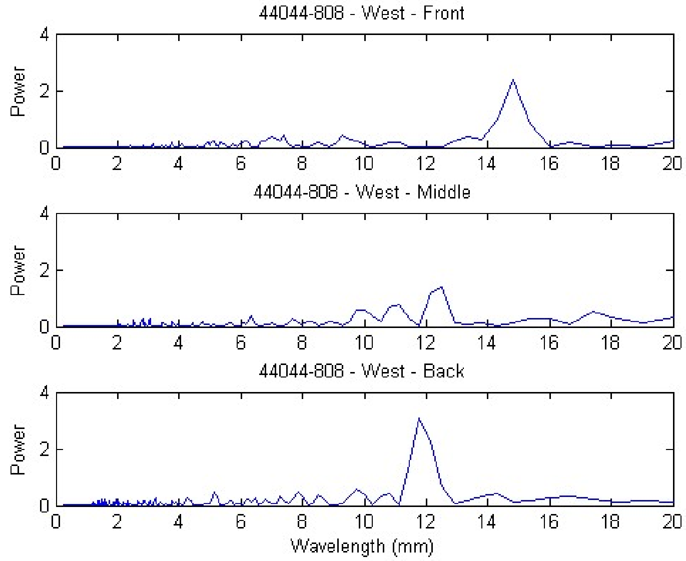
Billet surface profiles

Often difficult to see individual oscillation marks

Very variable even on the same billet

Some information can be extracted – frequency, variability





72 cpm

90 cpm

Off-line profile measurements

Slab surface profiles

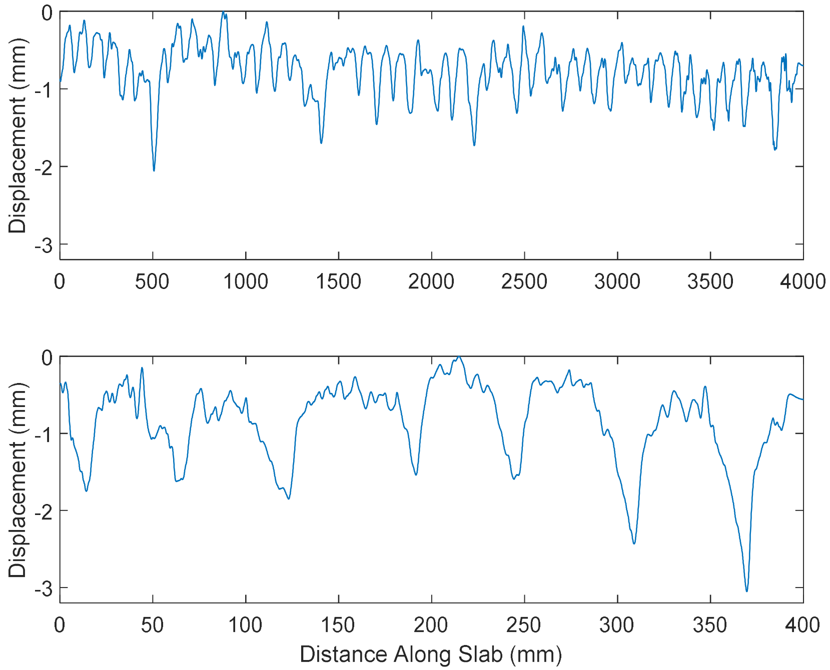
Slabs usually have much better defined oscillation marks

0.5mm to 1mm deep at pitch related to mould oscillation frequency

Some slabs show much deeper 'oscillation marks'

Up to 3 mm deep at 50mm to 100 mm pitch

Associated with uneven shell shrinkage



On-line profile measurements

Slabs with deep 'oscillation marks' tend to have increased mould level deviations

Off-line profile measurements were taken on side of slab – top and bottom faces much smoother

Similar troughs should be present on broad faces but are not usually visible – they may be rolled out during soft reduction and straightening/withdrawal

On-line surface profile measurements taken in top zone of caster to see if broad faces show similar troughs

Simple contacting probe designed and applied on-line

On-line profile measurements

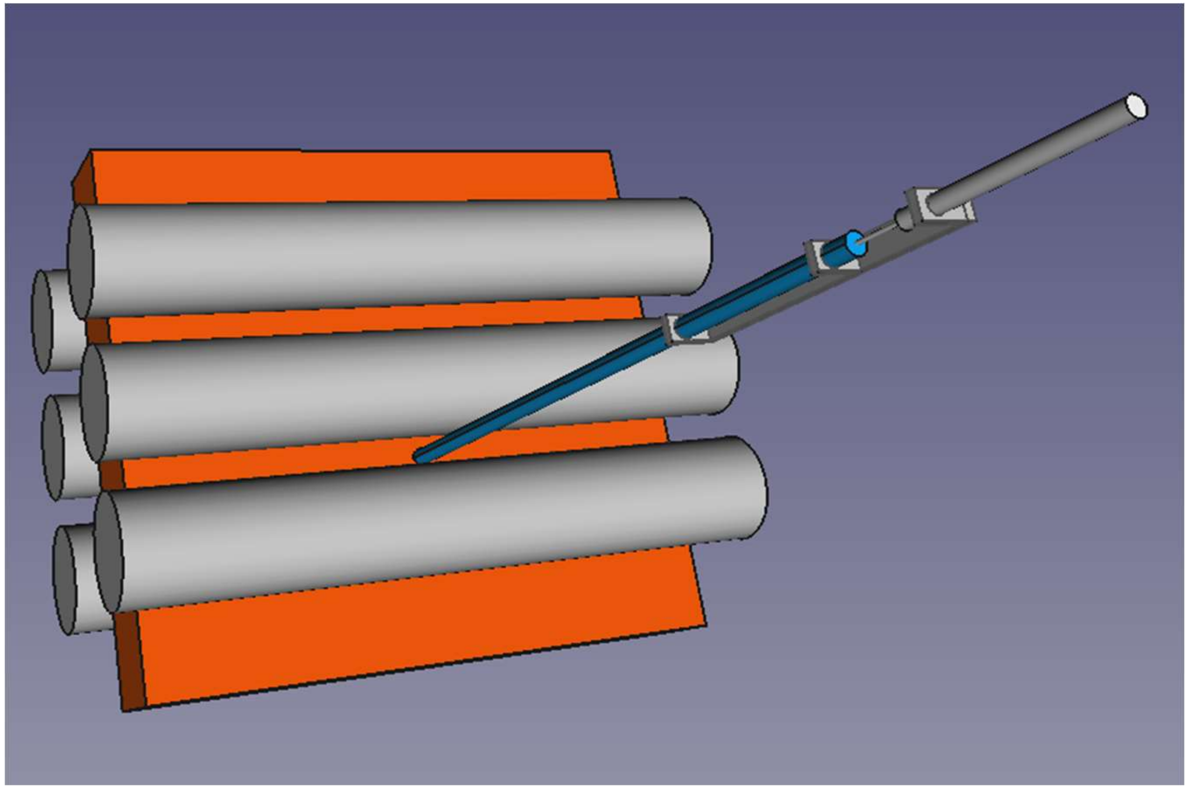
Surface probe

15mm roller ball welded to end of stainless steel pole

Spring loaded against slab surface in top-zone

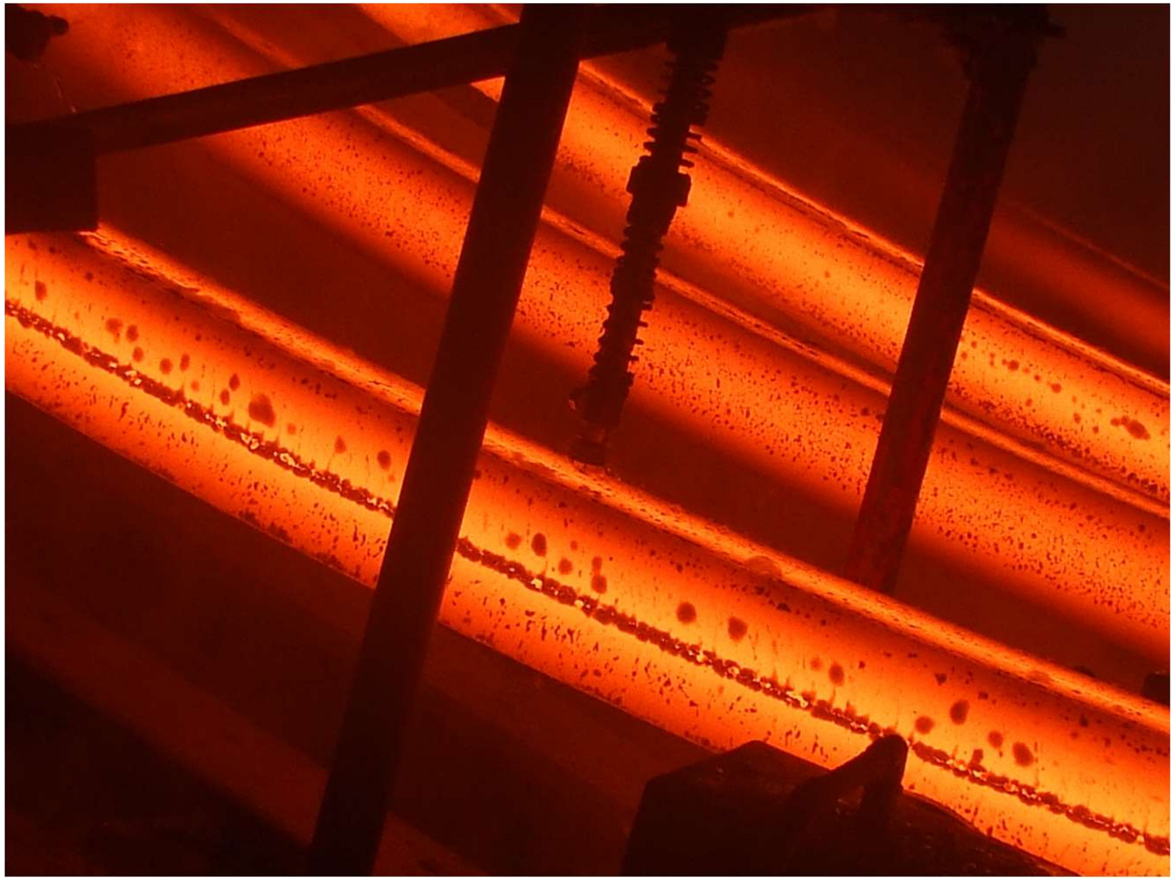
LVDT spring loaded against top of contact probe

Two probes at different heights



On-line profile measurements

Similar probe in use on billet caster



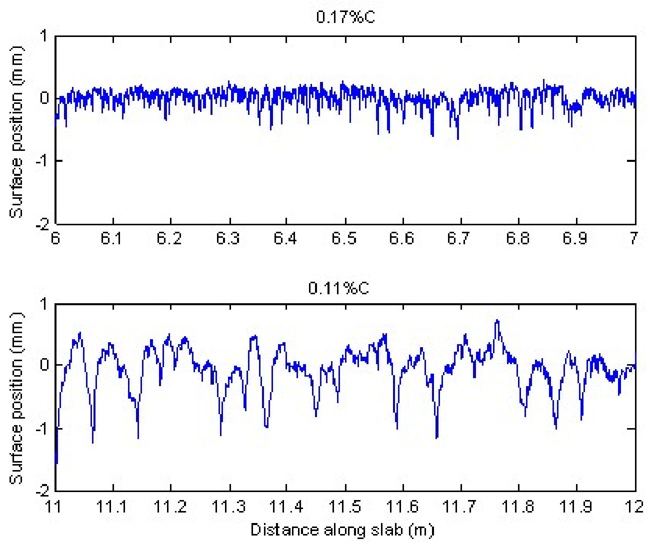
On-line profile measurements

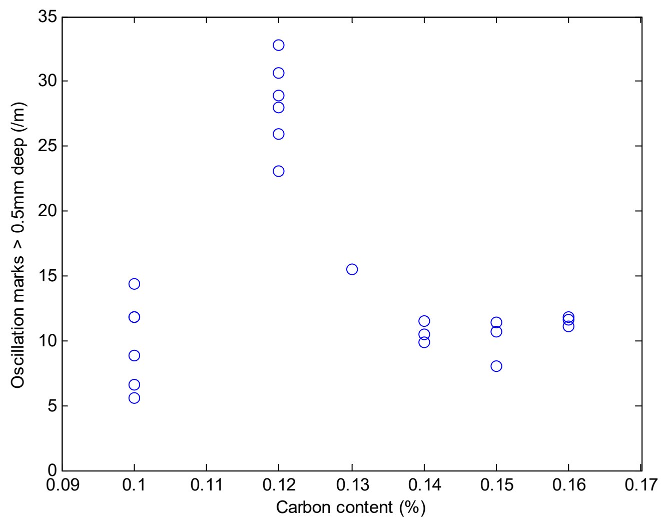
Surface probe results

Measurements indicate surface troughs in broad face

Repeatable between two probes at different heights

Frequency of deep marks related to carbon content





On-line profile measurements

Surface-roll interaction

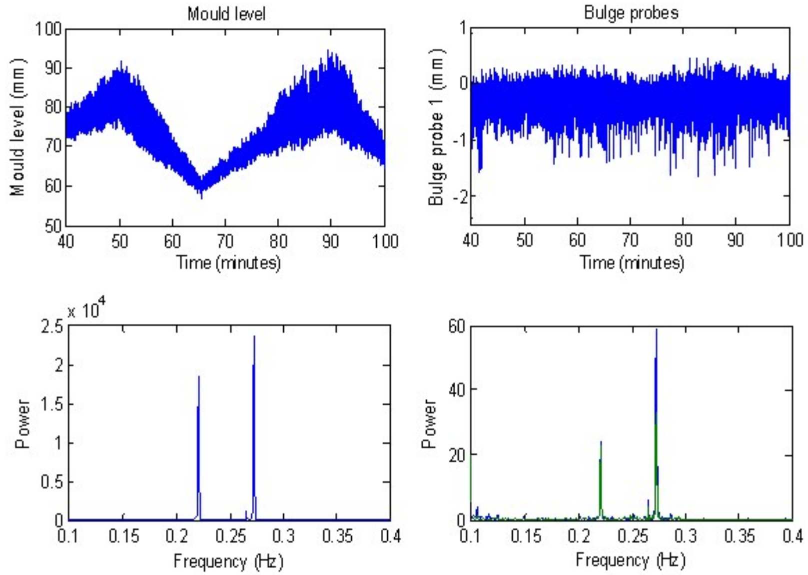
Period with poor level control and irregular surface

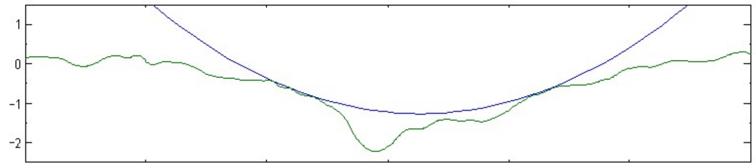
Same frequencies present in both surface and mould level measurements

Two possibilities as ‘trough’ passes roll:

- Gap forms between roll and steel shell
- Steel shell moves out to contact roll

If the shell moves out, the internal strand volume changes → mould level change





End plate taper measurement

- Mould taper is an important parameter on casters
- Taper is typically set and measured using templates or inclinometers
- For width adjustable moulds, continuous taper measurement is provided based on adjustment cylinder position
- Cylinder position is not necessarily an accurate indication of taper
- Inclinometers have been installed on mould end-plates to measure taper on-line
- Multiple inclinometers can be used to measure taper at different positions on end-plate

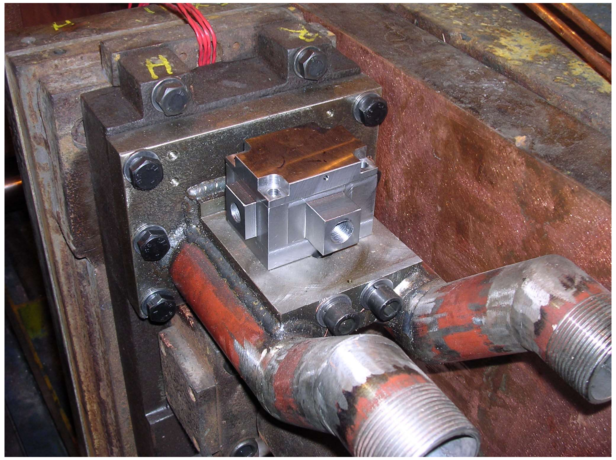
End plate taper measurement

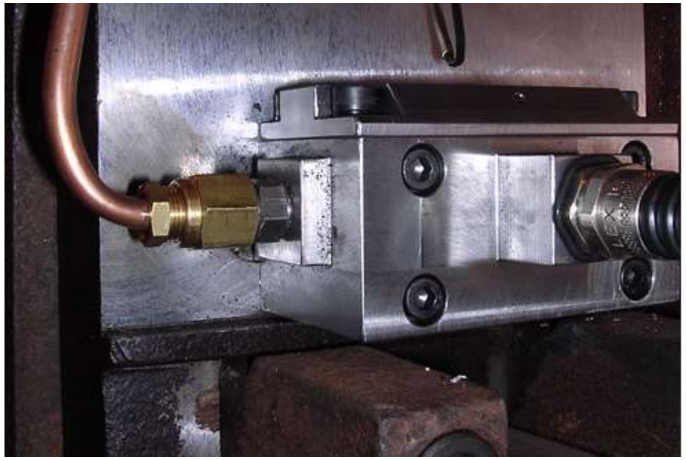
Inclinometer installation

Force balance type inclinometer with low range (+/- 1°)

Water cooled machined housing for protection

Securely bolted to mould backing plate





End plate taper measurement

On-line inclinometers

Two inclinometers, near top and midpoint of mould endplate

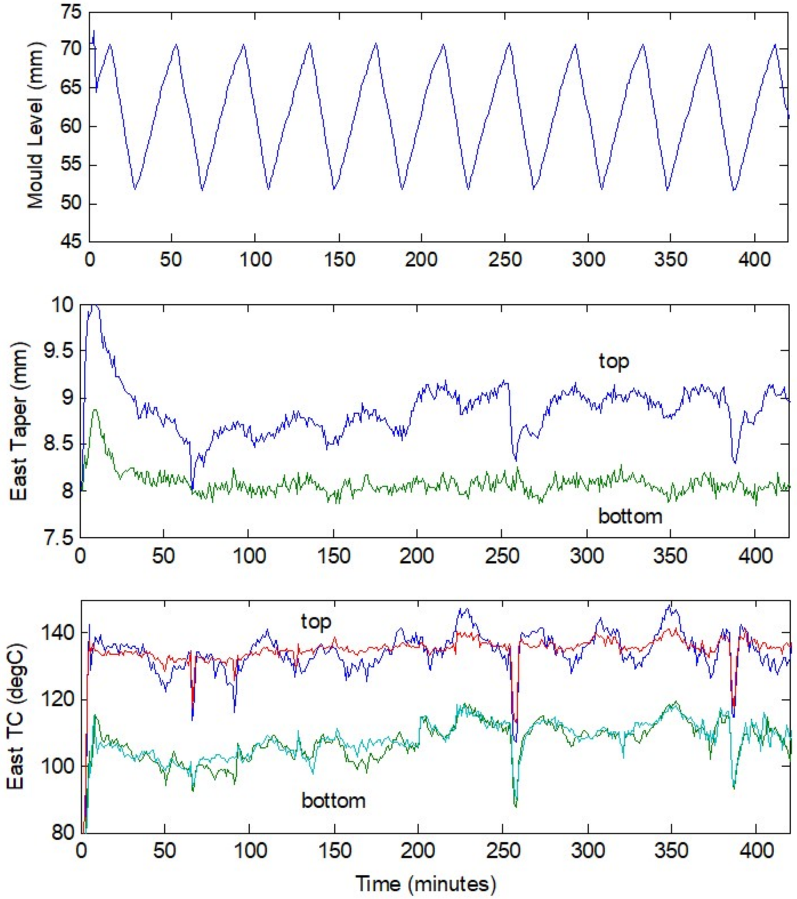
Taper increases at start of cast

Measured taper (top) changes as mould level setpoint is ramped

Mould temperatures also change

Step changes at 250 and 380 minutes correspond to speed changes

Mould plate bends with changing temperatures, affecting taper

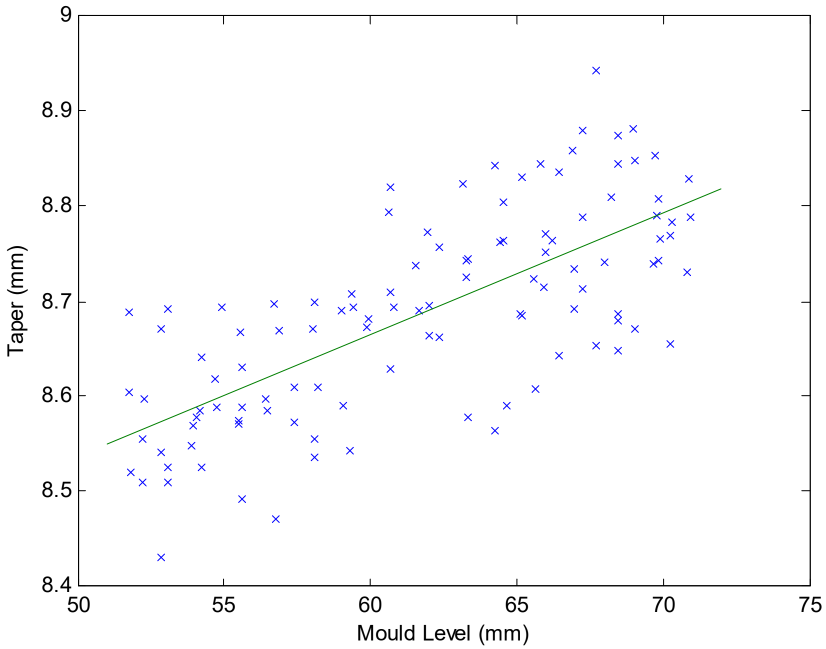


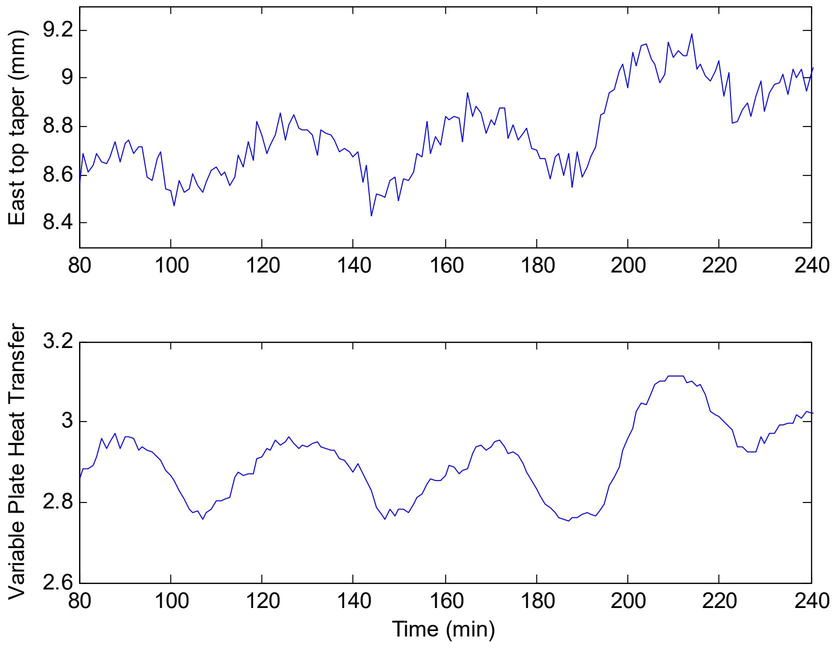
End plate taper measurement

On-line taper measurements

Taper increases with mould level

Strong correlation between taper and heat transfer





Strand speed measurement

Strand juddering is often seen on casters

Strand speed varies at mould oscillation frequency

All casters affected to some degree depending on:

- Mould taper
- Casting speed
- Steel grade
- Oscillation parameters
- Lubrication
- On-line width changes

Speed measurements can be made using laser velocimeters or encoders on non-driven rolls

Strand speed measurement

Speed fluctuations

Measurements with encoder on non-driven withdrawal roll

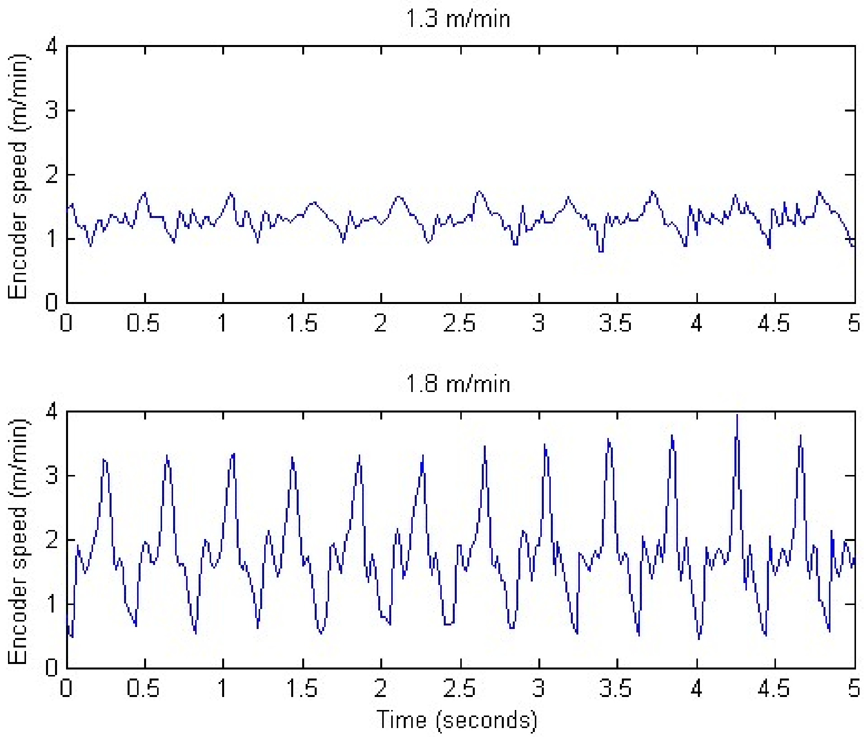
Billet caster with open teeming

Speed varies during mould oscillation cycle

0.5 – 3.5 m/min at 1.8 m/min

Strand almost stops during up stroke of oscillator

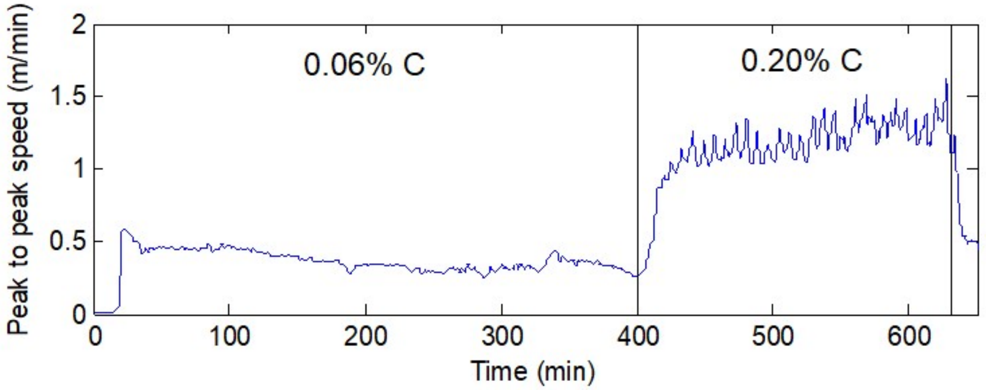
Reduced speed fluctuations at lower casting speed

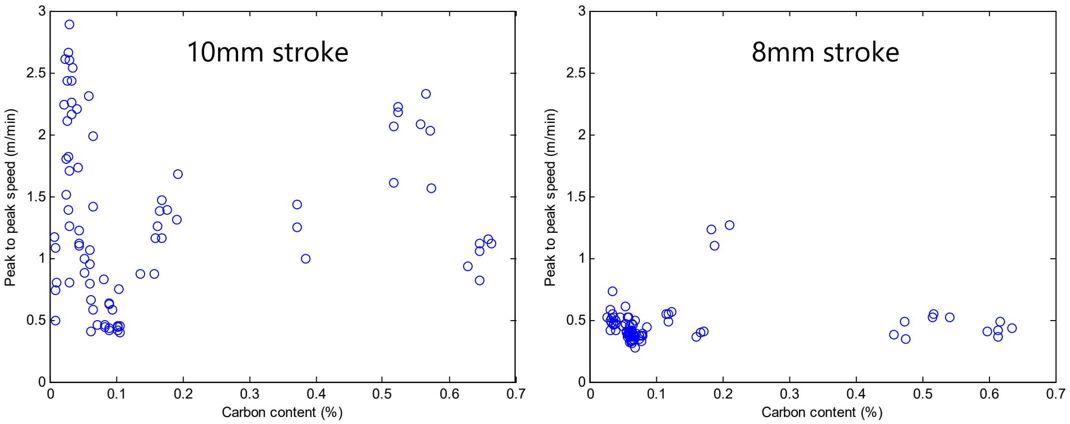


Strand speed measurement

Speed variation

- Peak to peak speed variation indicates juddering
- Mixed zone cast shows increased fluctuations at higher carbon
- Peak to peak fluctuations vary with carbon content
- Minimum around 0.1% carbon
- Reducing oscillation stroke reduces peak to peak fluctuations





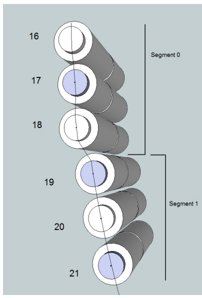
Strand alignment

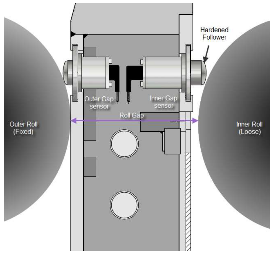
Strand condition monitor

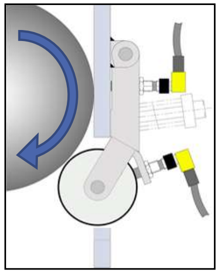
Accurate machine alignment is vital for good internal quality

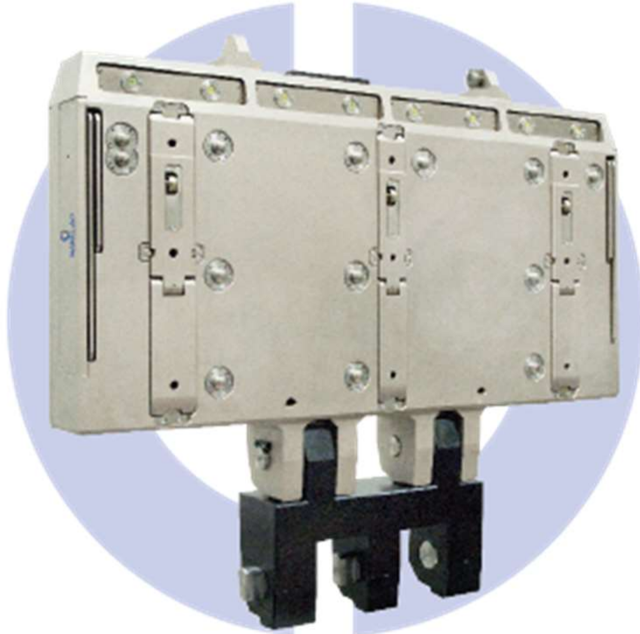
Strand condition monitors (e.g. Sarclad SCM) are used extensively for off-line measurements

- Roll gap
- Outer roll alignment
- Roll rotation
- Water cooling
- Outer roll condition
- Roll bend







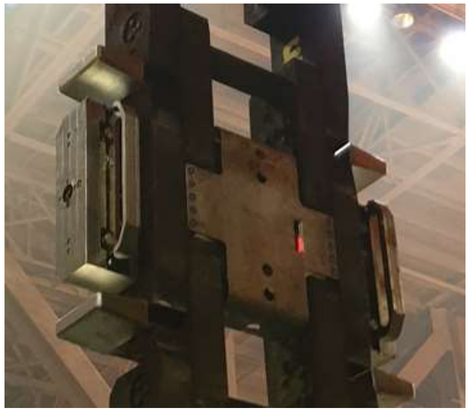


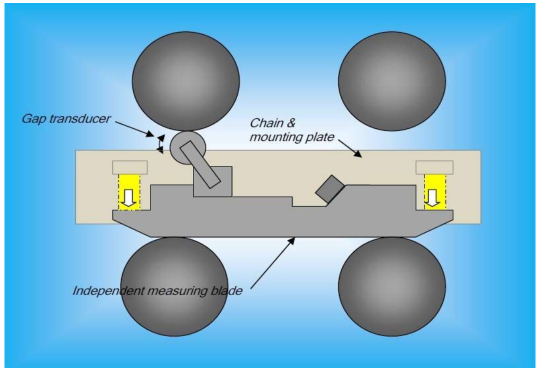
Strand alignment

Strand condition monitor

Mounted on dummy bar chain between sequences

- Prediction of failures
- Maintenance planning
- Quality assurance





In-chain device gives reduced set of measurements at start of every sequence

Use in combination with full gap head

Strand alignment

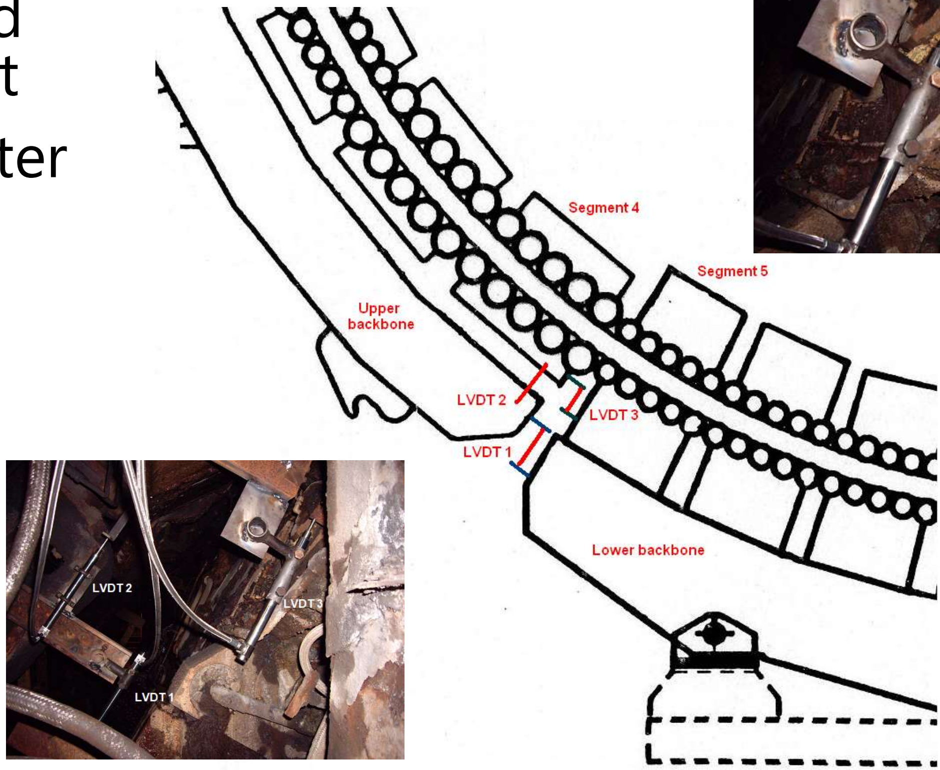
Movements of caster structure

SCM measures alignment without steel

Structure can move with load and temperature, changing alignment

Measurements taken on slab caster with 2 piece backbone structure

LVDTs used to measure
- Movement between upper and lower backbone
- Segment movements relative to backbone
- Segment movements relative to each other



Strand alignment

Movements at start of cast

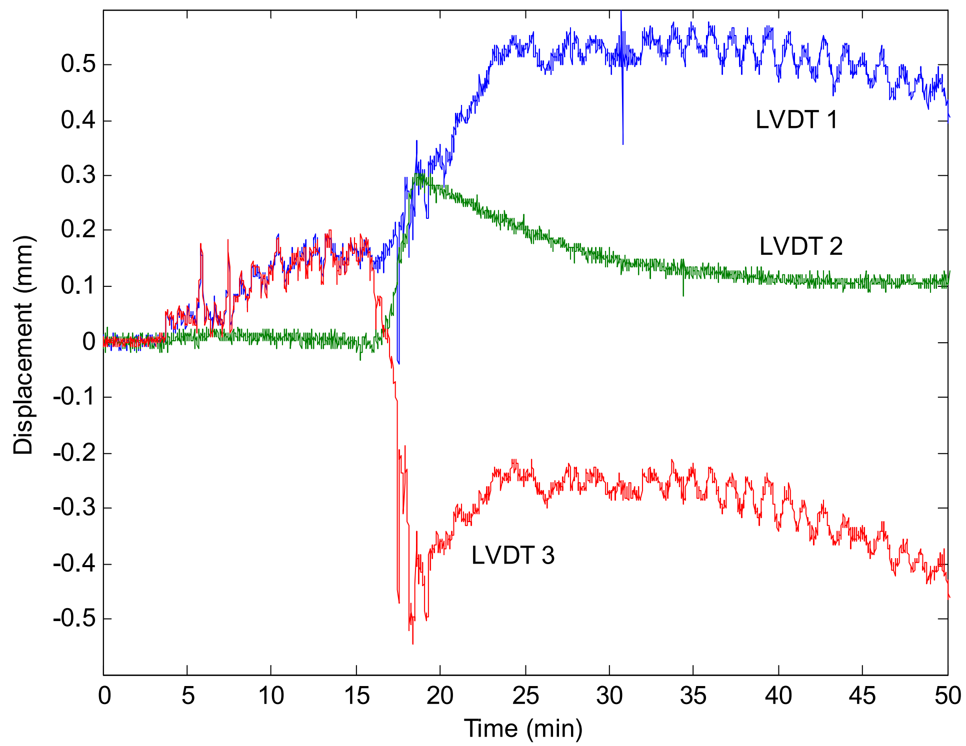
Movement at start of cast
- Upper backbone moves relative to lower (LVDT 1)
- Segment 4 lifts relative to upper backbone (LVDT 2)
- Segment 5 drops relative to segment 4 (LVDT 3)

Further drift during sequence

Movements are reversable

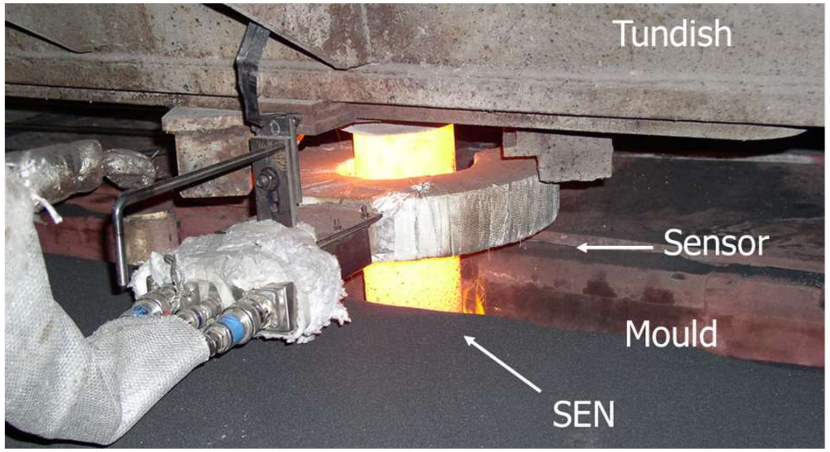
Original positions reached after several hours

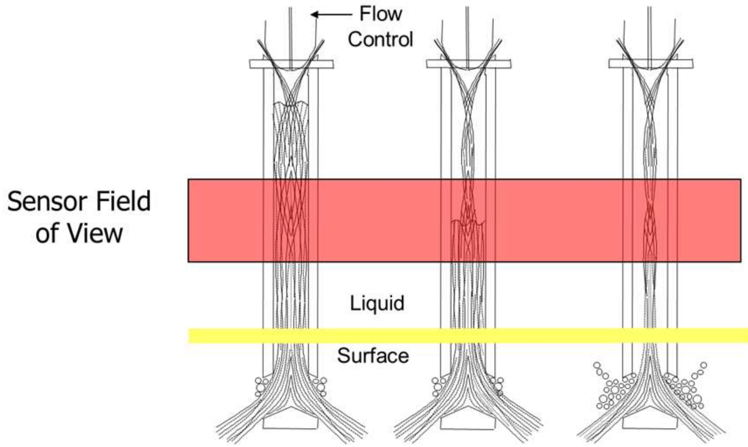
Small oscillations at roll frequency



Steel Flow Visualisation

- The control of steel flow in the continuous casting process is critical
- Much work has been carried out to study the flow conditions in the SEN including physical and mathematical modelling
- No way to verify these studies in the real system





- Steel Flow Visualisation uses an electromagnetic sensor to penetrate the “black box” that is the SEN and directly measure conditions within it.
- The sensor consists of pairs of electromagnetic transmitter and receiver coils. The intensity of the received signal varies with volume of steel in the SEN.

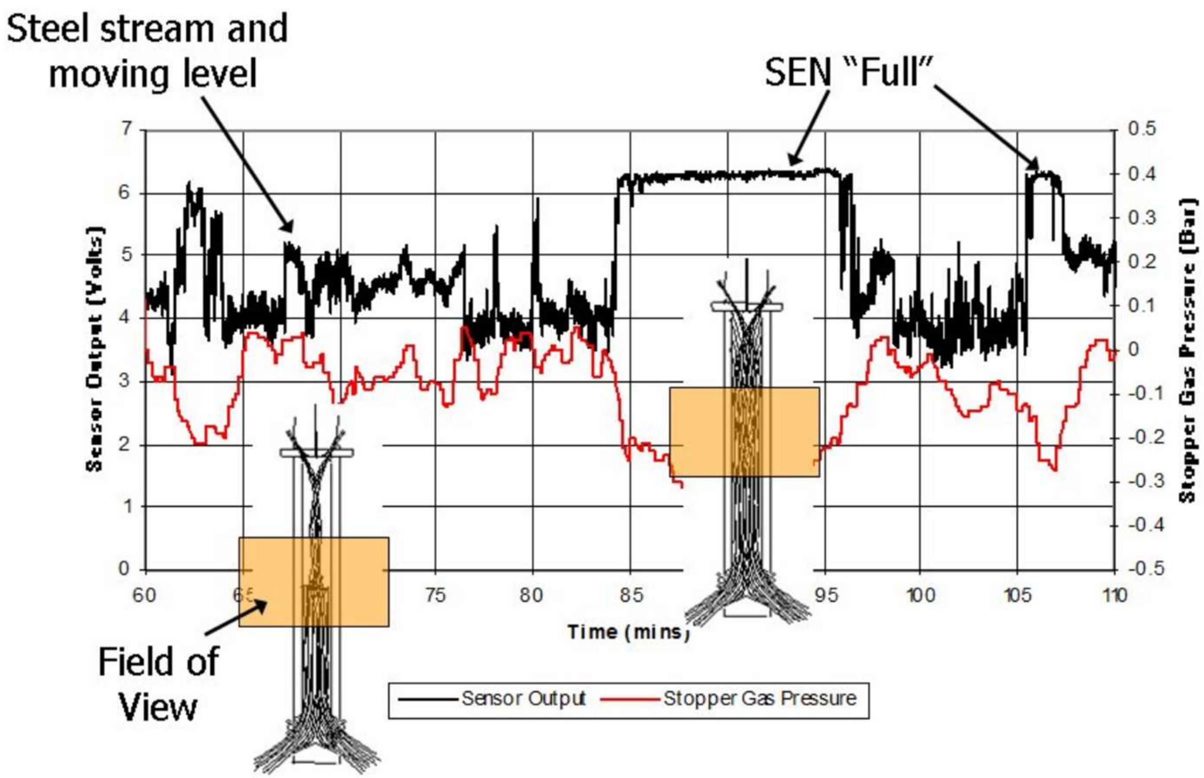
Steel flow visualisation

Flow transition

Interpretation of data is qualitative with reference to data from known flow patterns obtained in calibration trials

Gross changes in flow pattern are clearly identified

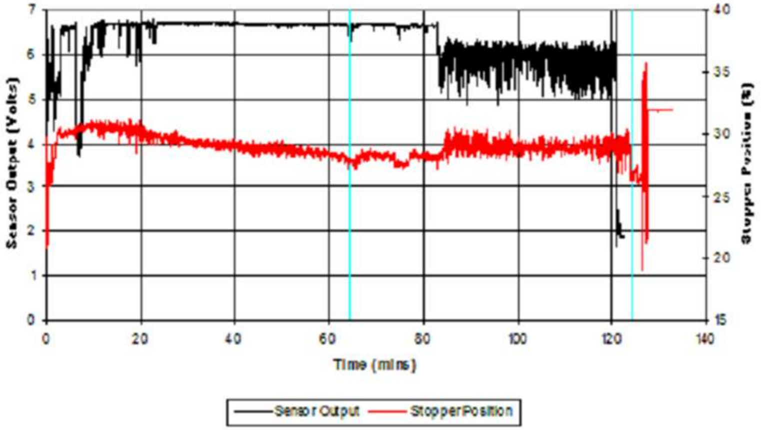
e.g. SEN full or not full

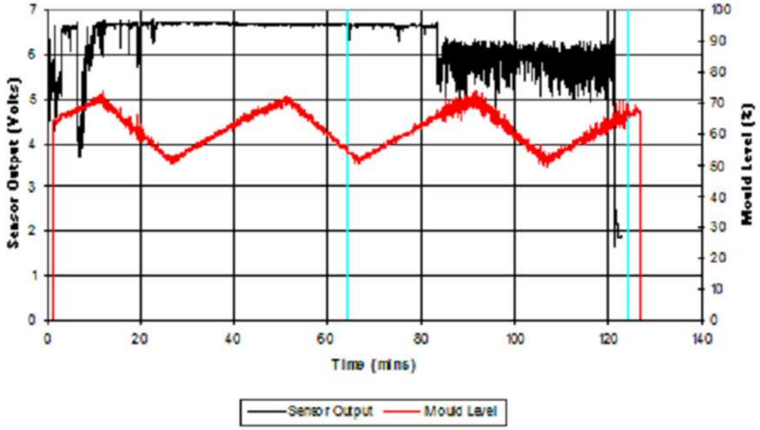


Steel flow visualisation

Effect of argon

- Transition between full and not full could be linked with the argon injection through the stopper
- Full/not full transition forced by manipulating the argon injection
- Flow pattern in the SEN has an influence on mould level and flow control stability





Conclusions

Presentation includes work from several European funded projects

Acronym	Title	Year	Report Number
SOLIMOULD	Enhanced as-cast product quality by optimised mould taper design	2009	EUR 24176 EN
ICCRACK	Intercolumnar cracking and its relationship to chemistry and applied strain	2015	EUR 27078 EN
Steel Flow Visualisation	Improvement in cast product quality by the visualisation and control of the steel flow pattern in the tundish pouring nozzle	2005	EUR 21247 EN
FLOWVIS	Measurement, prediction and control of steel flows in the casting nozzle and mould	2010	EUR 24205 EN

Thank you for your attention.

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