Industrial measurement techniques for model validation

28/11/2025

Overview

- **Continuous casting** is a highly complex and dynamic process.
- **Numerical simulations** are essential for optimizing performance and ensuring product quality.
- Reliable models require **accurate validation** using industrial data.
- Validation ensures simulations **reflect real process behavior**.
- Enables **confident decision-making** in process control and defect prevention.

Industrial Measurements techniques:

1. Laser vibrometer

- Industrial laser vibrometers used to measure the vibration in hard-to-reach areas, harsh environments and on very hot surfaces without contact within save distance from cm's to several meters
- To measure vibrations, the beam of a helium neon laser is directed at the measuring object and scattered back
- Surface vibrations on the solidifying strand due to periodic and continuous excitations by the casting machine can be recovered from the laser frequency modulation
- Purpose:
  - Characterization of the degree of solidification of the strand at measurement position based on specific vibration frequency signature
  - Detailed information about the position of crater end for validating and calibrating heat transfer and solidification models

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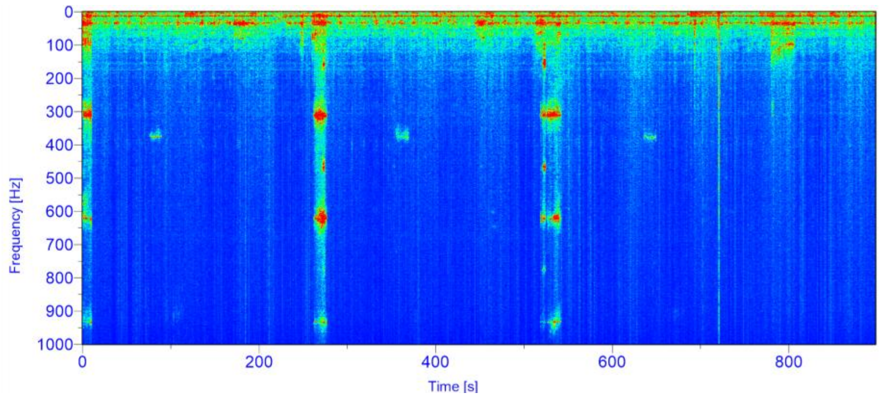

Industrial Measurements techniques:

2. Infrared (IR) Camera

- Infrared (IR) cameras are widely used in the steel industry for non-contact measurement of surface temperature, particularly in the continuous casting process.
- These cameras detect thermal radiation emitted by the hot strand and convert it into high-resolution thermal images, enabling continuous monitoring of the temperature distribution across the strand surface.
- This full-field temperature data is essential for validating thermal models
- Purpose:
  - detecting surface defects such as cold spots or uneven cooling.
  - optimizing secondary cooling strategies
  - Tertiary cooling temperatures characterization

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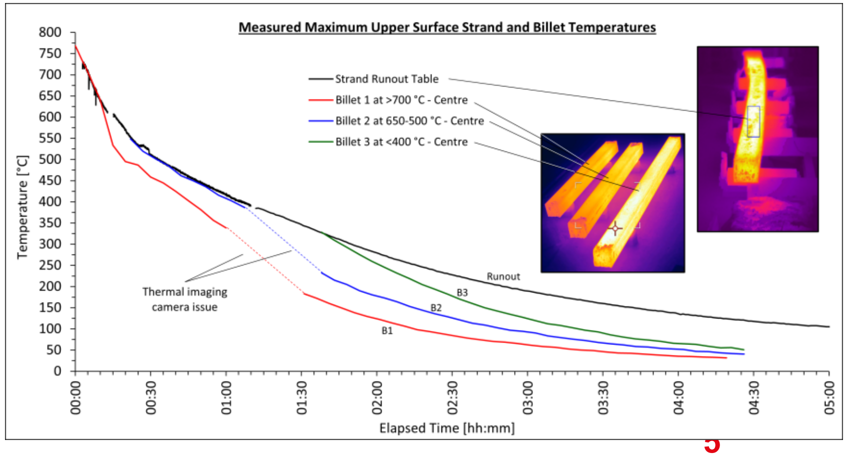
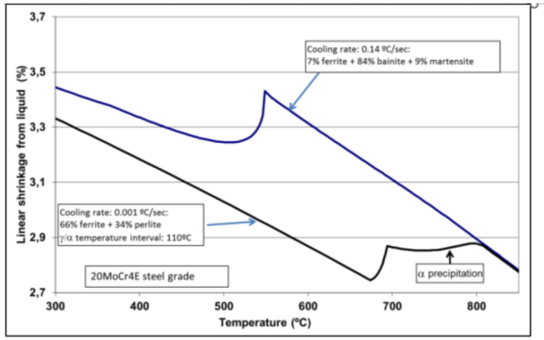


IDS Shrinkage simulation



Linear shrinkage evolution as a function of cooling rate – Grade 28MnCr5E (Sidenor)

Industrial Measurements techniques:

3. Laser Scanning pyrometer

- Infrared (IR) pyrometers are widely used in the steel industry to measure high temperatures without contact
- By detecting the infrared radiation emitted from hot surfaces, these pyrometers can accurately measure the temperature of molten metal, billets, and steel product surfaces
- Provides stable readings under harsh conditions (dust, steam, high temperatures).
- Laser Scanning Purpose:
  - Full Surface Temperature mapping across strand width-> complete temperature profile
  - Generates detailed thermal data for validating and calibrating heat transfer and solidification models
  - Enables integration with Level 2 for designing an alarm system based on real-time strand temperature monitoring

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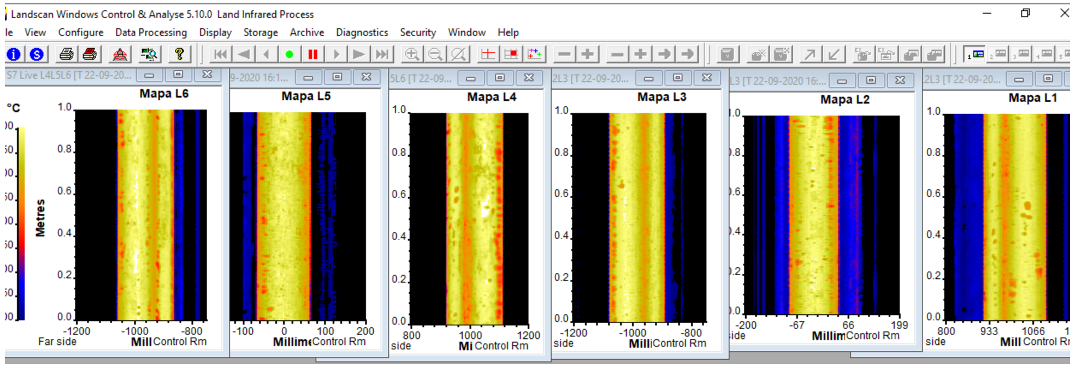

Industrial Measurements techniques:

4. Thermocouples

- Thermocouples are widely used in the steel industry for temperature measurement due to their reliability, simplicity, and ability to withstand high temperatures.
- **Limitations** Only point measurements → no full surface mapping and requires physical installation and maintenance.
- In continuous casting, thermocouples are used to monitor temperatures in the mold, tundish, ladle, and molten steel y, simplicity, and ability to withstand high temperatures.
- Their robust design makes them ideal for harsh environments.
- Purpose:
  - for validating thermal models
  - Monitoring critical zones for process safety and control.

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Industrial Measurements techniques:

5. FOTS (Fiber Optic Temperature Sensors)

- Uses optical fibers with distributed sensing capability based on changes in light properties to measure temperature along the fiber length.
- The advantages is that they provide a continuous temperature profile instead of discrete points.
- It has a great Spatial Resolution which enable them to detects localized hot spots and thermal gradients.
- Purpose in CC:
  - Real-time monitoring of mold temperature distribution: Early detection of abnormal heat flux or breakout risks.
  - Supports optimization of cooling strategies and mold design.

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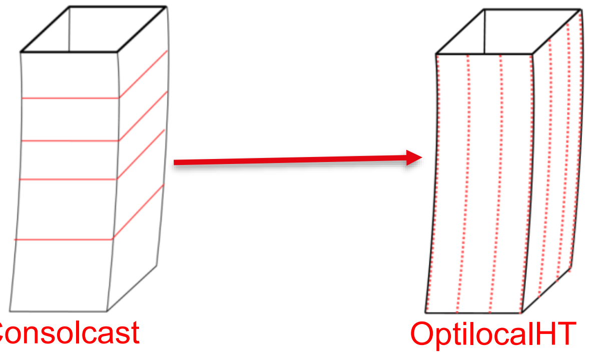
AGENDA

- INTRODUCTION:
  - OptilocalHT: precedents, objectives and actions
  - Fibre installation and positioning
- STUDY:
  - Recorded campaigns
  - Measurements
  - Analysis tool functionality
- RESULTS:
  - Maximum temperature
  - Equivalent Carbon
  - *Decay* coefficient

INTRODUCTION

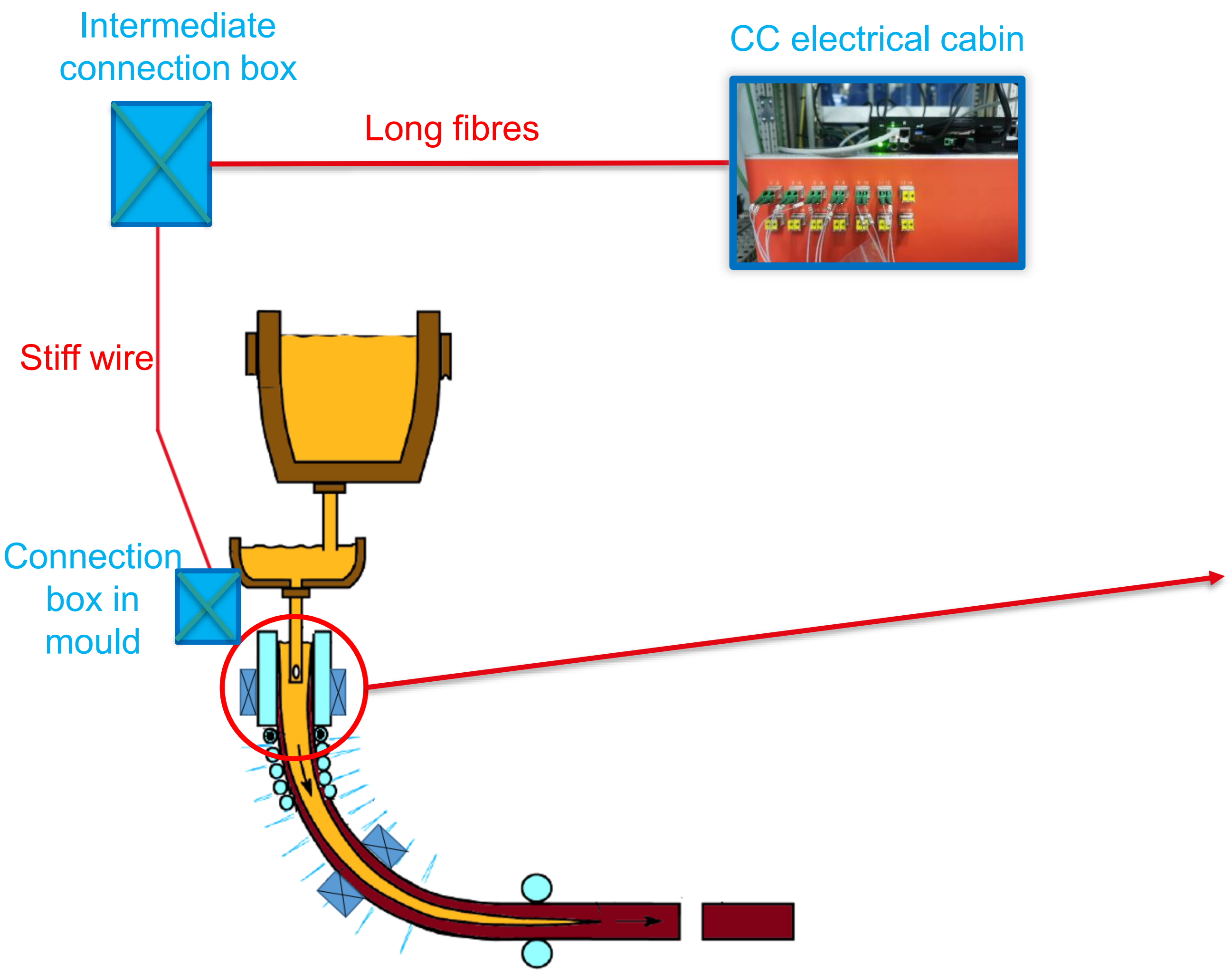
PROJECT FUNDAMENTALS

- PRECEDENTS:
  - Consolcast: Utilisation of measurements targeting temperature differences in CC mould faces to prevent breakouts. Aiming conclusion consolidation, OptilocalHT is designed to further extend the study, carrying out longitudinal measurements this time
- OBJECTIVES:
  - Obtain an accurate thermal profile from the billet continuous casting mould
  - Consideration about potential impacts on production thanks to fibres
  - Validate results obtained in Consolcast

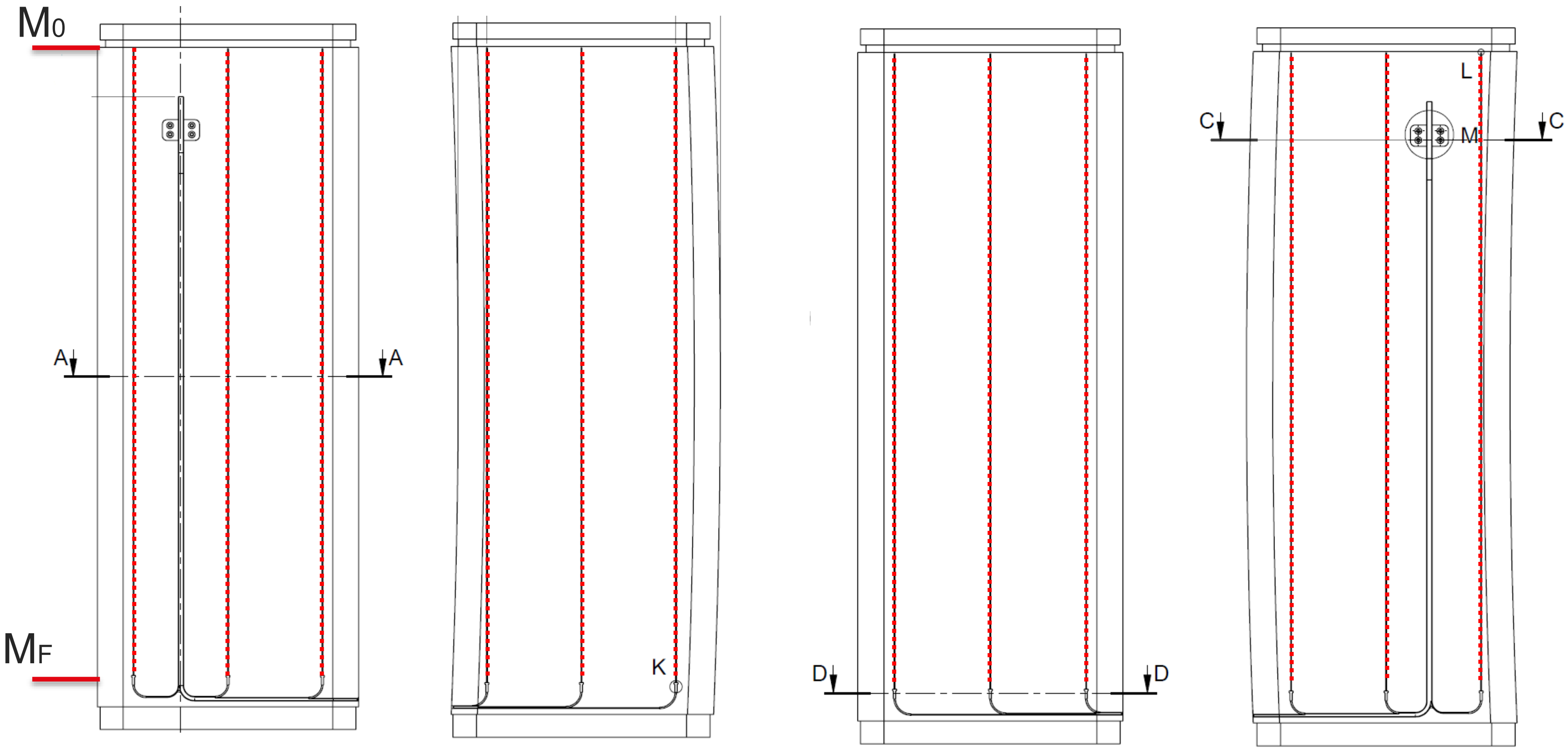


- ACTIONS:
  - There have been installed several fibres in the outside face of billet caster's mould (240x240 format) lengthwise to measure temperature
  - The data have been extensively analysed using software towards extracting useful metrics, enabling the comparison among several steel families

FIBRE LOCATION (I)



FIBRE LOCATION (II)



- 12 fibres (3/face)
- 70 measurement points/ fibre
- 840 total temperature measurements
- 48 measurements/minute

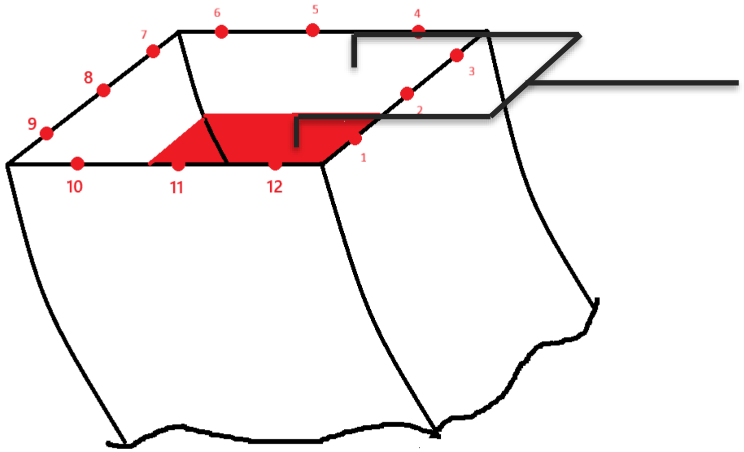
ANALYSIS

MEASUREMENT PERIODS

- Three periods:
  - 1st Campaign: 165 heats
  - 2nd Campaign: 74 heats
  - 3rd Campaign: 184 heats

→ 423 heats registered

- The heat population is big enough to reflect 7 of Sidenor steel grades
- Setbacks:
  - Not all registered heats are valid; some of them contain corrupt readings during some periods
  - Some of the installed fibres suffered deterioration during the heats



FUNCTIONALITY OF CALCULATION TOOL

- Extract data per steel family and fibre:
  - Among all the continuous temperature readings, the program isolates all heats for a given steel family
  - Posteriorly the tool plots the temperature profile of each fibre along the length of the mould
  - The plots are helpful to extract metrics towards comparison between families

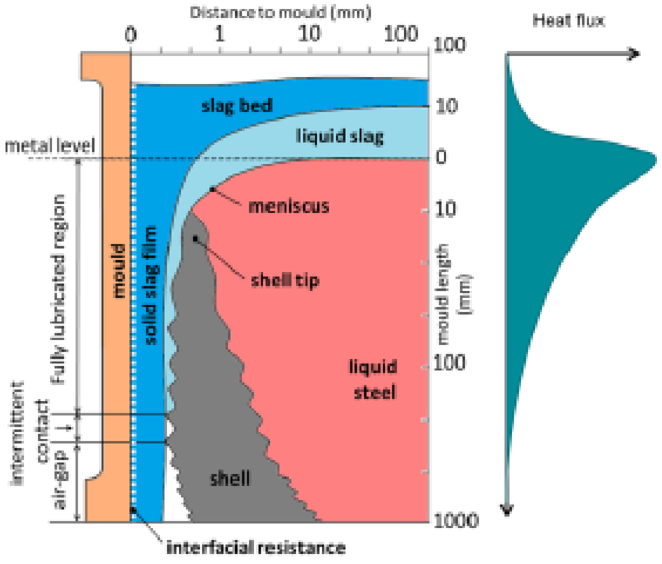
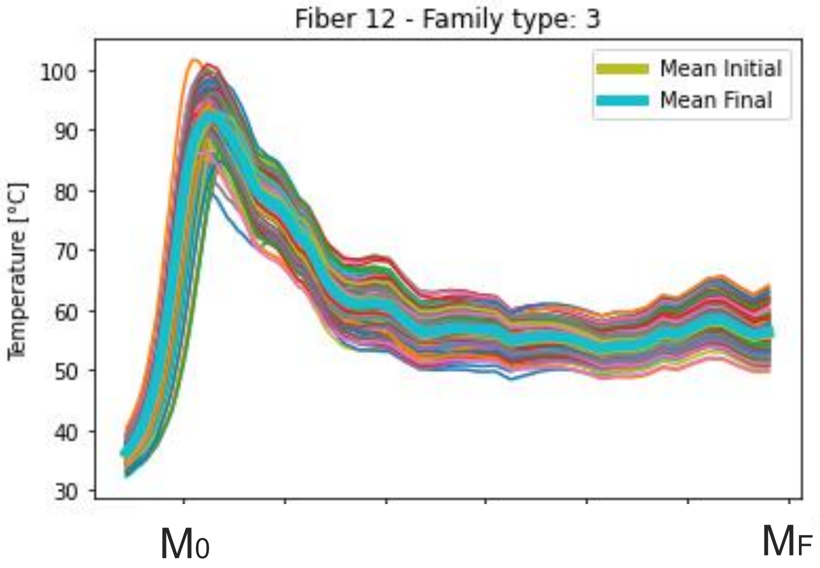
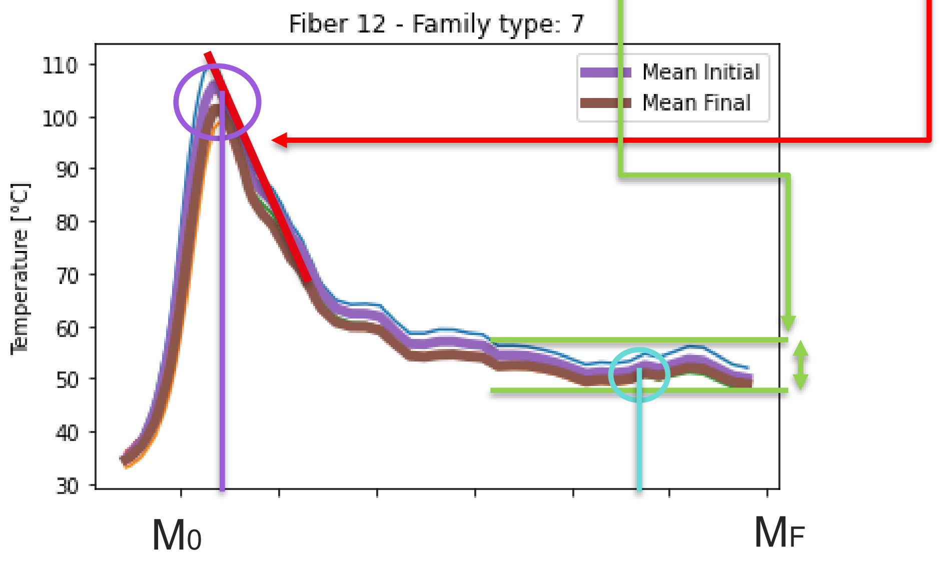


Fig 1: Heat transfer and lubrication in the mould

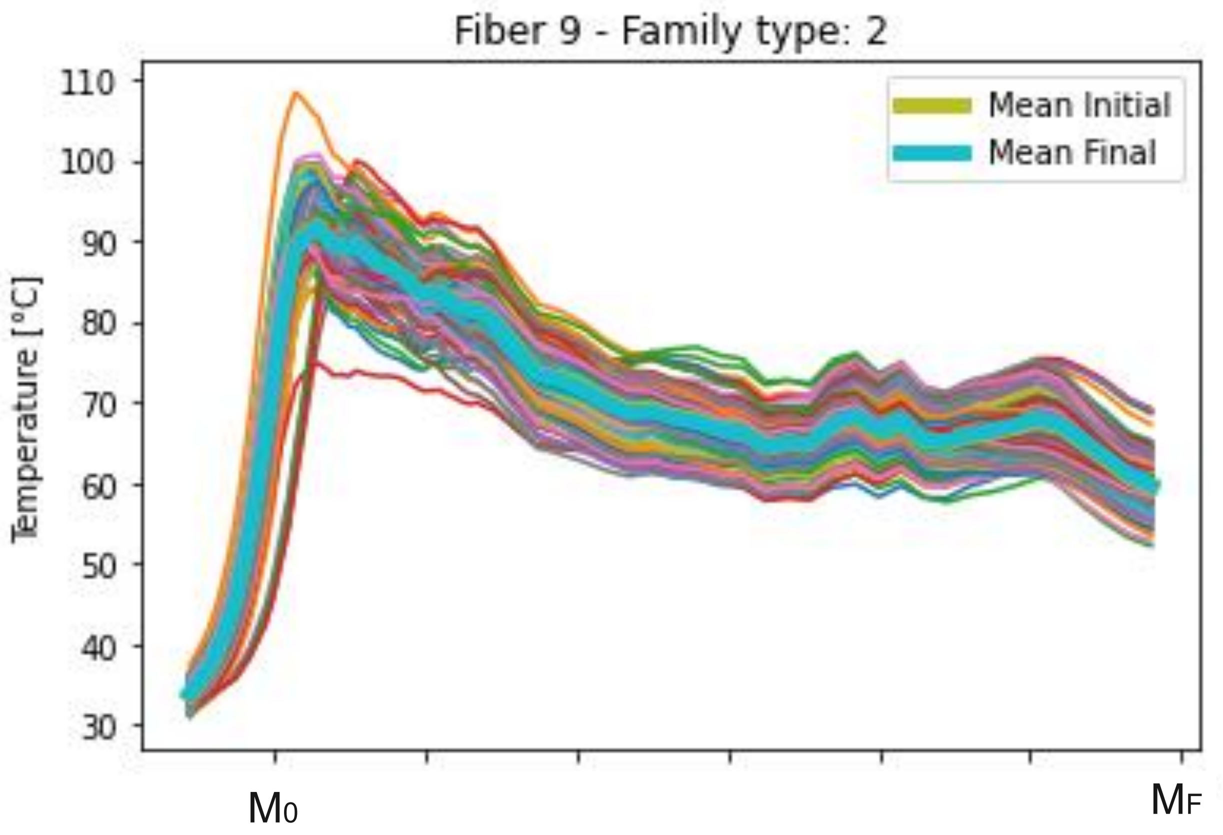


KPI OF THERMAL PROFILES

- For each curve, several metrics that will be helpful towards comparing temperature profiles among steel families have been defined. These *Key Performance Indicators* are the following:
  - Value and localisation of maximum and minimum temperatures. Standard deviation and distribution of these maximums
  - Temperature drop after the maximum (named Decay coefficient)
  - Temperature increase due to electromagnetic stirring (named Stirring ΔT)



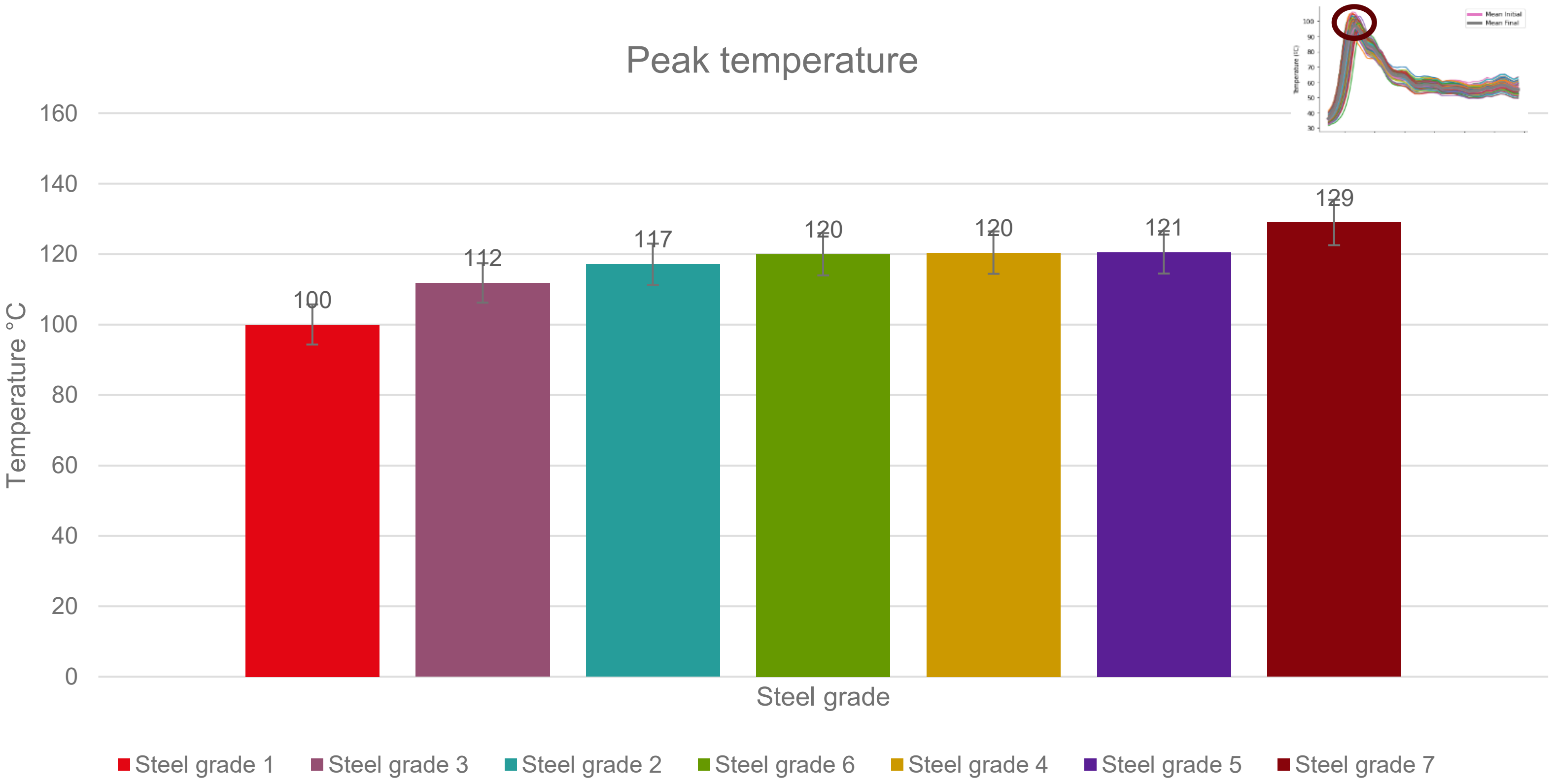
RESULTS



Fiber 9 - Family type: 2
Mean Initial
Mean Final
Temperature [°C]
110
100
90
80
70
60
50
40
30
M0
MF

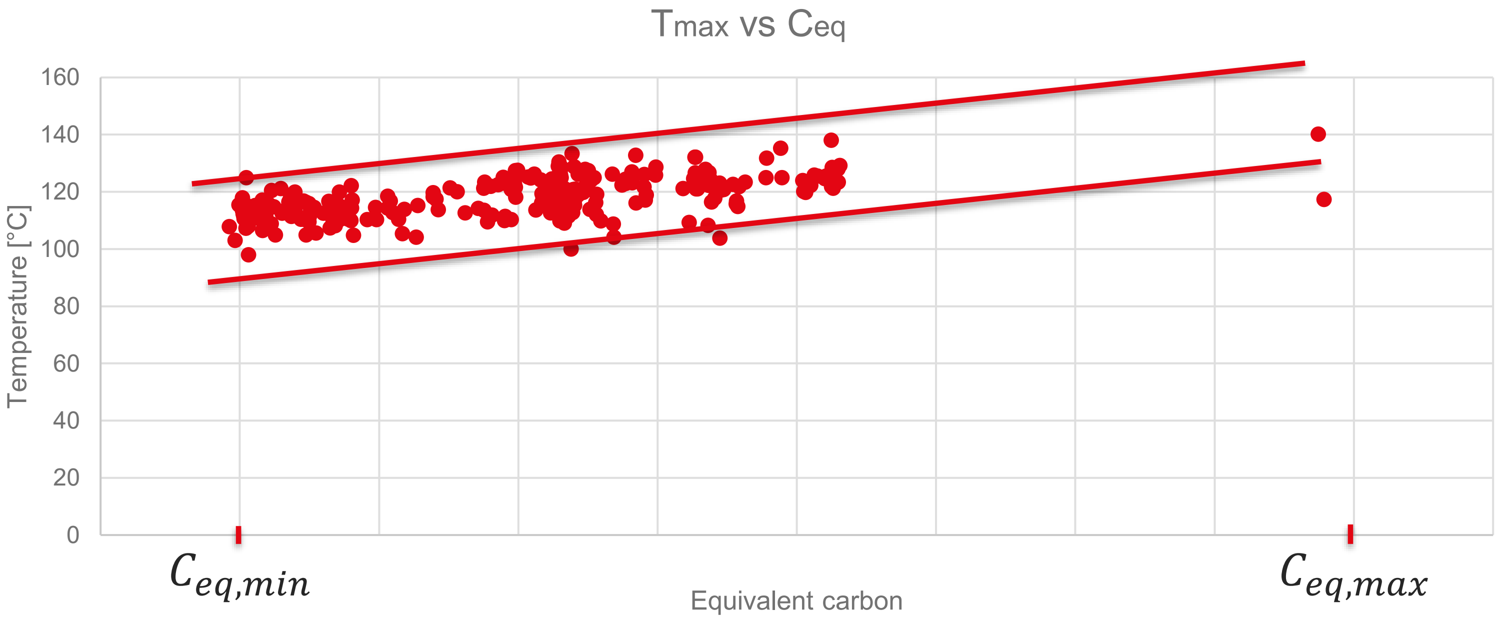
RESULTS – MAXIMUM TEMPERATURE

- 7 steel families have been studied, and posteriorly ordered by their respective average maximum temperature all along the mould, as depicted below
- The order is the same throughout the mould



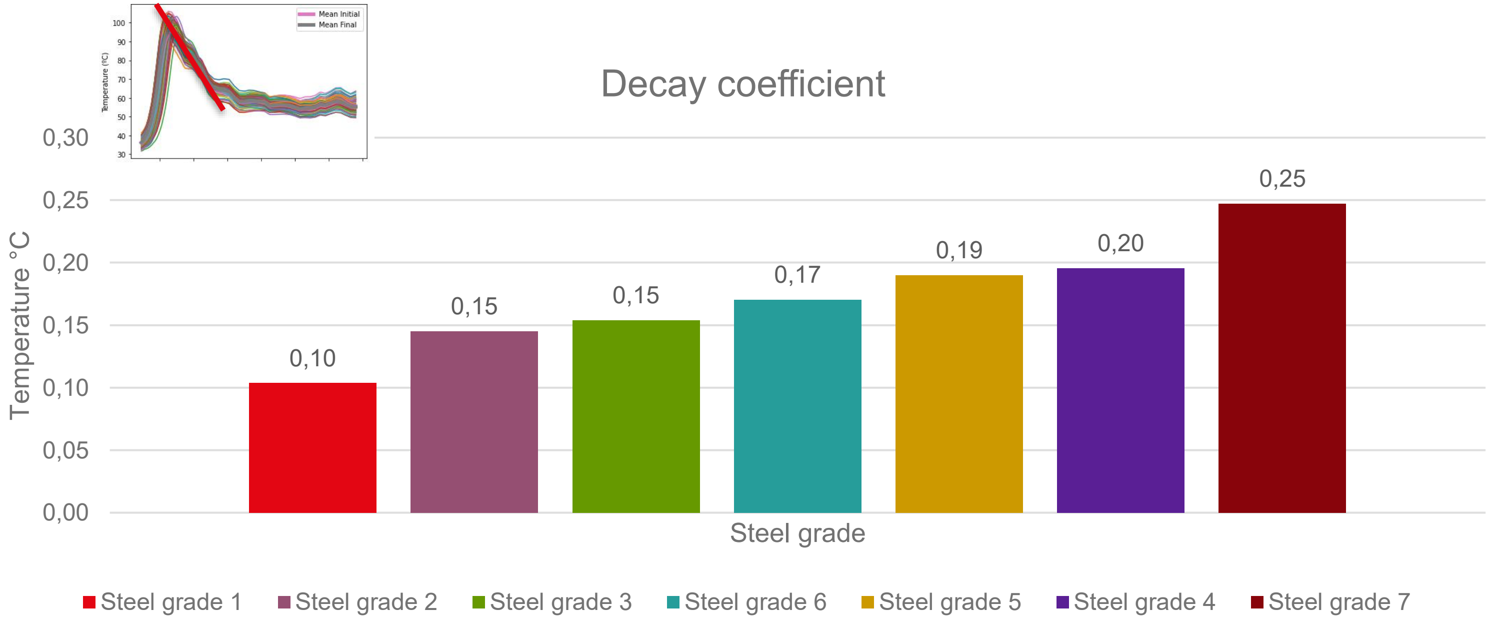
RESULTS – TEMPERATURE VS %C EQUIVALENT

- The following graph plots the equivalent carbon value of each casting against the maximum temperature measured in the mould, portraying the correlation between the variables
- The temperature increase can be explained through decreasing mould shrinkage



RESULTS – DECAY COEFFICIENT

- The *Decay coefficient* outlines the rate of cooling of a given steel family in the mould
- Portraying the 7 steel families over their average *Decay* as follows:
- The order is the same throughout the mould



CONCLUSIONS

- Advantages:
  - Fibres enable steelmakers to record detailed information about thermal transfer in the mould
  - They can play a pivotal role in the security realm, e.g. breakouts

- Disadvantages:
  - Their installation is extremely laborious and requires mould machining, as well as operational expertise
  - They are susceptible to damage, and eventual failure, in the harsh environment of the continuous casting