Processing of liquid silicon alloys

Presenters: Lars K. Jakobsson (Elkem), Kasper Linnestad (Cybernetica)

Meeting: Breakfast Webinar Series

Organiser: DigiPro – National Centre for the Development of the Process Industries of the Future

Location: Microsoft Teams (online)

Date: January 11th, 2022

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Processing of liquid silicon alloys

- Cognitwin Project
- Introduction to Elkem and Cognitwin Pilot site
- Cognitwin Pilot
  - Infrared camera sensors
  - Online process model

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COGNITWIN – An EU project on developing a platform for digitalisation of European process industry.

- The project objective is to achieve improved performance in production plants
- Elkem's pilot case is a digital twin of the post tap hole operations at Elkem Bremanger furnaces 2/4.

Sensor Network

continuous monitoring and data collection from various plant processes

Digital Twin

using process data

Cognitive Capability

self-learning and predictive maintenance for optimal plant operations

Project kick-off meeting at Hydro Sunndalsøra

Partners

Hydro, Sumitomo SHI FW, sidenor, Elkem, saarstahl, German Research Center for Artificial Intelligence, CYBERNETICA, Nissatech innovation centre, Fraunhofer, teknopar Industrial Automation, UNIVERSITY OF OULU, NOKSEL Steel Pipe Co. Inc., SCORTEX

Coordinator

SINTEF

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Elkem and Cognitwin Pilot site

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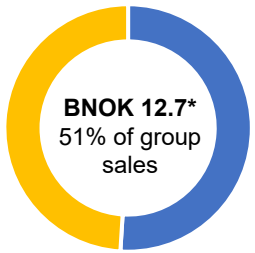
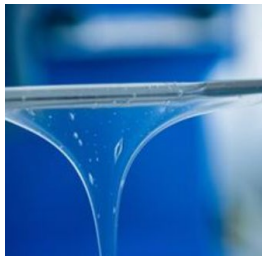
Elkem offer silicones, silicon products and carbon solutions through dedicated business divisions

Silicones
Fully integrated silicones manu-facturer with focus on specialities

Markets
- Paper & film release
- Automotive
- Silicone rubber
- Chemical formulators
- Personal care
- Textile
- Healthcare
- Construction

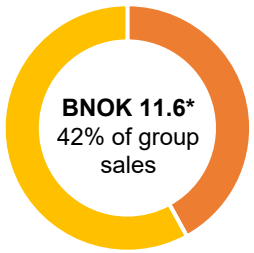


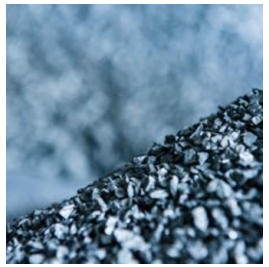


12 plants worldwide

Silicon Products
Global producer and provider of silicon, ferrosilicon and specialties

Markets
- Silicones
- Automotive
- Construction/Engineering
- Electronics
- Solar & wind
- Specialty steel
- Refractories
- Oil & gas

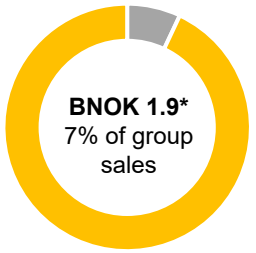




11 plants worldwide

Carbon Solutions
Leading producer of electrode paste and specialty products

Markets
- Ferroalloys
- Silicon
- Aluminium
- Iron foundries



6 plants worldwide

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*Based on external sales FY 2020

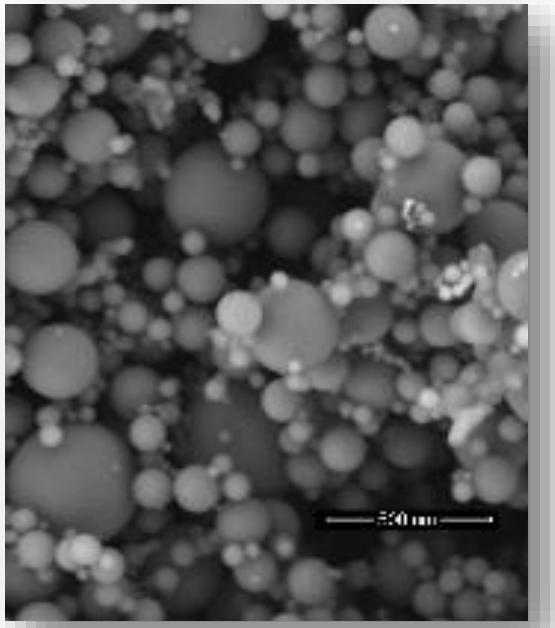
Elkem Silicon Products is organised into three main business areas

Silicon Products

Silicon (Silicon products)

- Polysilicon
- Aluminium
- Chemicals
- Silicon Specialities

Materials (Microsilica & other materials)



- Construction
- Refractories
- Oilfield
- Polymers

Ferrosilicon alloys

- Iron Foundries
- Steel Industries

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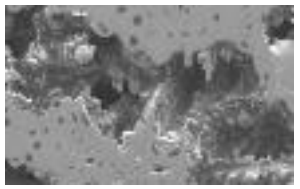
Elkem Bremanger (furnace 2 and 4) produces ferrosilicon alloys for the Iron Foundries

Iron Foundries			
Nodularisers	**Inoculants**	**Preconditioners**	**Conditioner**
			
Elmag ®	Alinoc ®	Tenbloc ®	Preseed ®	Topseed ®
Lamet ®	Barinoc ®	Ultraseed ®		
CompactMag ®	Foundrisil ®	Vaxon ®		
ReMag ®	Reseed ®	Zircinoc ®		
	SMZ ®	Superseed ®		
	Superseed ® Extra			

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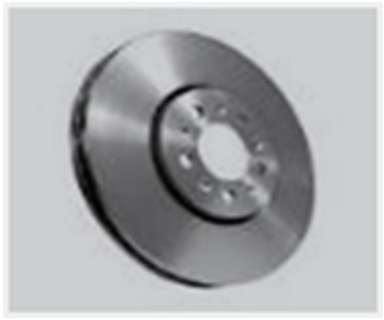
Challenges

- Multiple products with different composition
  - FSM (FerroSiliconMagnesium)
  - Inoculants
  - FeSi75 (various grades)
- To achieve 100% hit rate, process control is of utmost importance
- Yield is increased by utilizing excess heat for remelting of fines.

FeSi75 – deoxidation in steel production



Inoculants – grey and ductile iron special applications

FSM – ductile cast iron applications

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Cognitwin project

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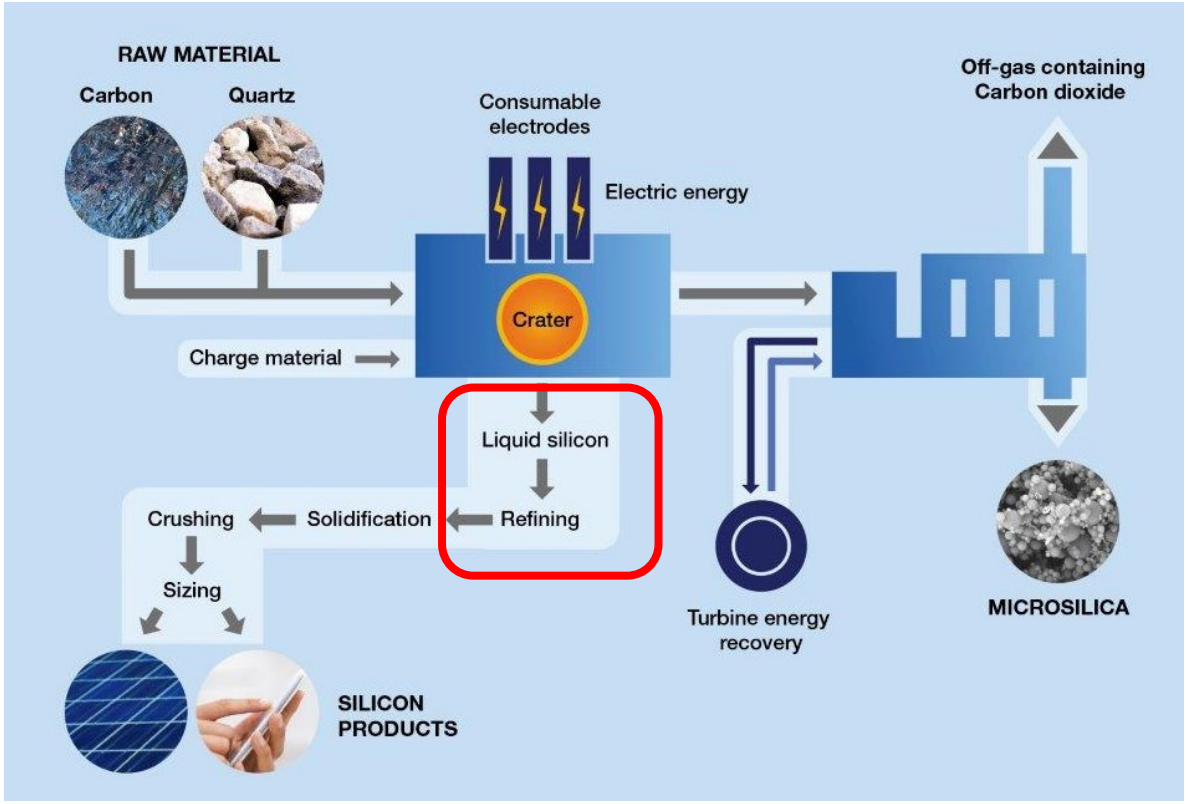
Elkem's COGNITWIN pilot:

- Processing of liquid silicon alloys at Elkem Bremanger



- Elkem participates in the project with R&D resources from Elkem Technology and Elkem Silicon Products, and with operational personnel from the plant in Bremanger.

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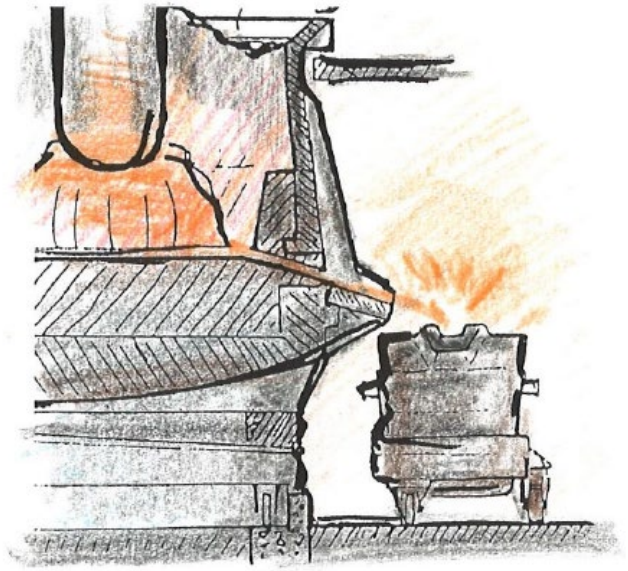
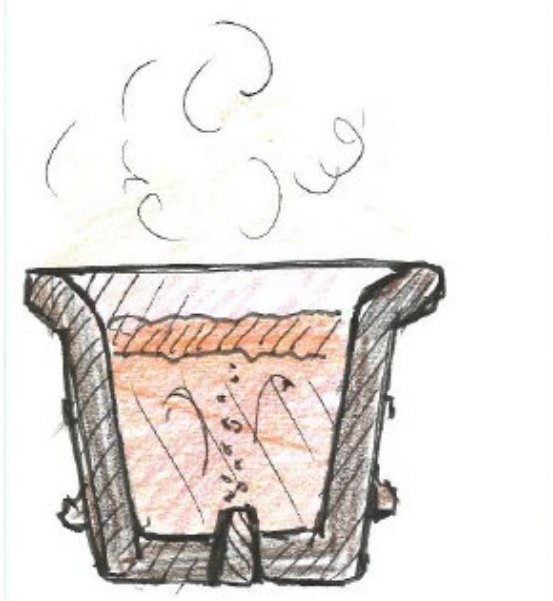
Elkem's pilot case in COGNITWIN: Processing of liquid silicon alloys

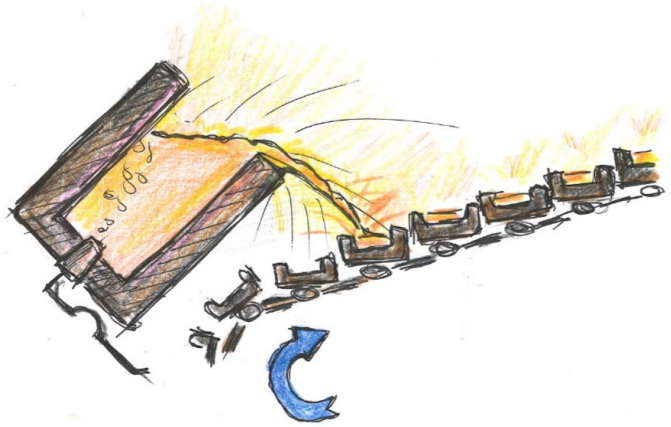
1. TAPPING



2. REFINING AND ALLOYING



3. CASTING



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Elkem's pilot case in COGNITWIN: Processing of liquid silicon alloys

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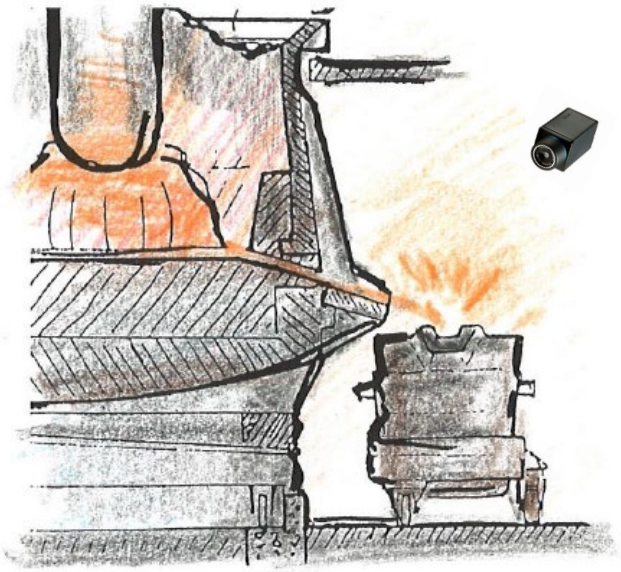

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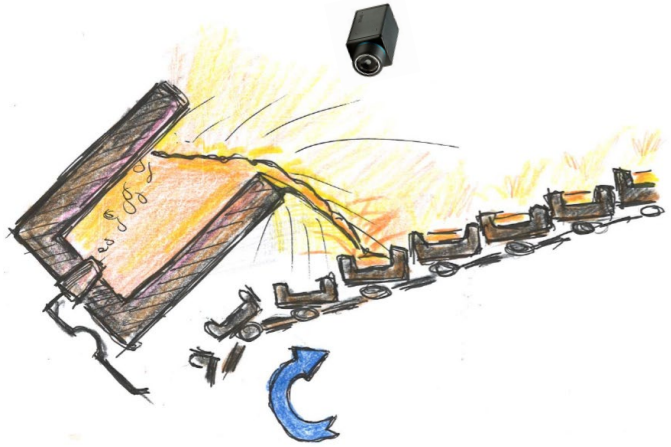

Main focus:

- Increase process information flow by applying infrared cameras to the process monitoring.
- Develop on-line models for material and energy balance from tapped metal to solidified product.

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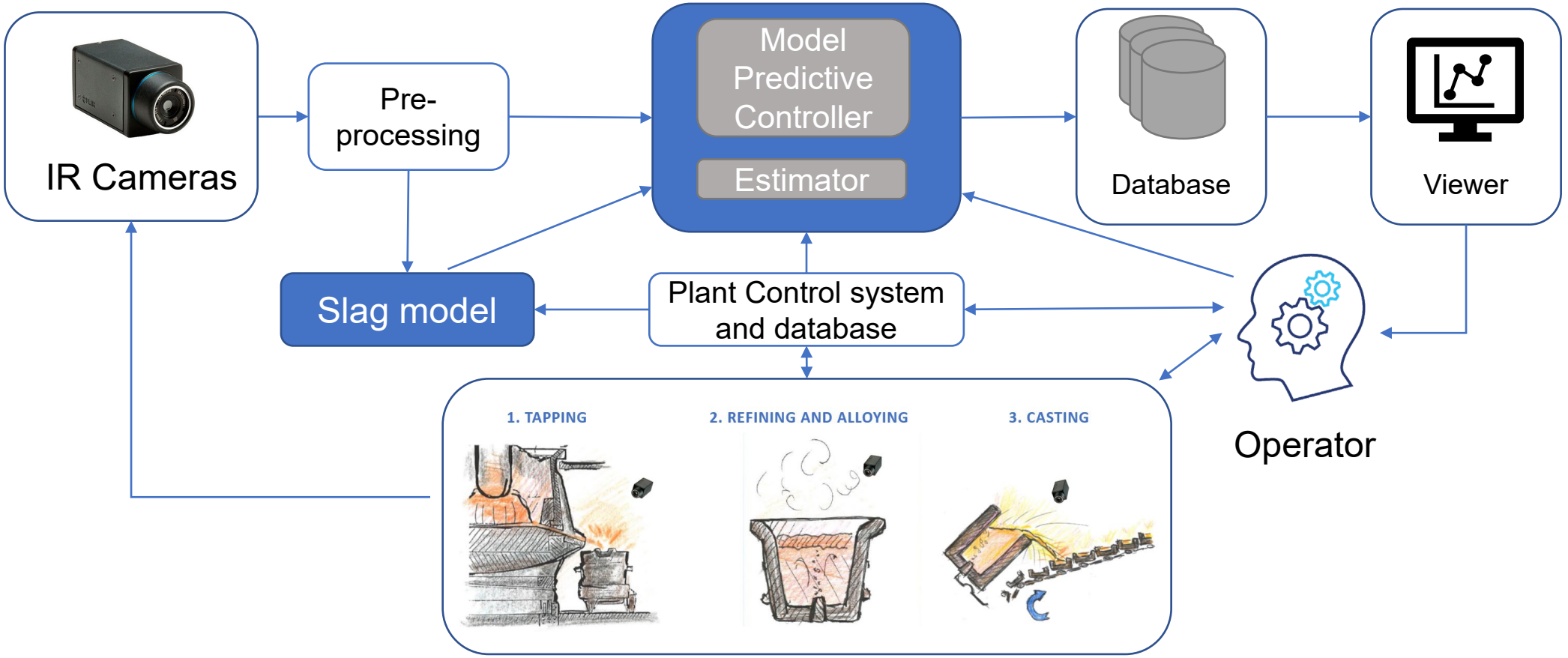
Online model for estimation and control of the ferrosilicon refining process



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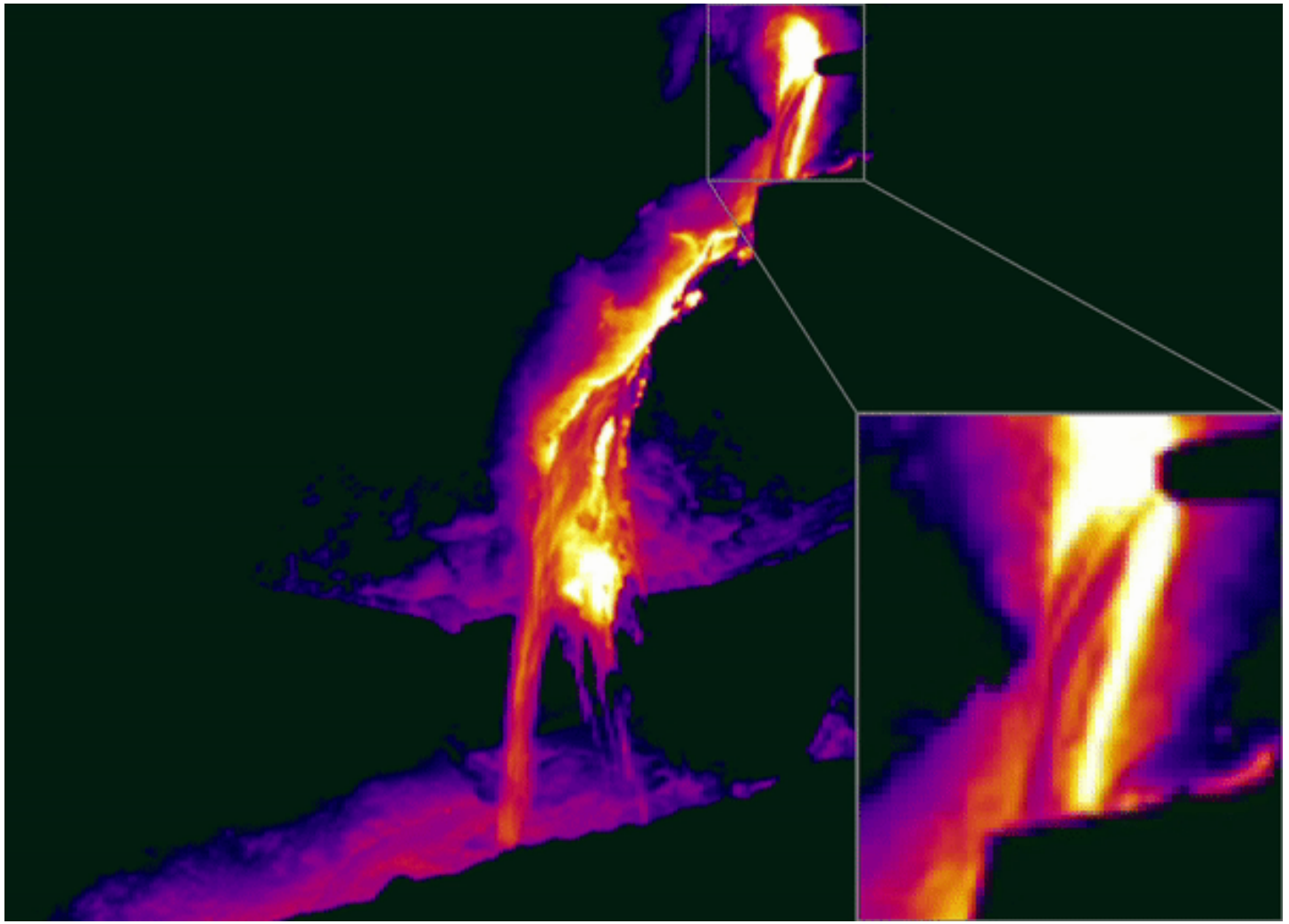
Infrared Camera Sensors

Tapping

Objective:
Optimize liquid alloy processing

Use IR camera to:

- **Identify slag in tapping stream**
- **Measure temperature**



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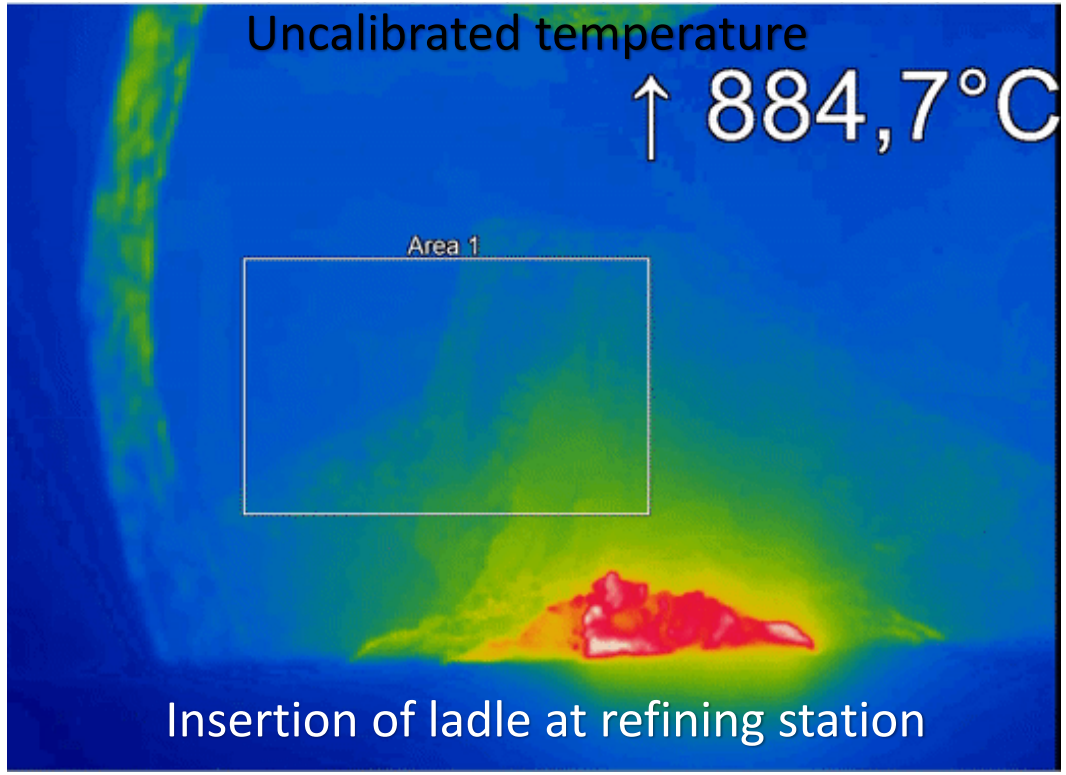
Refining

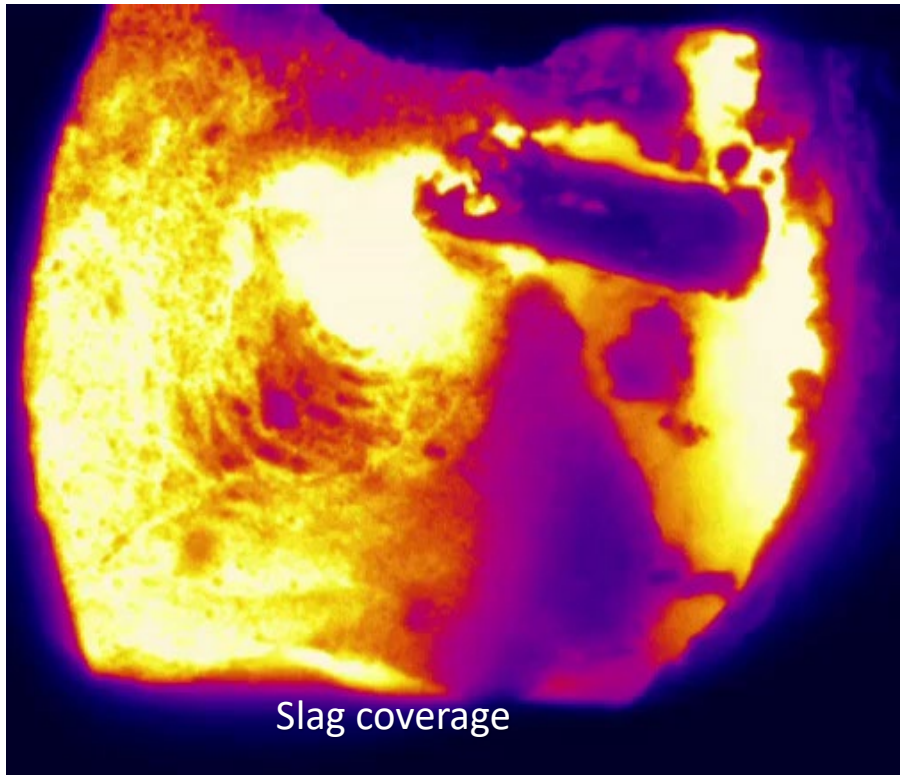
Objective:
Optimize liquid alloy processing

Use IR camera to:

- **Identify amount of slag**
- **Measure temperature**



Insertion of ladle at refining station


Slag coverage

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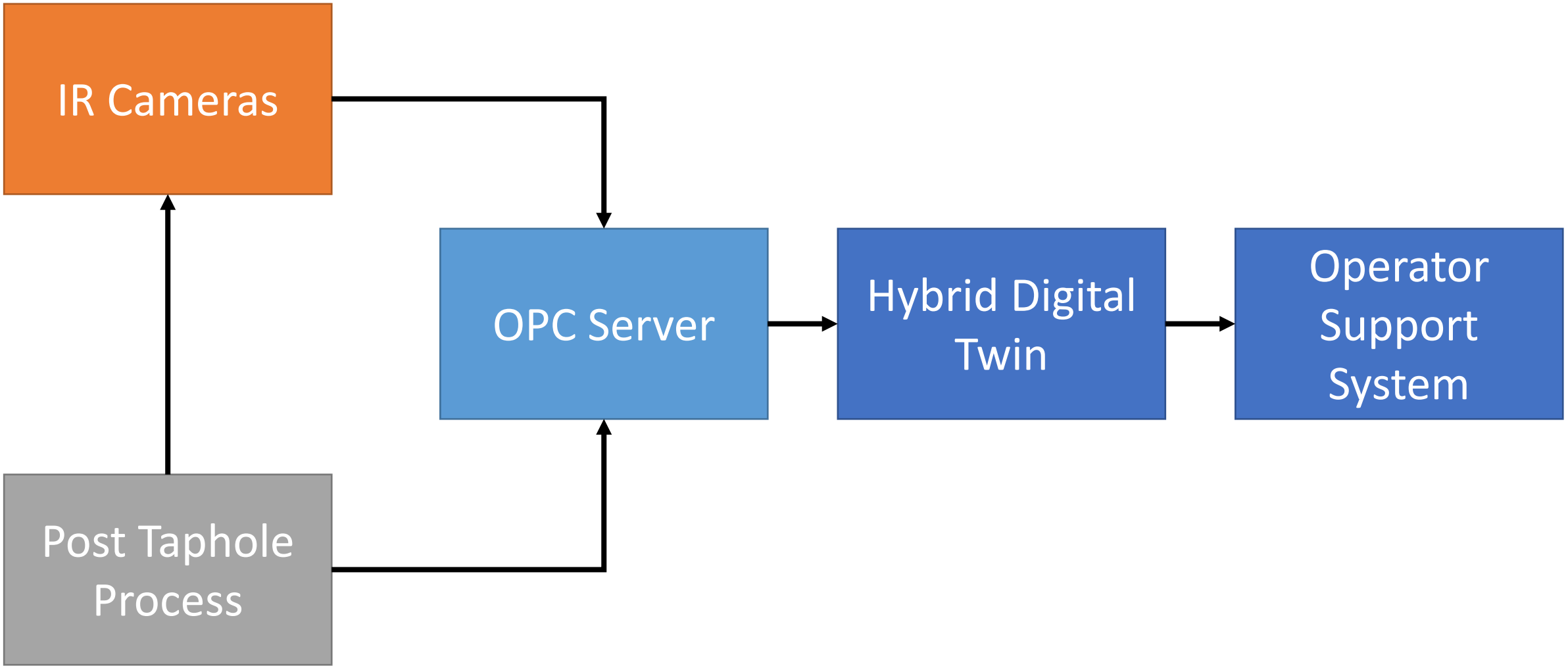
Hybrid Digital Twin



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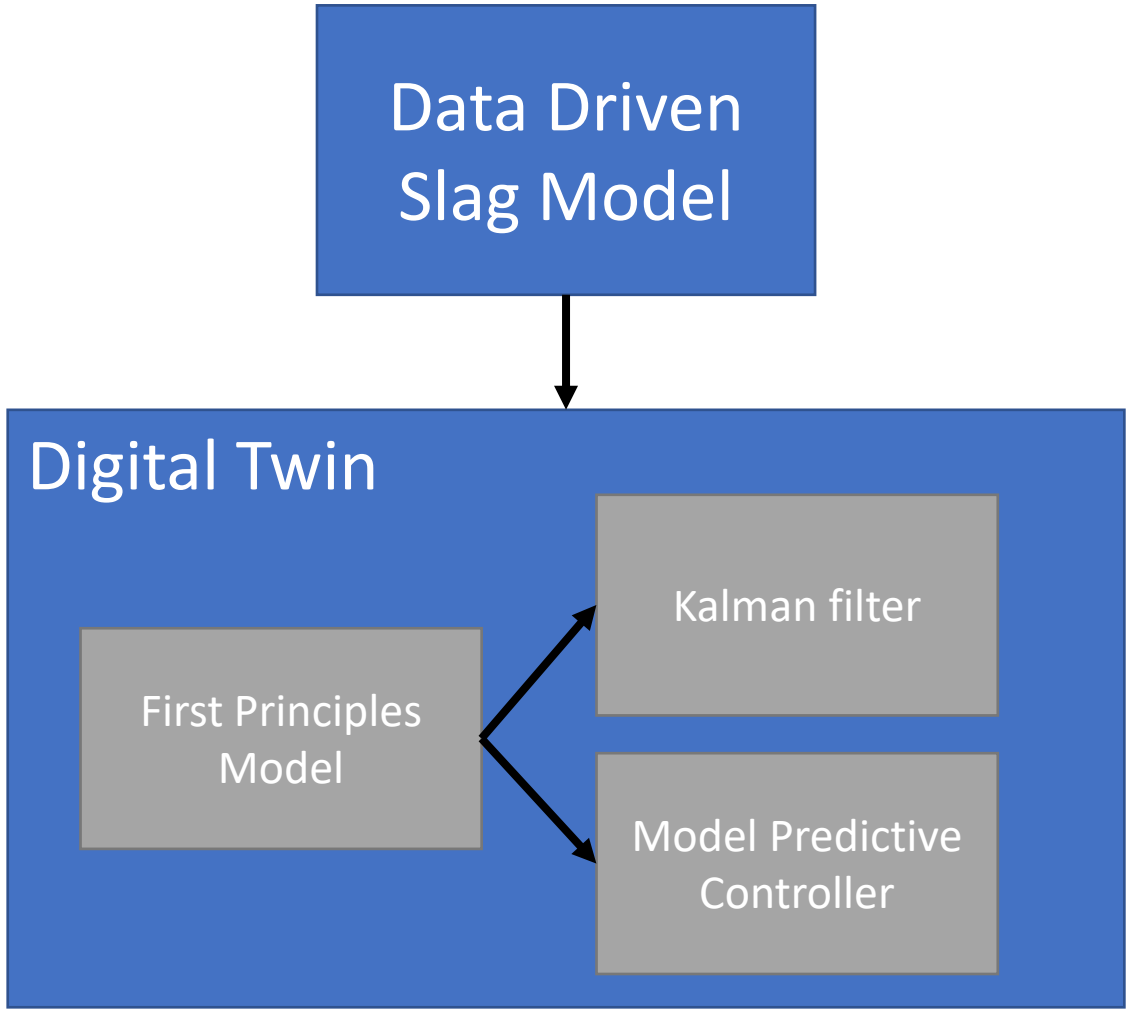
Hybrid Digital Twin

- Data Driven Slag Model
  - Amount of slag from furnace
  - Machine learning
  - Combines data from furnace, tap and IR
- Digital Twin
  - First principles refining model
  - Recursive estimator (e.g. Kalman filter)
  - Model Predictive Controller



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First principles model

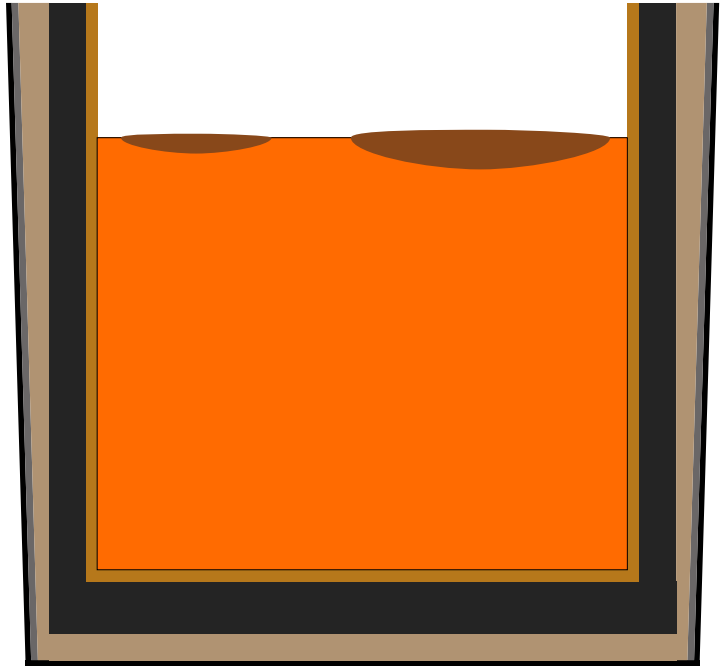
- Mass and energy balances
  - 19 metal species
  - 7 slag components
  - Heat transfer
- Slag forming

$$2Si + Fe_3O_4 \rightarrow 2SiO_2 + 3Fe$$

- Equilibrium reactions

$$\frac{4}{3}Al + SiO_2 \leftrightharpoons \frac{2}{3}Al_2O_3 + Si$$

$$2Ca + SiO_2 \leftrightharpoons 2CaO + Si$$



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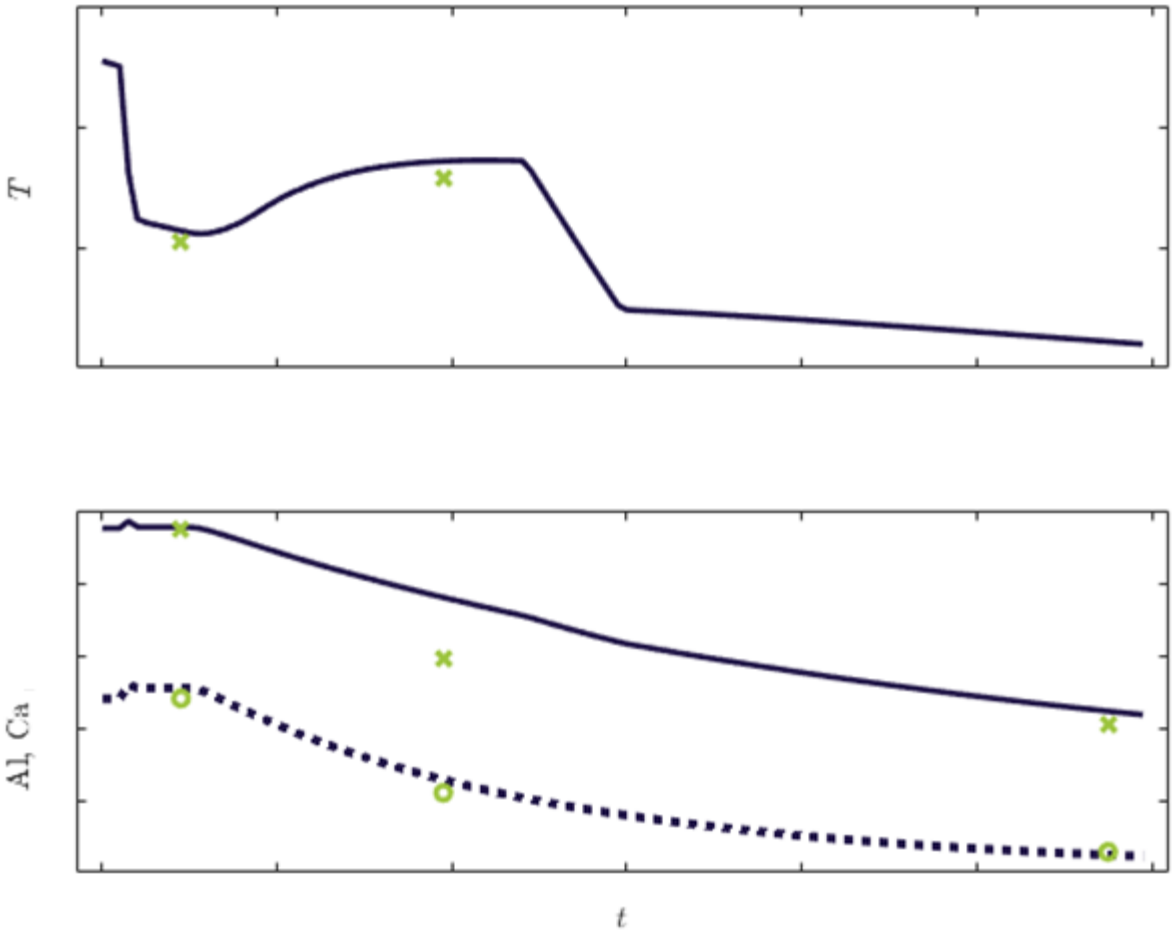
Model fitting

- Parameter estimation
  - Heat transfer coefficients
  - Reaction rate coefficients
- Using online data
- Next step
  - Data from IR-camera
  - Results of slag model



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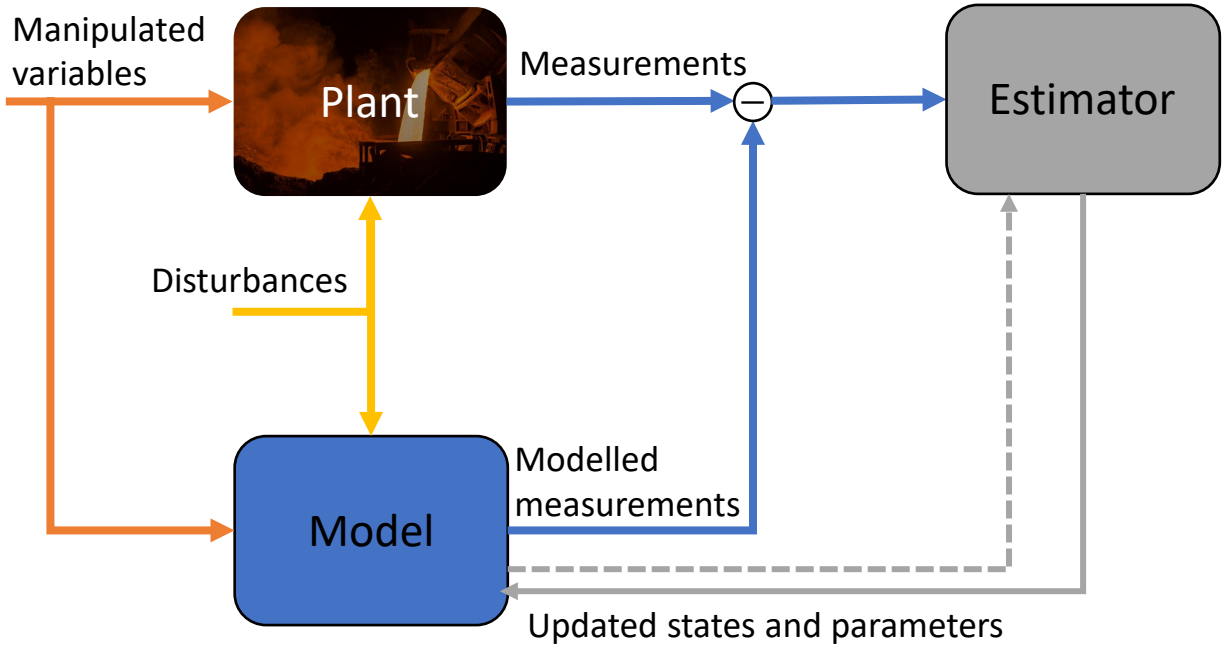
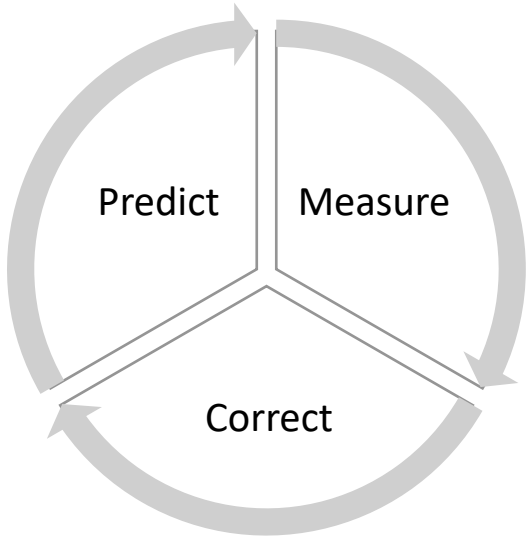
Estimator





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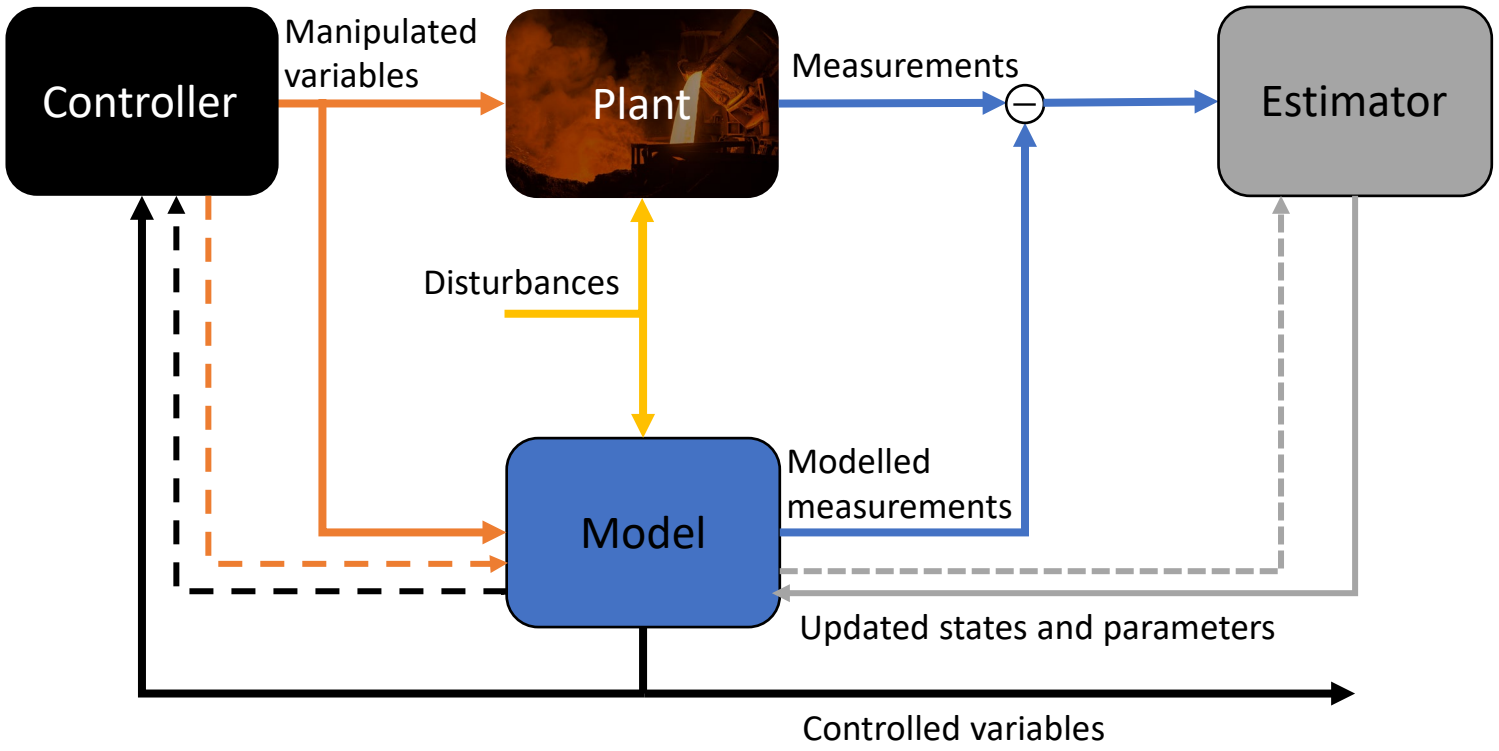
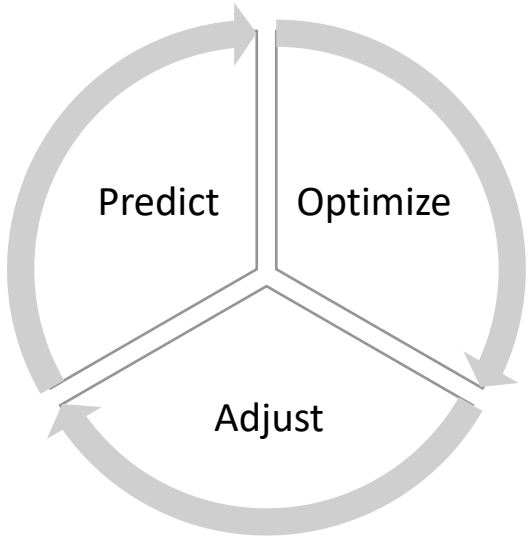
Model predictive control





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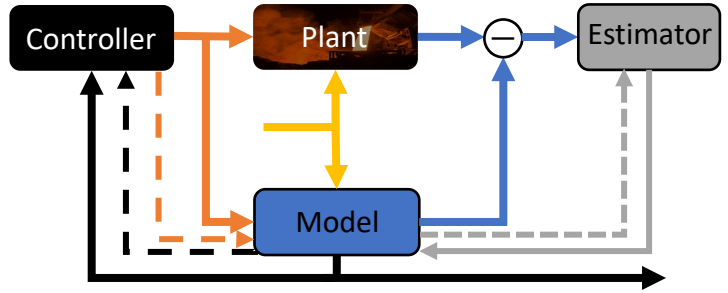

Achieve specification

Maximum remelting

Optimum additions

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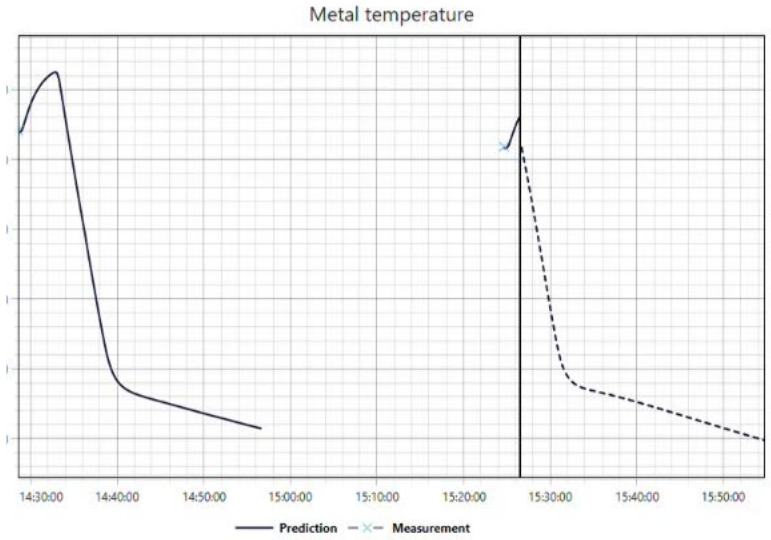

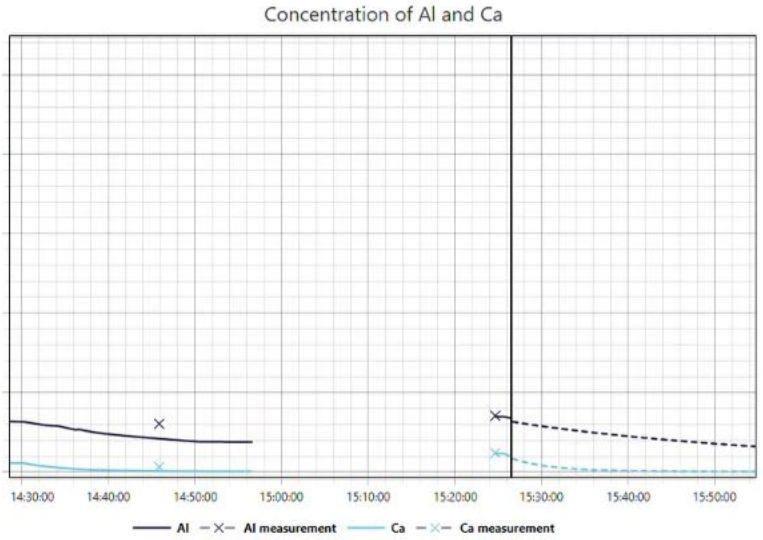

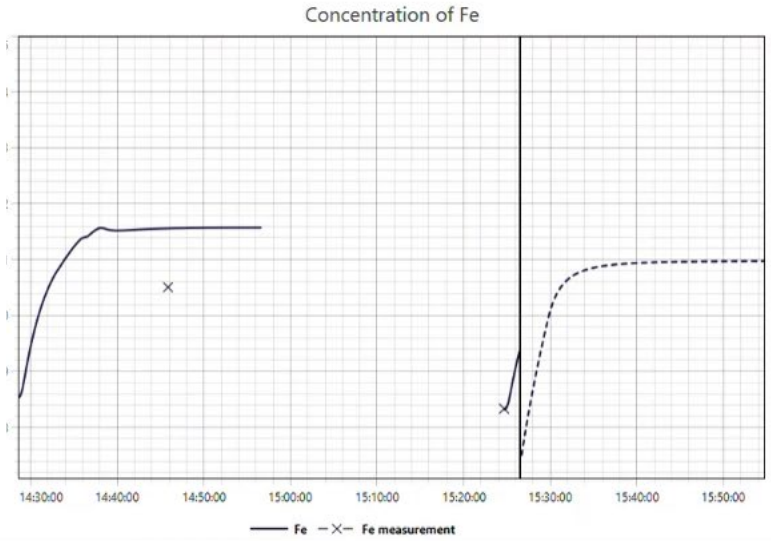

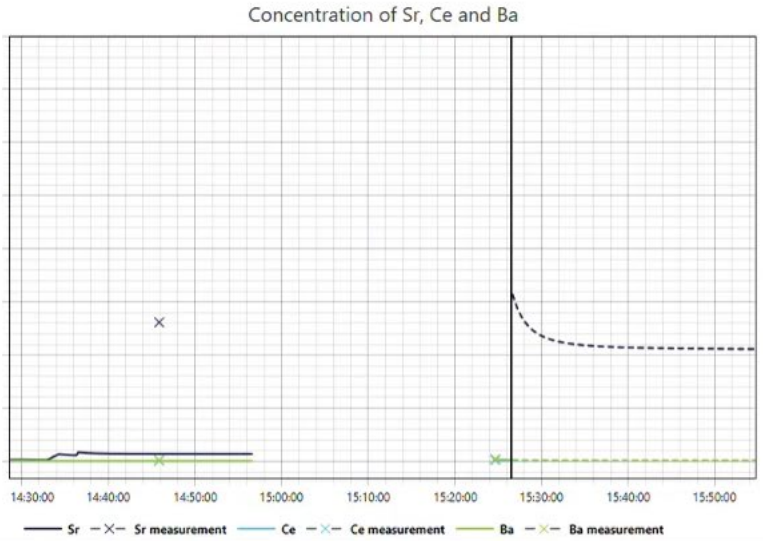

Elkem

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QUESTIONS ?

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Thank you for your attention!

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http://www.cognitwin.eu/

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