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By Hydro

Improving safety and performance of DC casting lines by applying digital twins, process models and vision systems

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San Diego, TMS 2023

The development of utilizing process models

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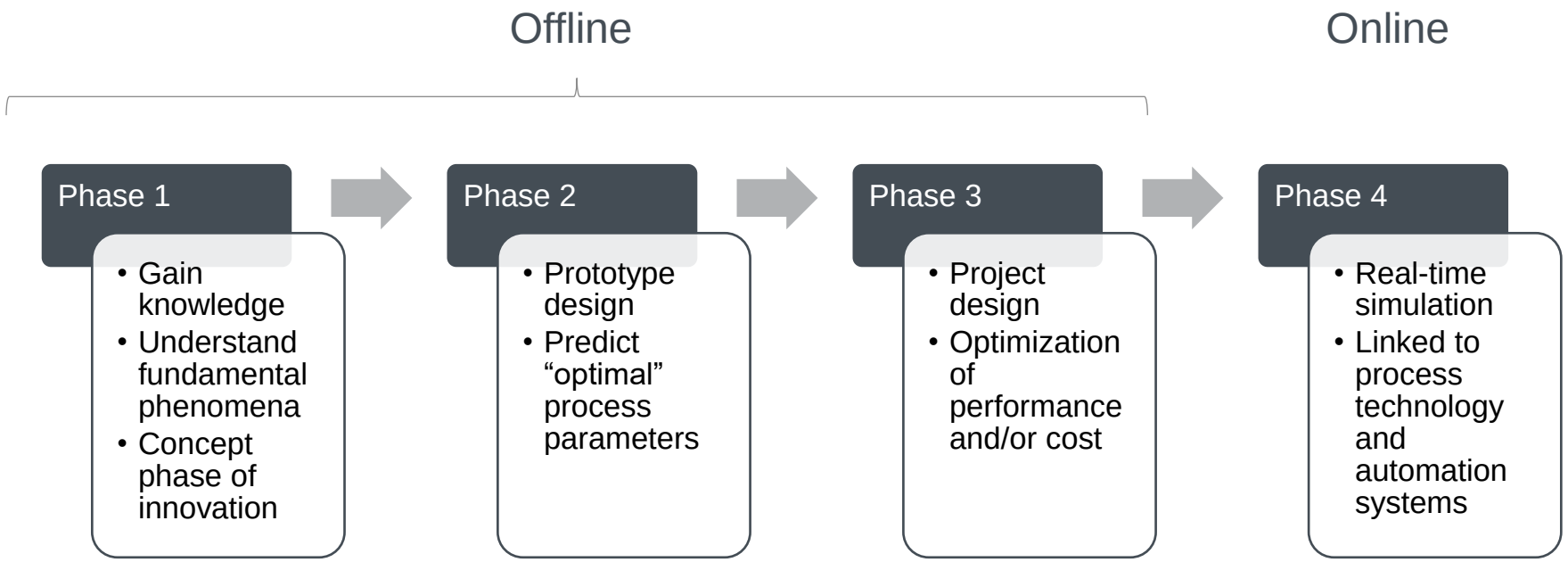
From basic research to digital twins



01

LPC forging stock – *Mission impossible..*

Saved by modelling..

Forge stock innovation

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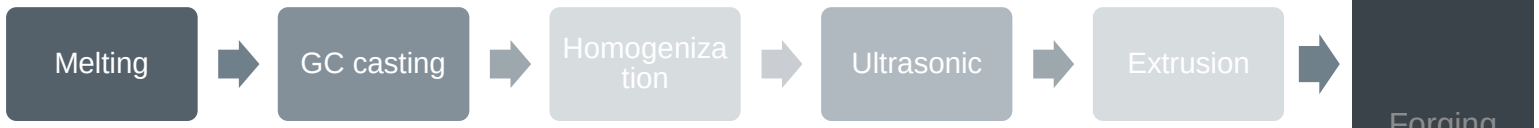
Simplifying the value chain – making aluminium more competitive

Traditional route



Innovation

Forging to final product

An innovation in high quality forge stock production:

- ~20% lower production cost
- Improved lead time
- More consistent mechanical properties
- New alloys with improved prop. may be used

LPC casting

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Starting point – casting of small-diameter LPC **2014**

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Ø80, Ø90 mm billets

Bleed-out

- Too short or long filling time

Freezing

- Too long filling time

Forge stock – R&D process

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2017 Q4

Development

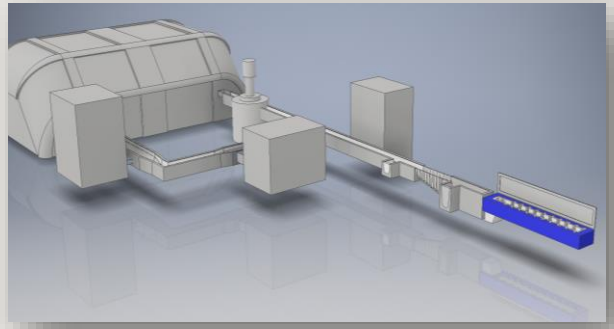
Implementation

2020 Q4

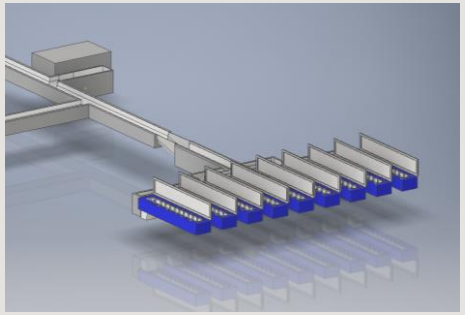
Experimental work

Reference center – forge stock casting

Simulations



Reference center – digital twin



Husnes – digital twin

Digital Twin of a casting line

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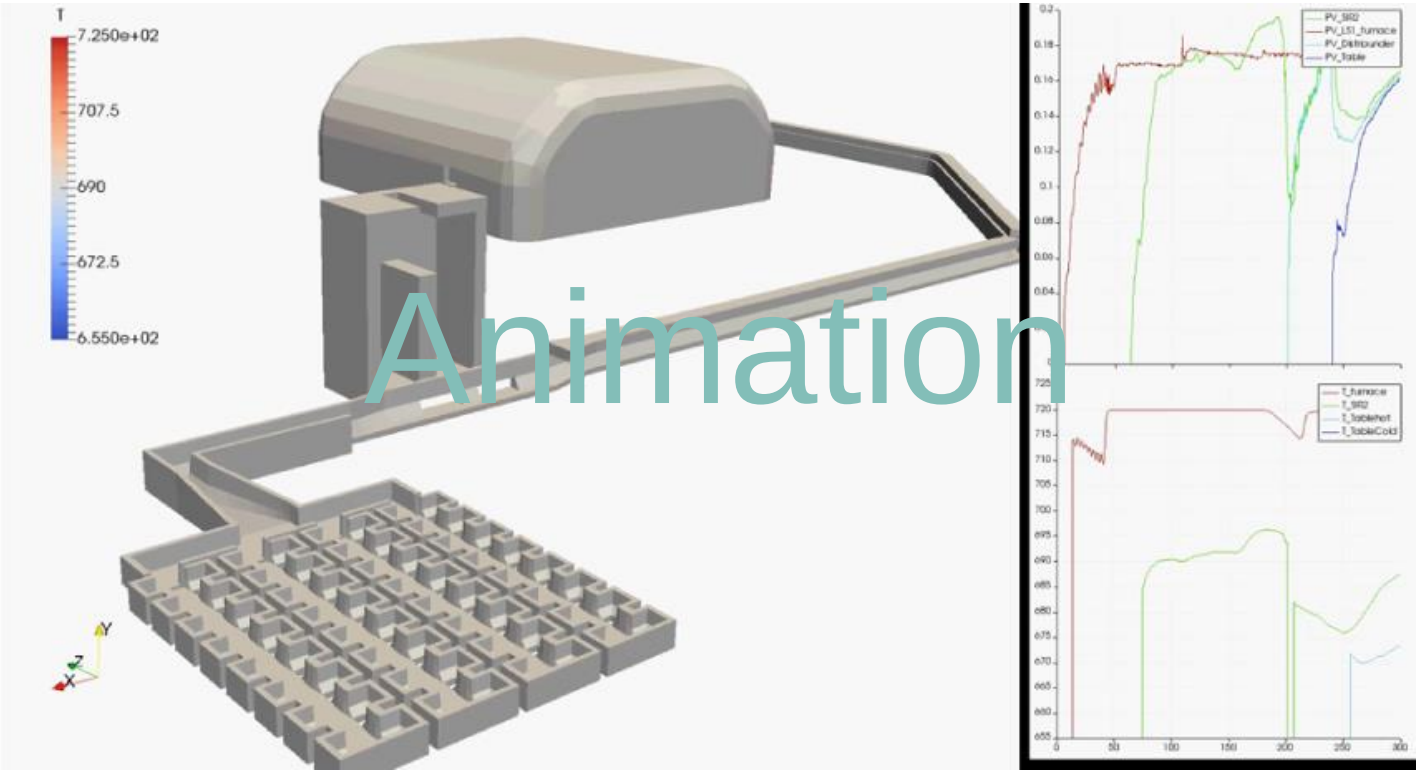
- Two-phase turbulent flow
- Heat transfer
- Radiation
- Integrated control system:
  - Sensors:
    - 5 level measurements
    - 12 vacuum measurements
    - 12 temperature measurements
  - Actuators:
    - 2 vacuum ejectors
    - 11 pneumatic dams
    - Control dam
  - Control systems:
    - 5 PID controllers



Casting line simulation – combining detailed models

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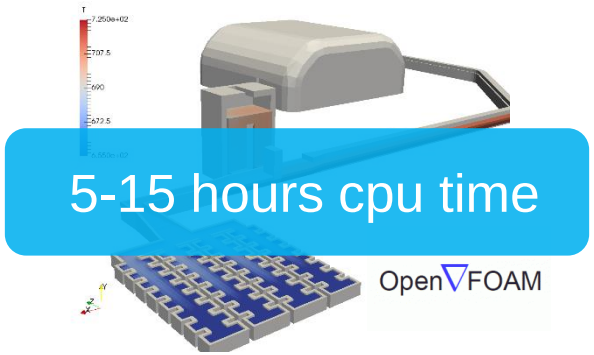
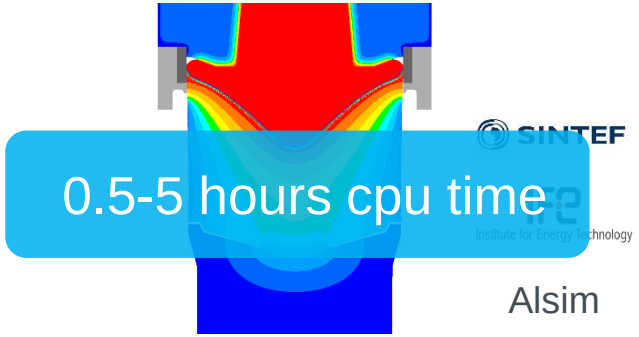
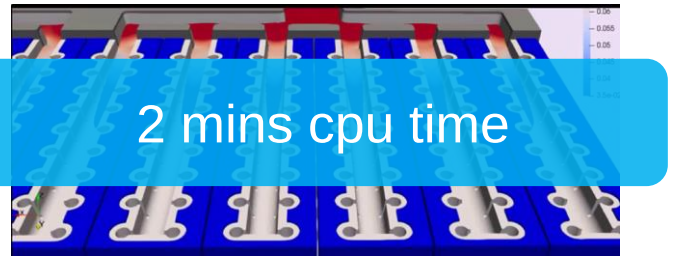


1. Detailed simulations of full casting line

2. Detail simulation of filling



3. Thermomechanical simulation of DC casting using Alsim



Reduced model of casting line

python
OpenFOAM

Animation and comparison with video

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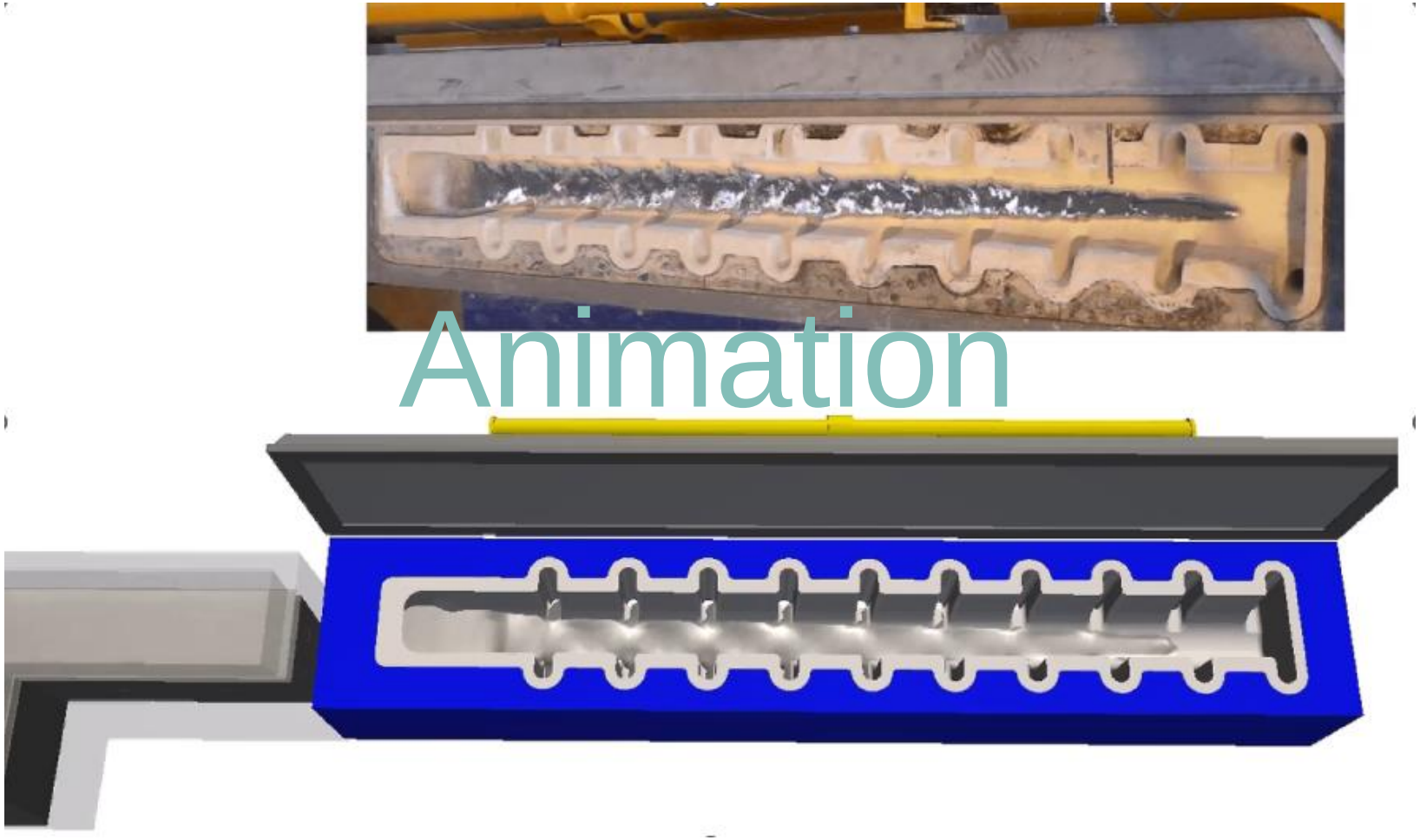

Variation in filling and holding time

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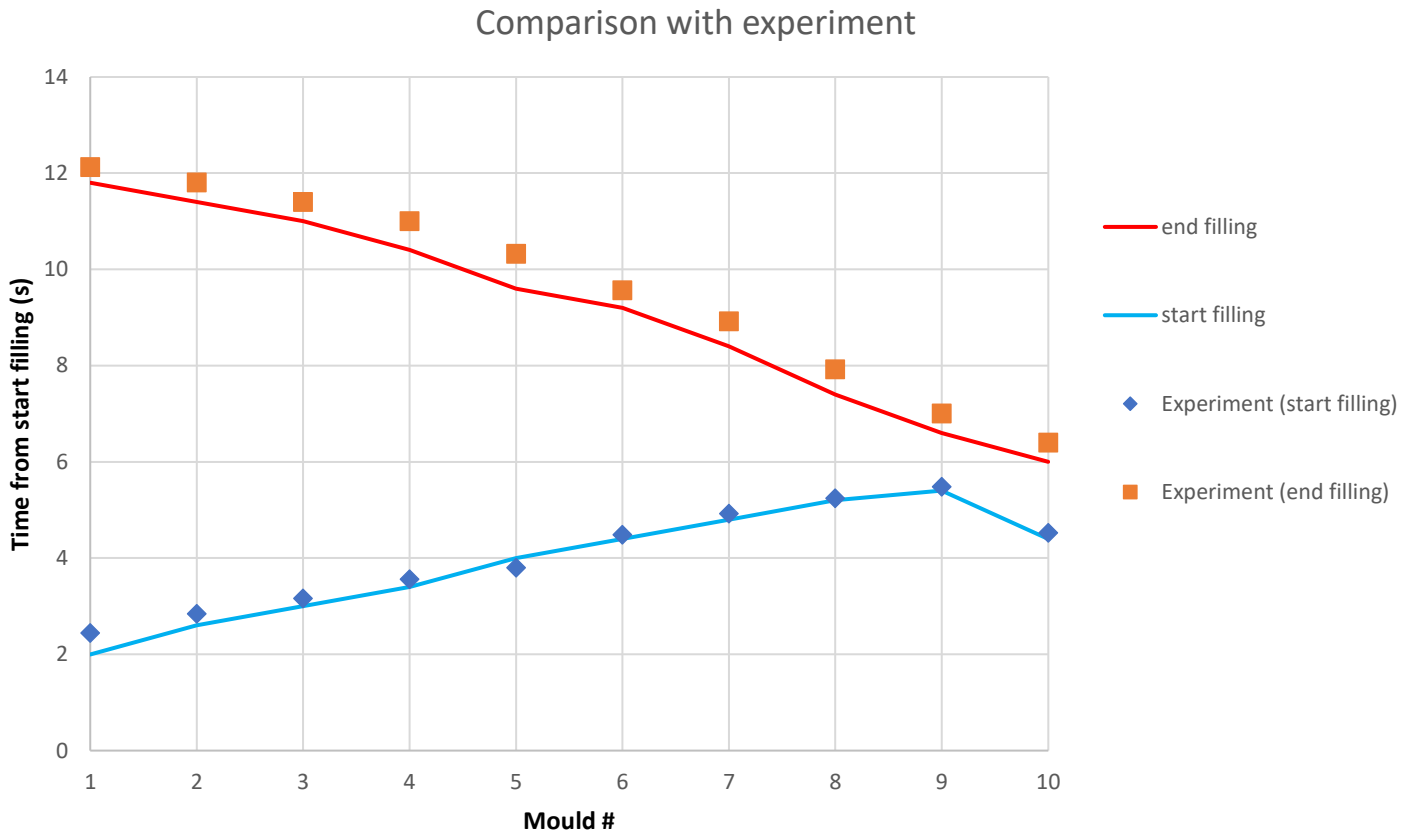
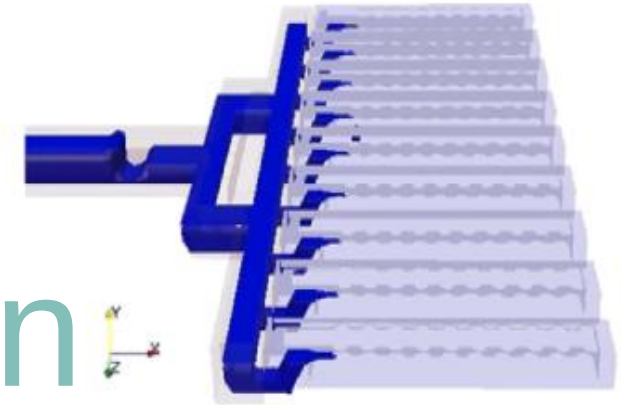
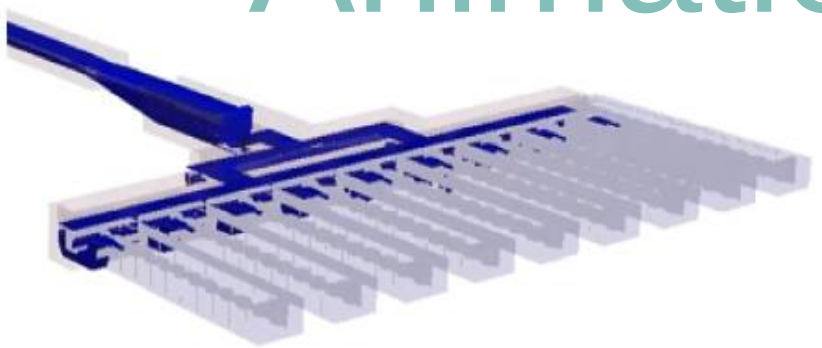
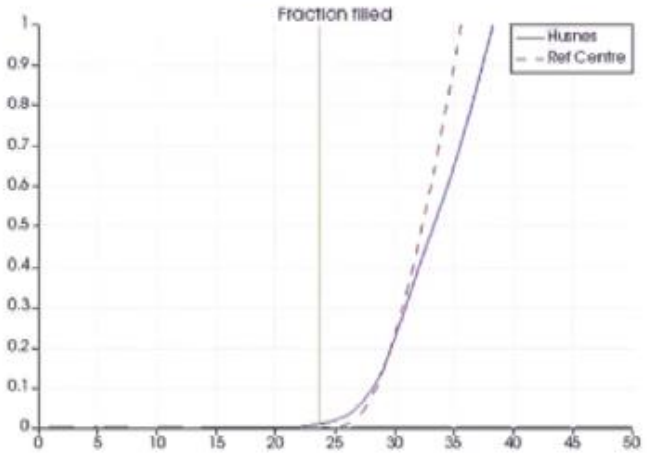




Animation




Fraction filled
Husnes
Ref Centre
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
40
45
50

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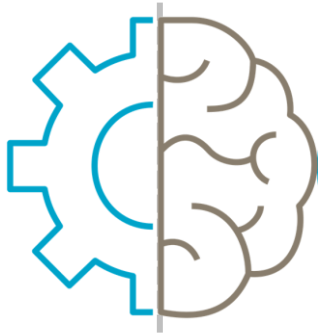
Experiment  **Simulation**

Husnes wk1	Ref.centre		Ref.centre	Husnes v64
	12.0 s		11.8 s	13.5 s ✓
	5-12 s		3-11 s	3-10 s ✓
	691 °C (min 675 °C)		694 °C (min 670 °C)	685 °C ✓

02

Robotic Metal Sampler

Less people close to liquid aluminium

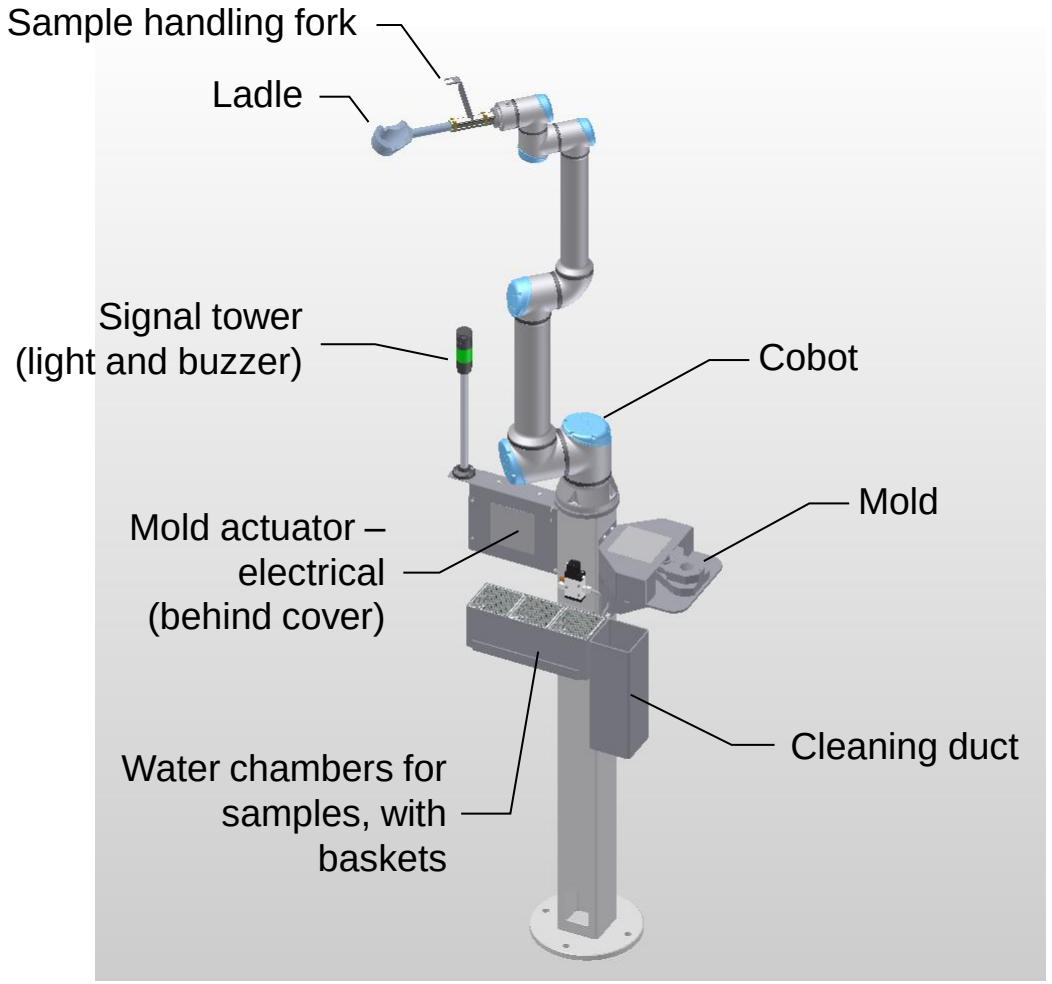
Benefits of a Sampling Robot

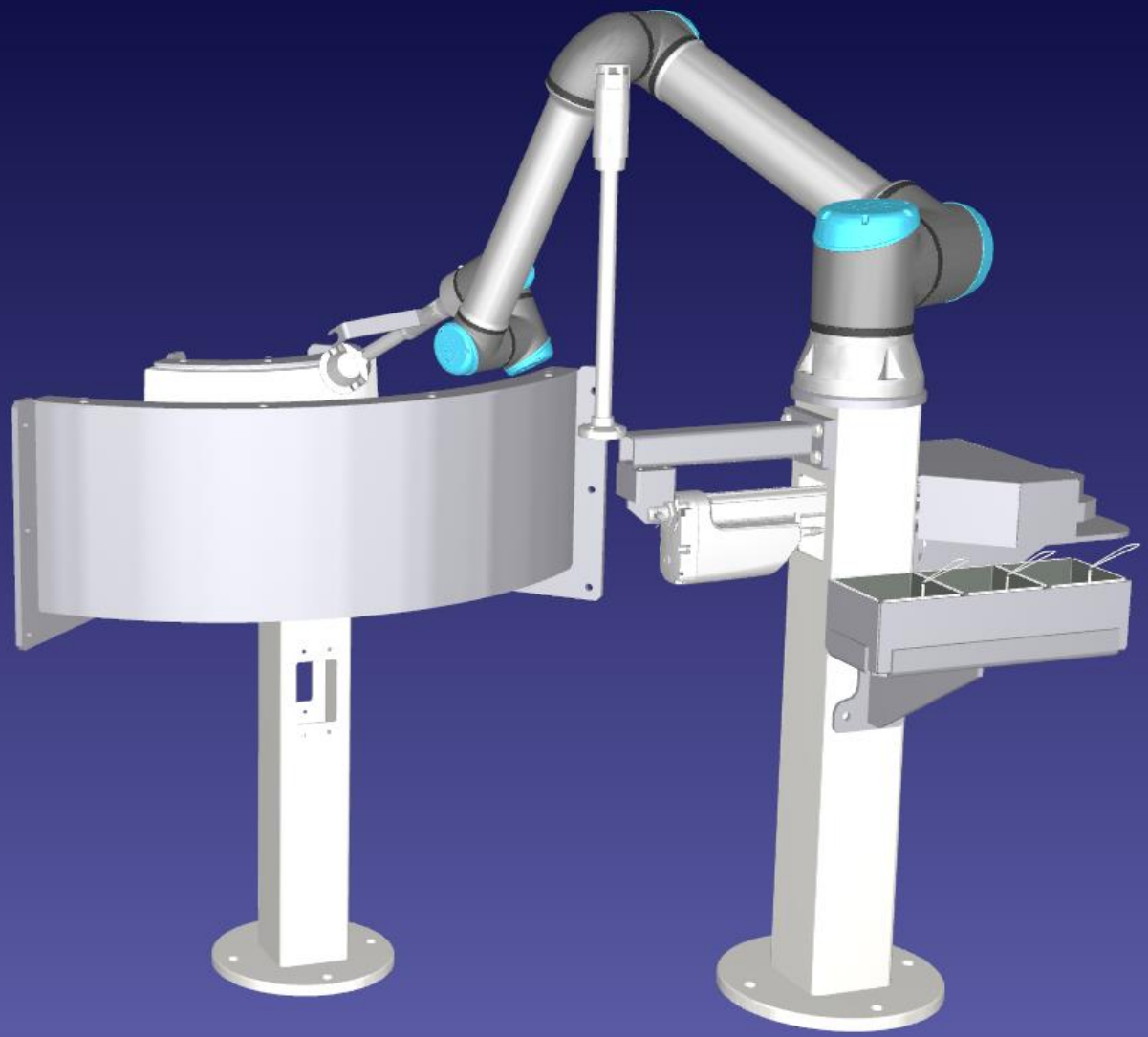
- Moving personnel away from the liquid metal.
- Reducing manual operations during casting.
- Making sure all samples are taken at the correct time.
- Better repeatability, as the sampling is performed the same way every time.

Robotic Metal Sampler

Main Parts

- Cobot (collaborative robot) – Robot that can work alongside people without fencing
- Tool with ladle and a fork for handling samples
- Mold for OES-samples
- Electrical actuator for the mold
- Cleaning duct where the ladle is cleaned using compressed air
- Water cooling in cassette system for sample tracking
- A signal tower with light and buzzer



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3
2
1


Video

03 High density table for extrusion billet

Skipping prototyping

Project challenge

- Casting pit was the bottle neck
- Challenge: Increase the number of billets
- New casting table design needed
- We would like to skip prototyping

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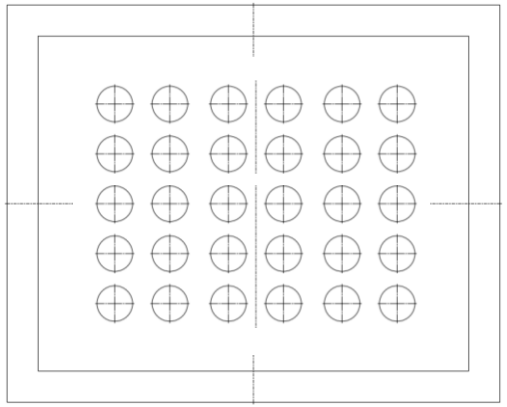
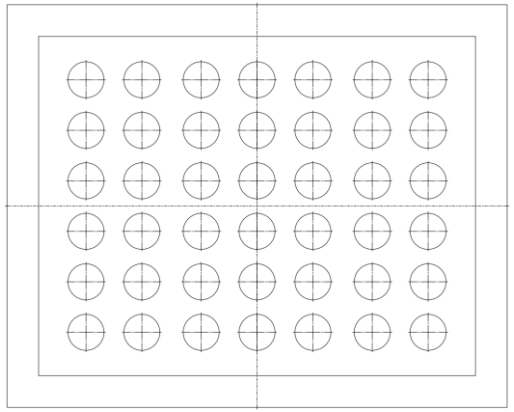
2003 GC228
30 billets



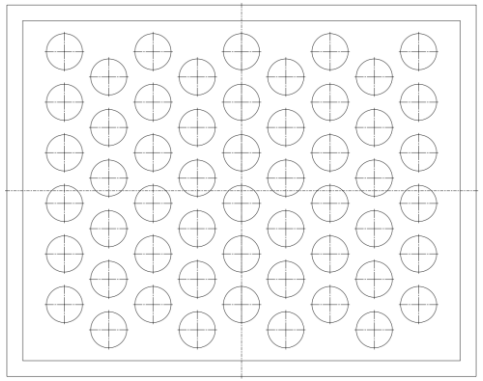
+1 column
+1 row

2014 GC228
42 billets



+2 columns

GC228 Compact
54 billets



+80%

Modelling

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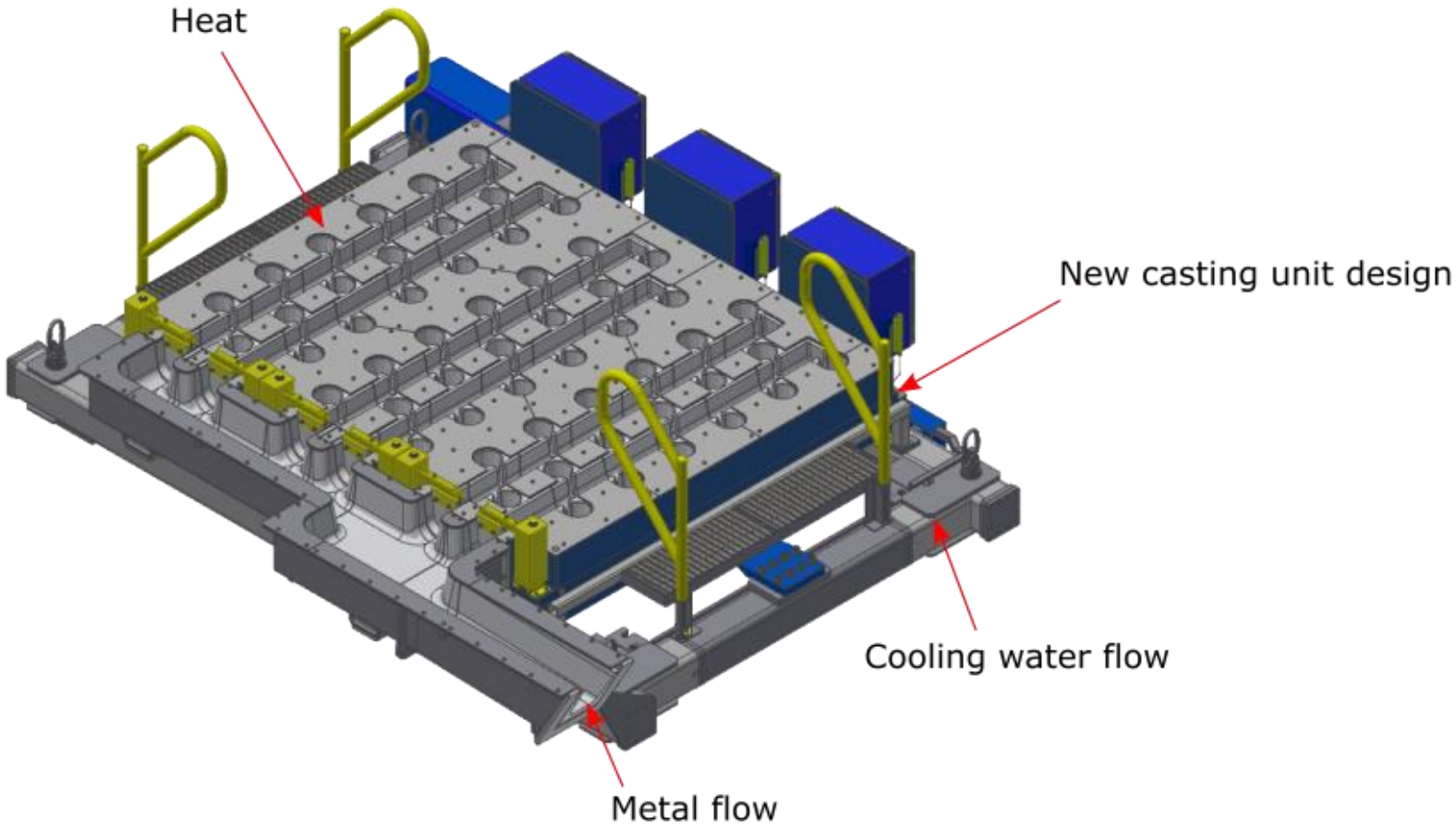
Decided to model the following parameters

- Metal flow
- Cooling water flow
- New casting unit design
  - Strength/stiffness
  - Stability
- Heat expansion
- Melt heat loss



Water flow simulation

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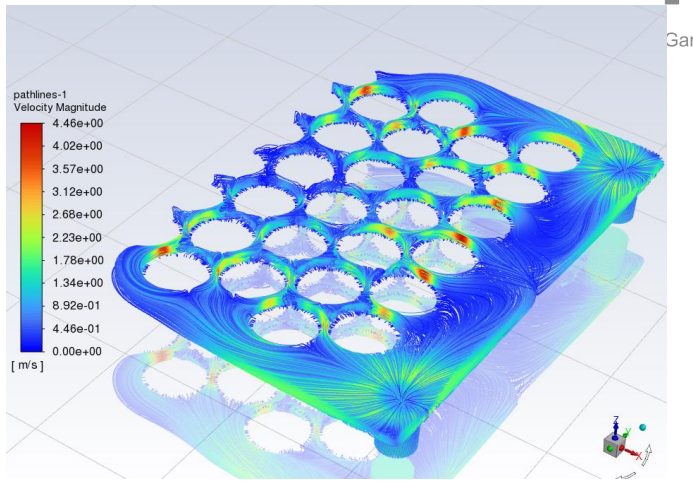
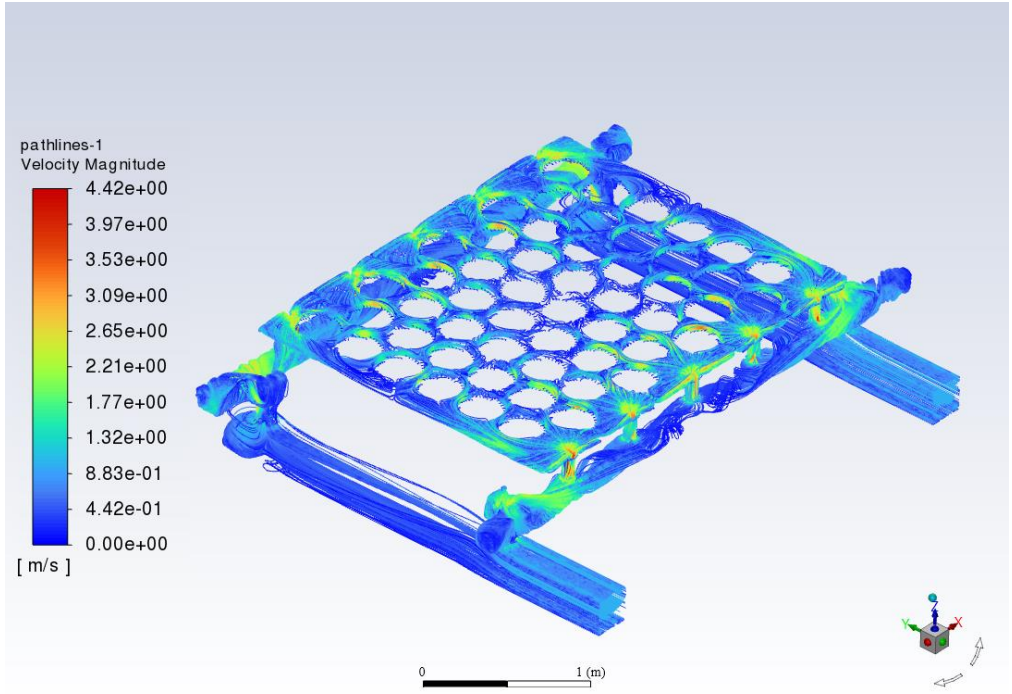
- Simulate water entering casting machine and exiting through moulds
- Water distribution
- Pressure drop across casting table (water supply requirement)
- Water velocities



Ansys
FLUENT



Casting unit temp. and deflection

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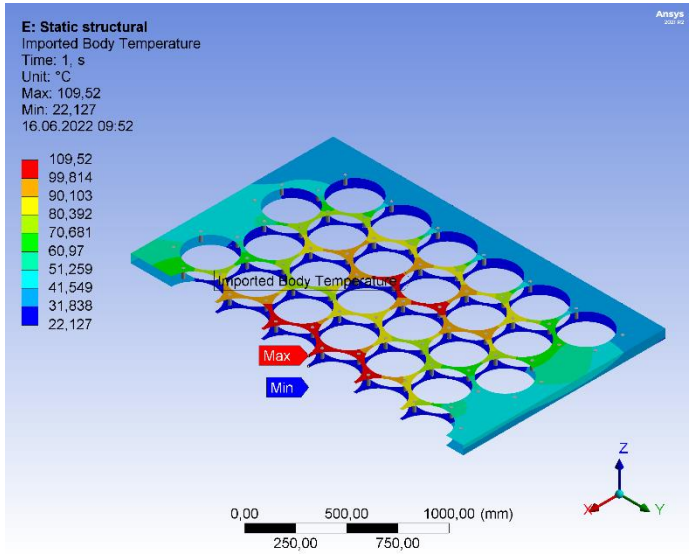
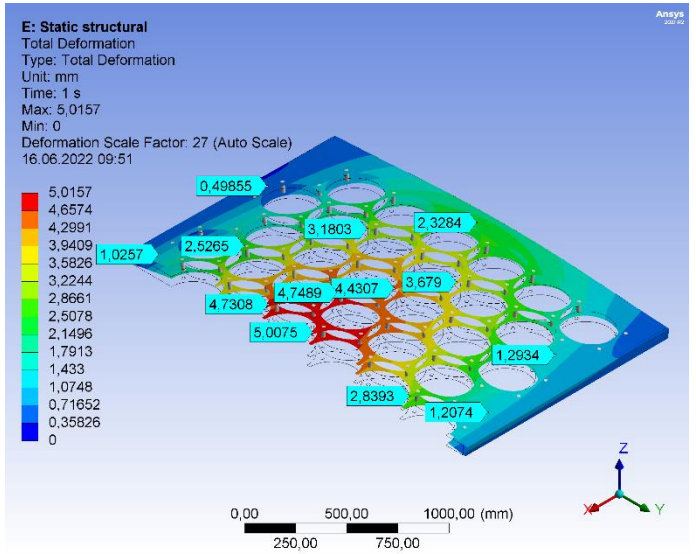


Casting unit temperature

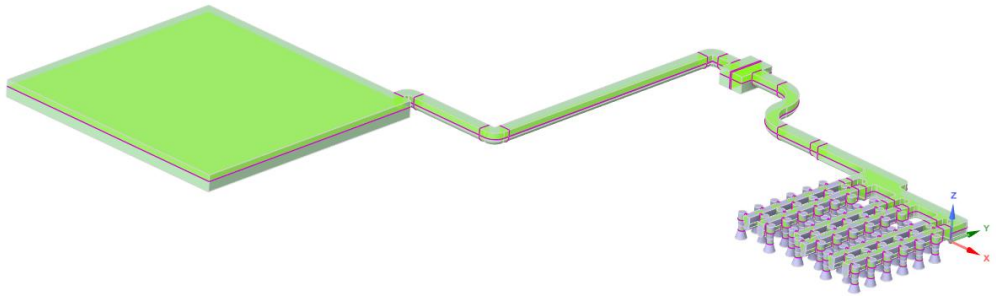


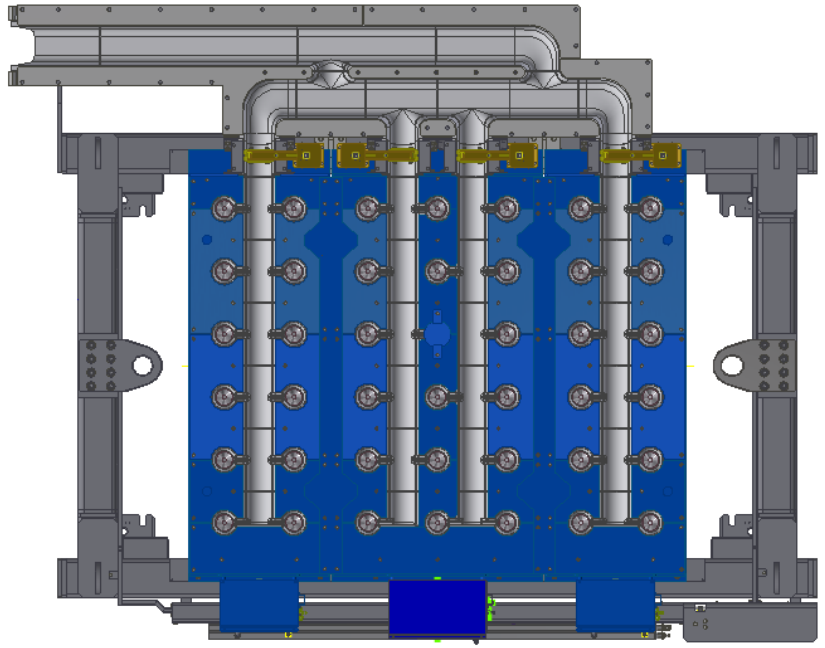
Casting unit deflection

Filling simulations

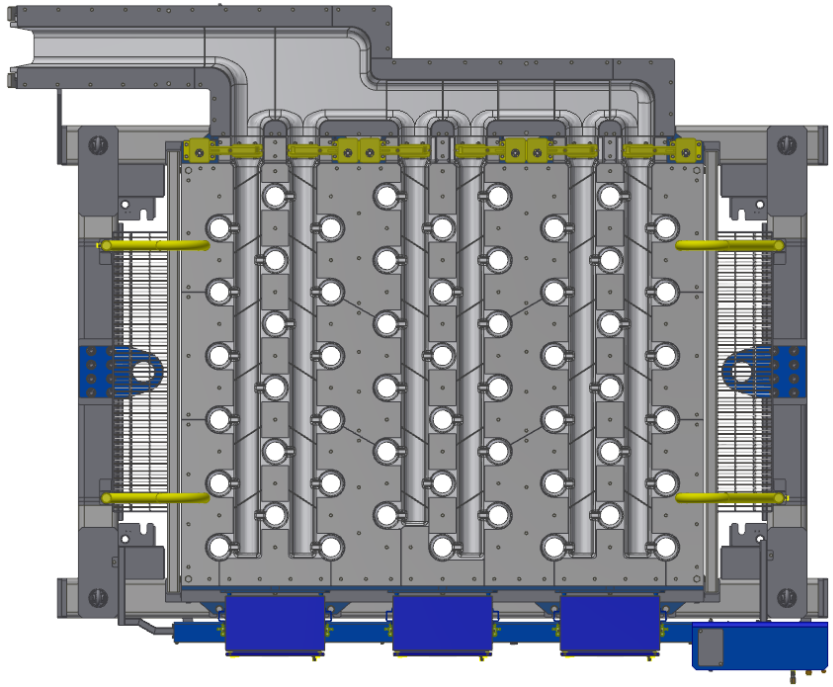
How should the distribution launder look?

- ~27 simulations ran before finalizing design
  - A lot of trial and error
  - ~48 hour runtime per simulation
- New distrubution launder design
- New distrubution pan design





Old design



New design, Commissioned Jan 2023

04 Pit monitoring

Better insight

Pit Monitoring

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Why Pit Monitoring?

- Increased safety
- Remove operators from the pit
- Continuous and automatic monitoring of billets and slabs
- Detect bleed outs early
  - limit material damage
  - Reduce propability of molten metal exsplosions

Development challenges

- camera must be mobile to see all billets in the casting table
- The units must be small and easy to install (retrofit)
- Challenging environment – moist and dark
- How to predict a bleed out?
- Camera needs to know its position (billet #)
- No or little “from the shelf” hardware and software

Source

Our strategy

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Compact mobile camera robot

- Wifi communication
- Rechargeable (battery driven)
- Rail-based robot
- HD-camera
- Thermal sensor
- Light source
- Auto-scan mode – and manual control
- Auto save of all data (local and cloud)

billet surface temperature and bleed outs

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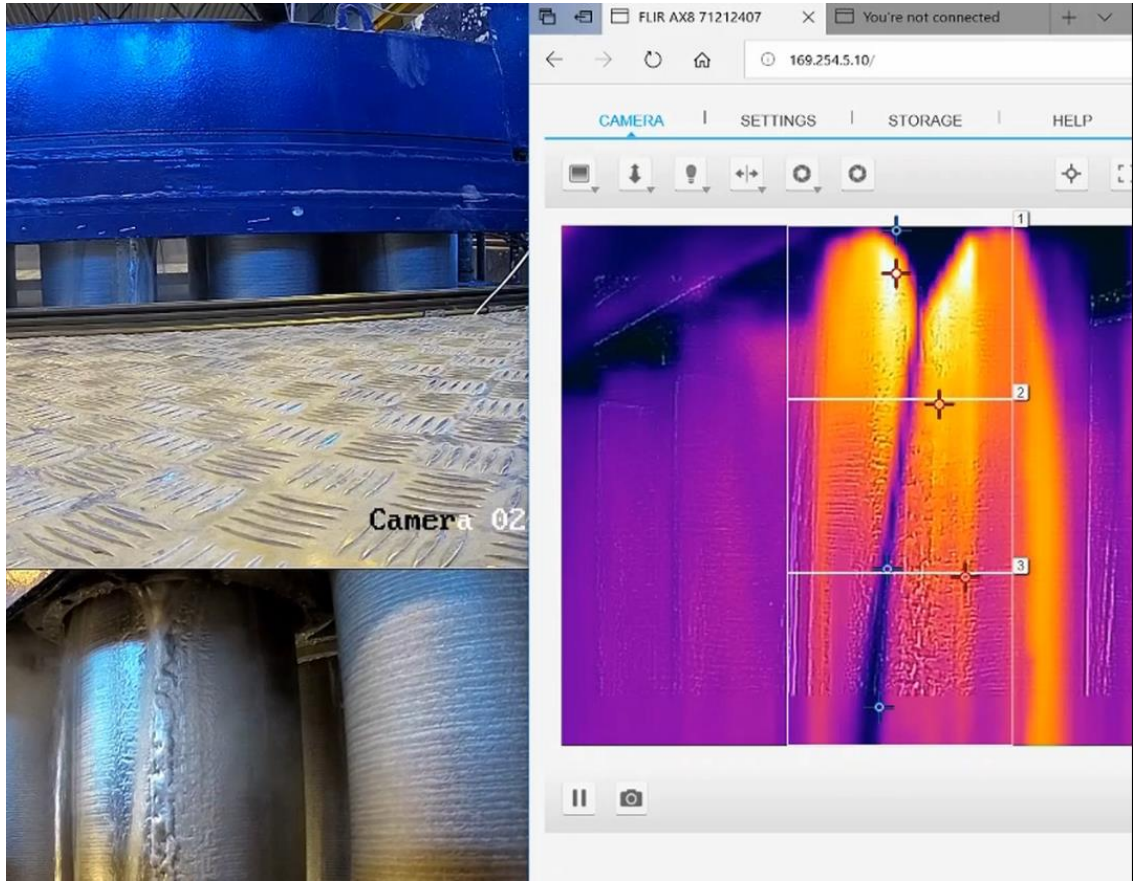
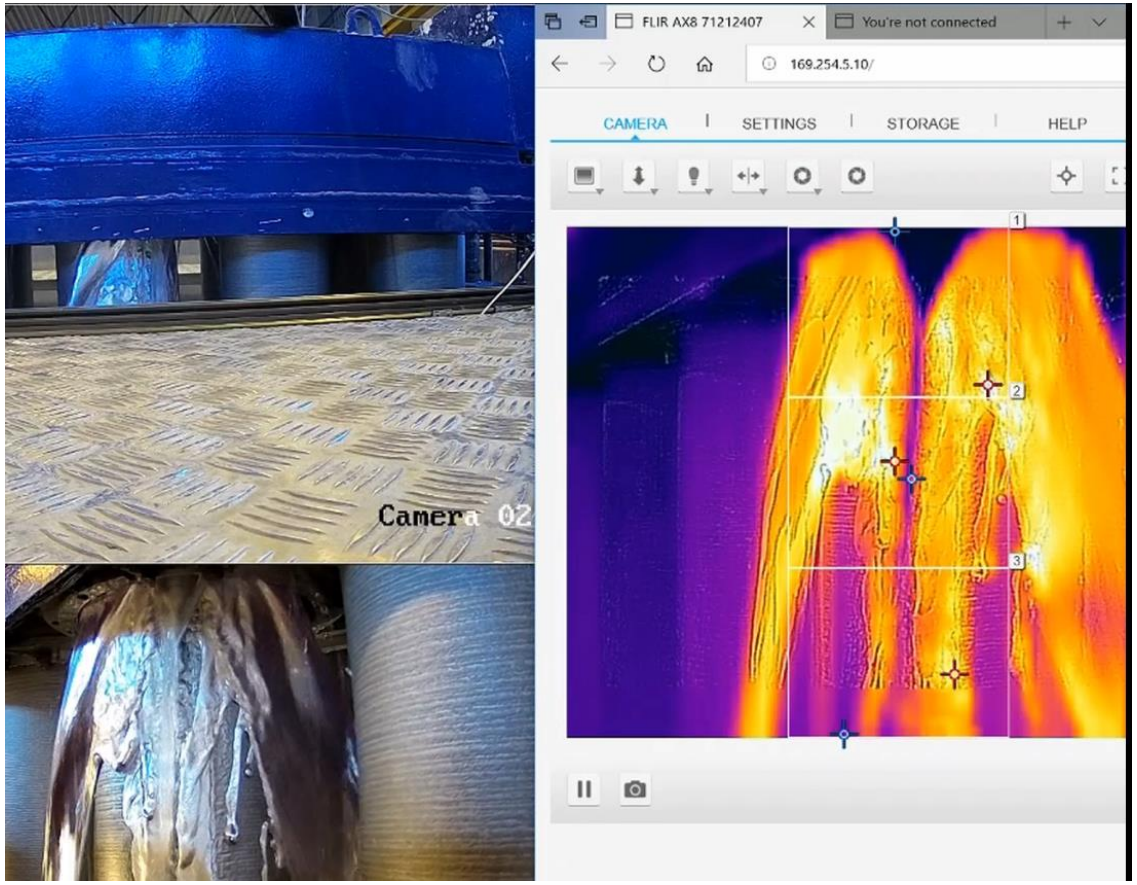
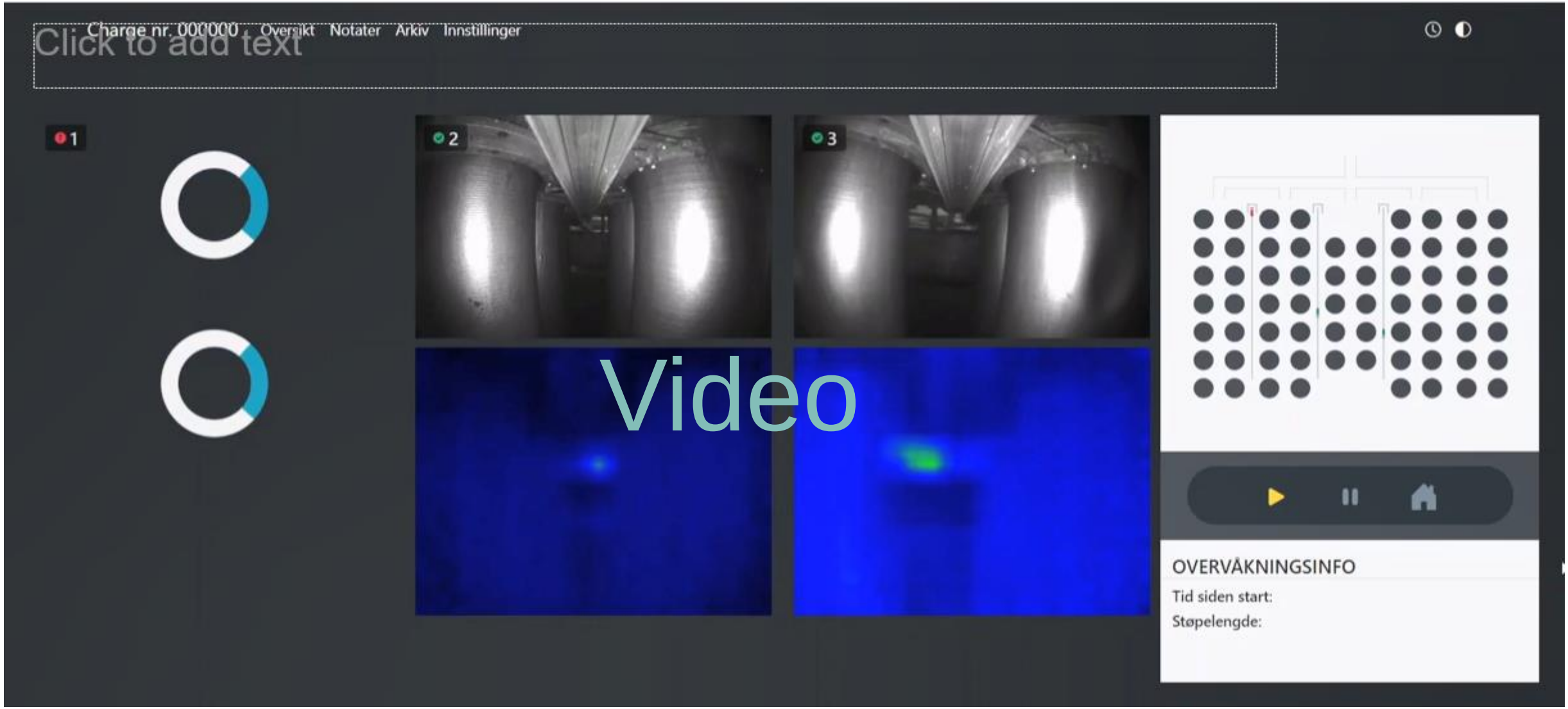




Camara robot video



05

Casting line simulator

Merging process models and automation systems

What is a control system?

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- Manipulates the process by controlling valves, actuators, motors, hydraulics etc
- The system’s input is based on sensors – level, temperature, pressure etc. – and time
- Process sequences, control loops and logic is programmed in the system
- Safety logic is part of the safety functions together with mechanical design and hard-wiring

Complexity

Typical hycast casting line control system

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- 50 valves
- 8 PID controllers
- 500 I/O
- 350 alarms
- 70 safety functions
- 80 timers

- Parts of the system are built at different locations and at different times
- Difficult to test the control system part-by-part
- Impossible to do complete system test before everything is assembled on site

Casting line simulator

Integrating process models

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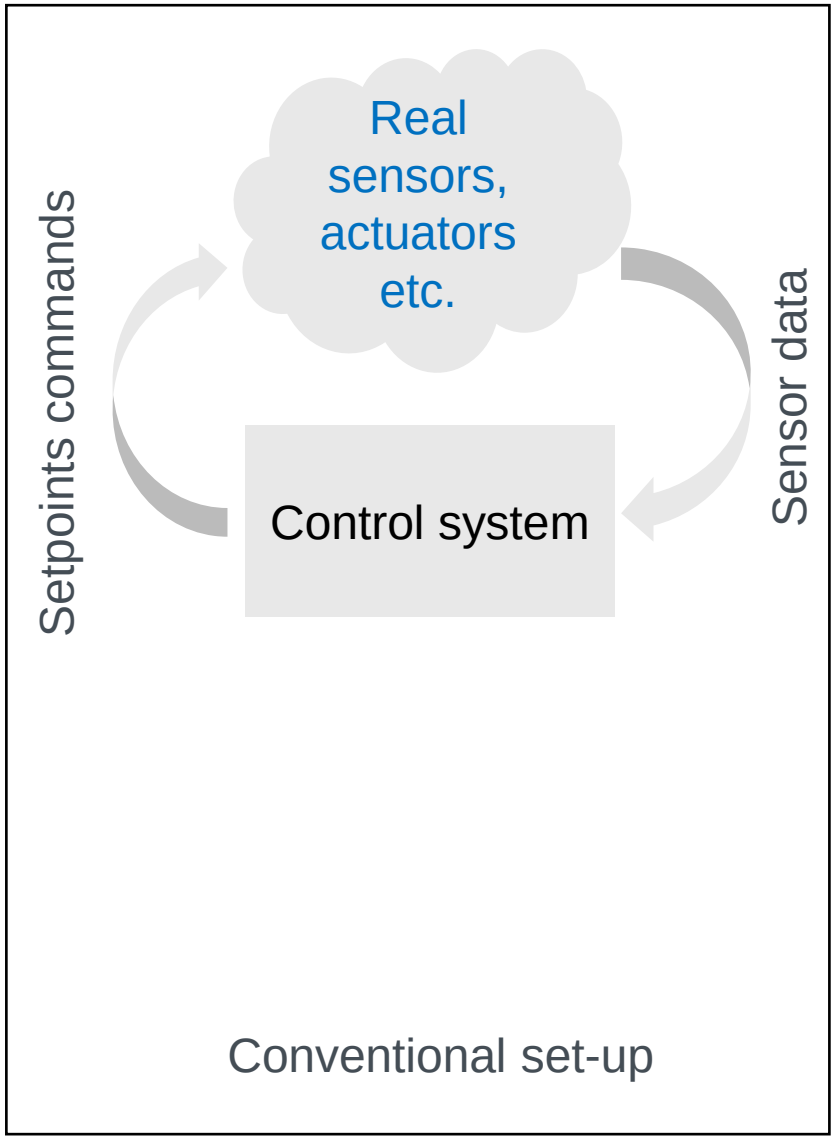

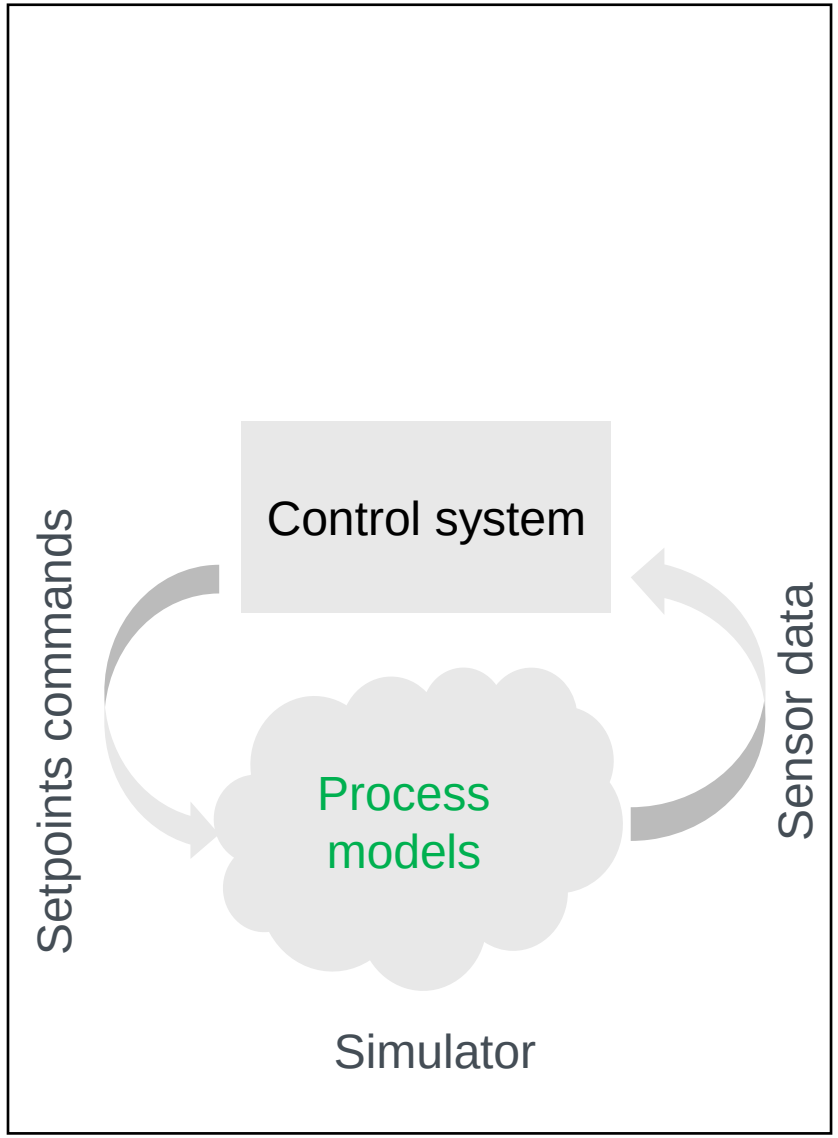

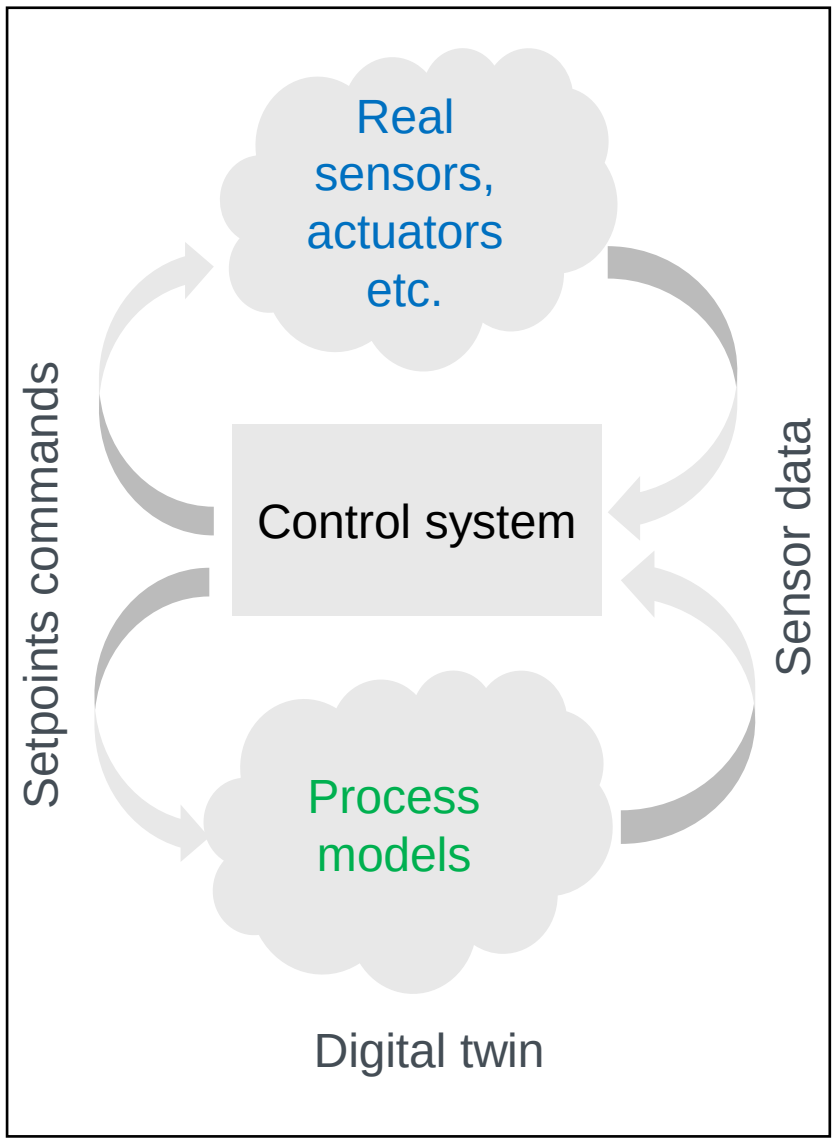

Benefits

Better, sooner

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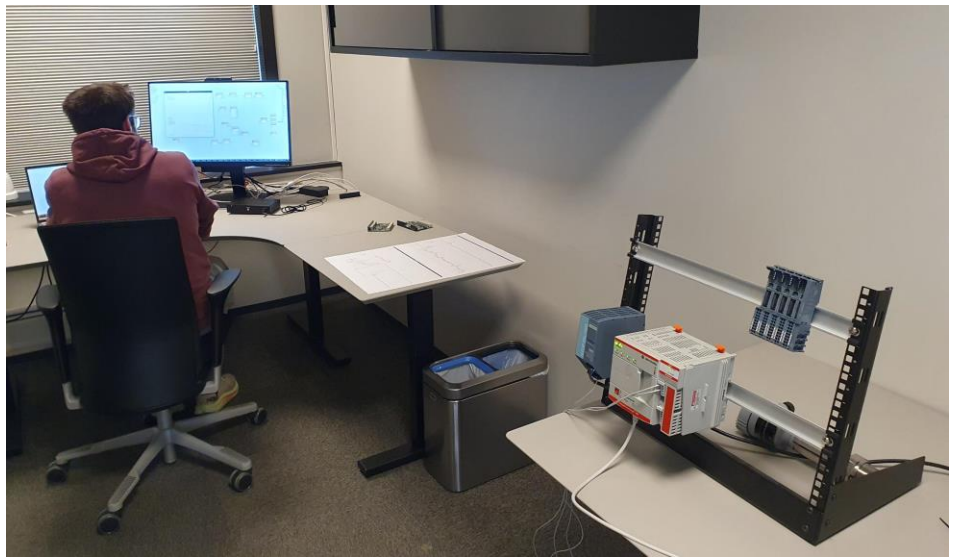
Present status (simulator)

- Test interlocks and sequences to ensure safety functions
- Complete control system test
- Virtual commissioning – tuning of control loops, adjustment of process parameters, configure alarm limits
- Test of HMI and trend applications
- Test new functionality or behaviour (modifications)
- Re-run scenarios based on historical data
- Testing «what if» anomalies
- Estimated time saved on site for el/aut: 2-4 weeks

Future work

- Improve and further validate process models
- 3d-visualization of the casthouse with live data, works both with simulated and actual data
- Simulator for training
- Utilize digital twins



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