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MMM Special Session
Future Perspectives of Automatic Control in Metal Processing

Modern control systems: the basis for meeting future demands in heavy plate rolling

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- Introduction
- Examples for modern control systems
    - Furnace optimization and control
    - Material tracking and optimal production scheduling
- Future demands on heavy plate production

Requirements

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Past demands on heavy plates

- plate dimension (w x t x l) as well as plate flatness and form: **(wider) tolerances**
- Tolerances in a few mechanical properties (e.g. tensile strength, strain)
- Wide spreads in delivery time
- Large number of same plates in each order

Future demands on heavy plates

- plate dimension (w x t x l) as well as plate flatness and form: **tight tolerances**
- Tolerances in many additional properties as crack resistance, sour-service resistance
- Exact delivery time (especially in projects)
- Single plate production

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- Plate surface
- Tracking of orders and single plates
- Additional Measurement data
- Energy consumption during plate production
- And finally: pricing pressure

Demands on automation

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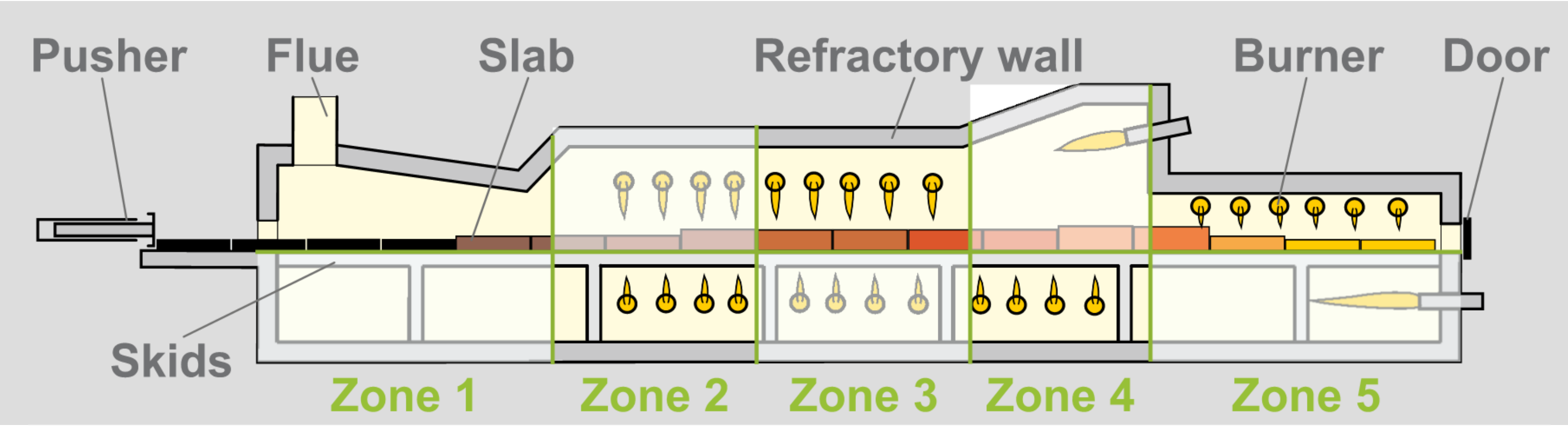
- Reliable Control of single processing steps (plate geometry, temperature, …)
- Interaction of processing steps
  - Feedforward control
  - Product-by Product control
- Automatic tracking and control of plate production schedule
- Cost reduction
  - Decreasing scrap rate
  - Optimizing degree of utilization and efficiency of the process steps
  - Minimizing energy consumption

Furnace optimization and control



Aim of the project (common research with ACIN, VUT)

- Improving final slab temperature
- Minimizing energy consumption by investments in new control concepts and energy recuperation systems

Procedure: Development of a mathematical model of the whole furnace as a basis for

- Optimization-based controller design (MPC)
- Design and pre-calculation of a new evaporator and economizer system

Model based control of a reheating Furnace

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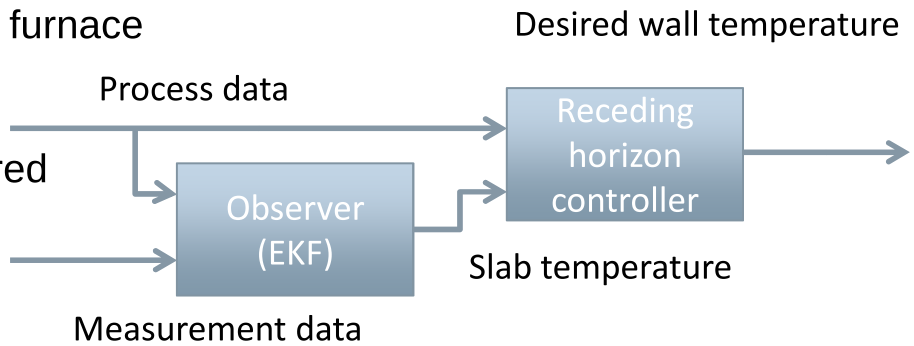
Modelling

- 1D heat conduction model for the products
- Temperature dependent material parameters
- Calculation of radiative heat transfer inside the furnace

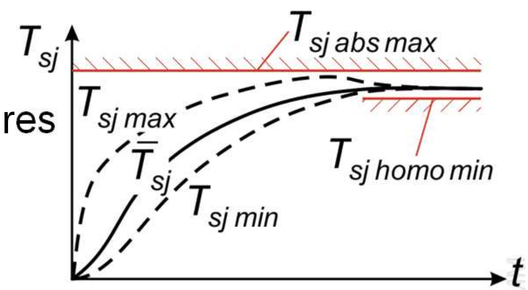
Challenges

- Slab temperature distributions can’t be measured
- Switching structure of the system



Controller design

- Furnace wall temperatures used as control variables for the underlying level 1 controllers
- Extended Kalman-filter design for an observer of the slab temperatures
- Design of an optimization-based receding horizon controller (A. Steinböck, ACIN)



Results

- **More accurate slab temperature realization!**
- **And additionally: Improved slab reheating strategy yields energy savings of approx. 9.7 %!**

Increase of production throughput

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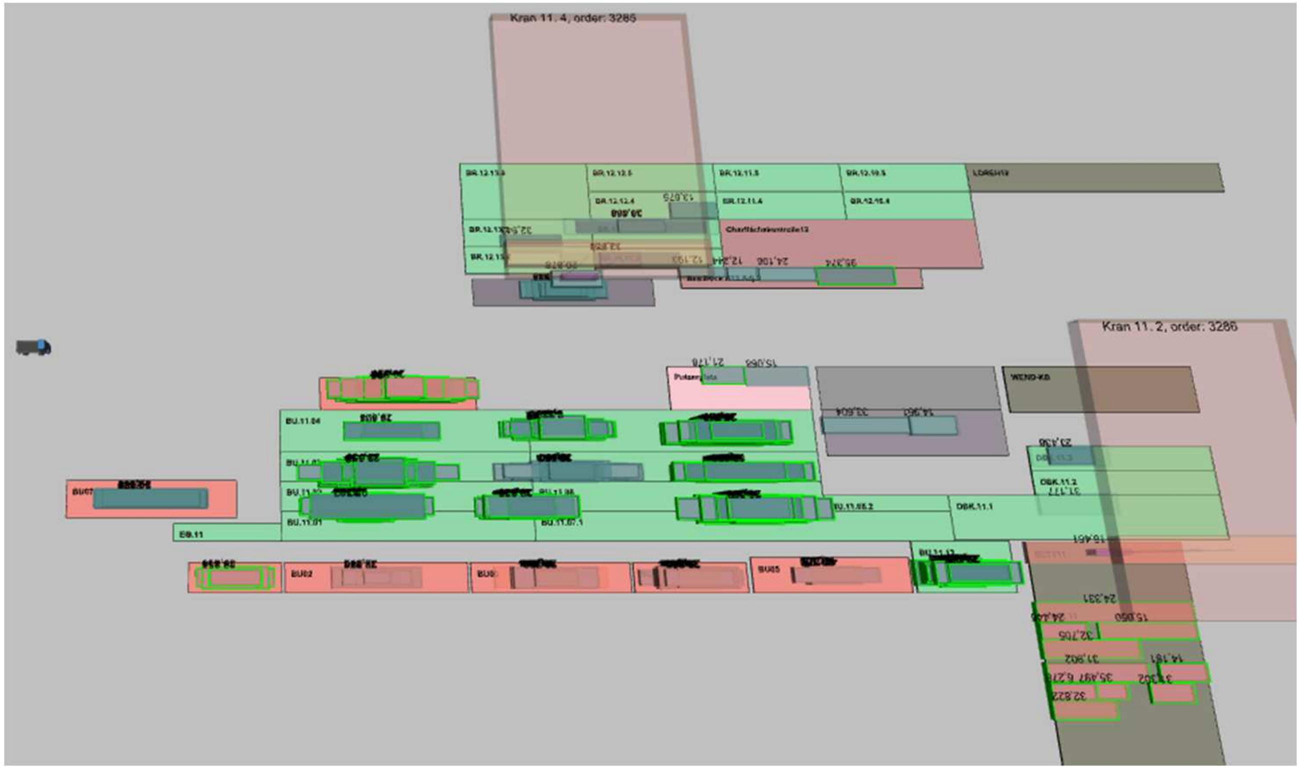
- Problem description:
  - Due to very varying market conditions, there is no steady state process in the production
  - Single plate production will replace large orders of same plates
  - In this situation capacity bottlenecks become more and more challenging
    → potential orders cannot be accepted or have to be shifted
  - Instead of investing in additional machines to avoid the bottlenecks
    → improvement and optimization of material
    flow inside the production facilities

- Strategy: on the example hydrogen effusion
  - Development of simulation model to simulate the material flow
  - Development of optimization-based scheduling systems for cranes and production machines (taking into account stocks, planned shutdowns, manpower)
  - Aim: Increasing throughput or at least creating a basis for new investments

Example: Hydrogen effusion of thick plates



➢ Conclusions:

- An investment in new machines is not always the only solution to increase the throughput of a production system.
- An investment in process optimization and automation is often less expensive and more flexible, especially in systems with highly fluctuating demands

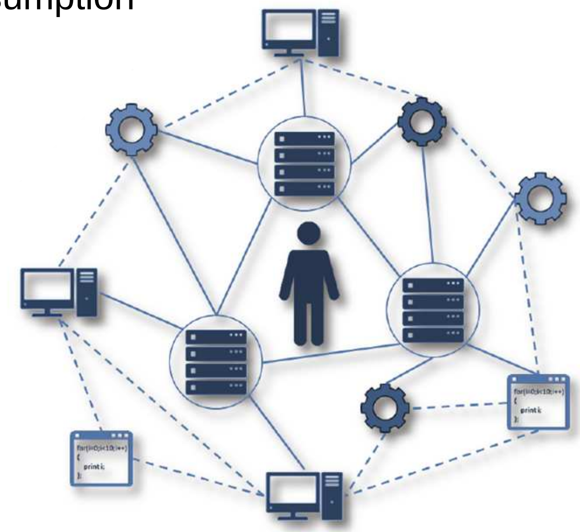
→ **Future perspective in plate production**

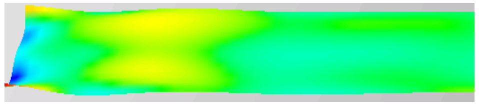
Operations research with optimization based scheduling in combination with automatic control

Demands on heavy plate production

Future perspectives for automatic control

- Improvement of machines and products as well as energy consumption
  - model-based or data-driven (nonlinear) control
  - Vision-based controller design
  - Optimization-based control
- FDI (Fault Detection and Isolation)
  - Support of maintenance for complex technical systems
- Ergonomic Improvement
  - More Intensive use of robots (e.g. material testing)
  - Support of human workers
- Operations research: Logistics optimization and scheduling algorithms
- Development of new measurement devices (e.g. surface inspection, Flatness) and use of the data for process control

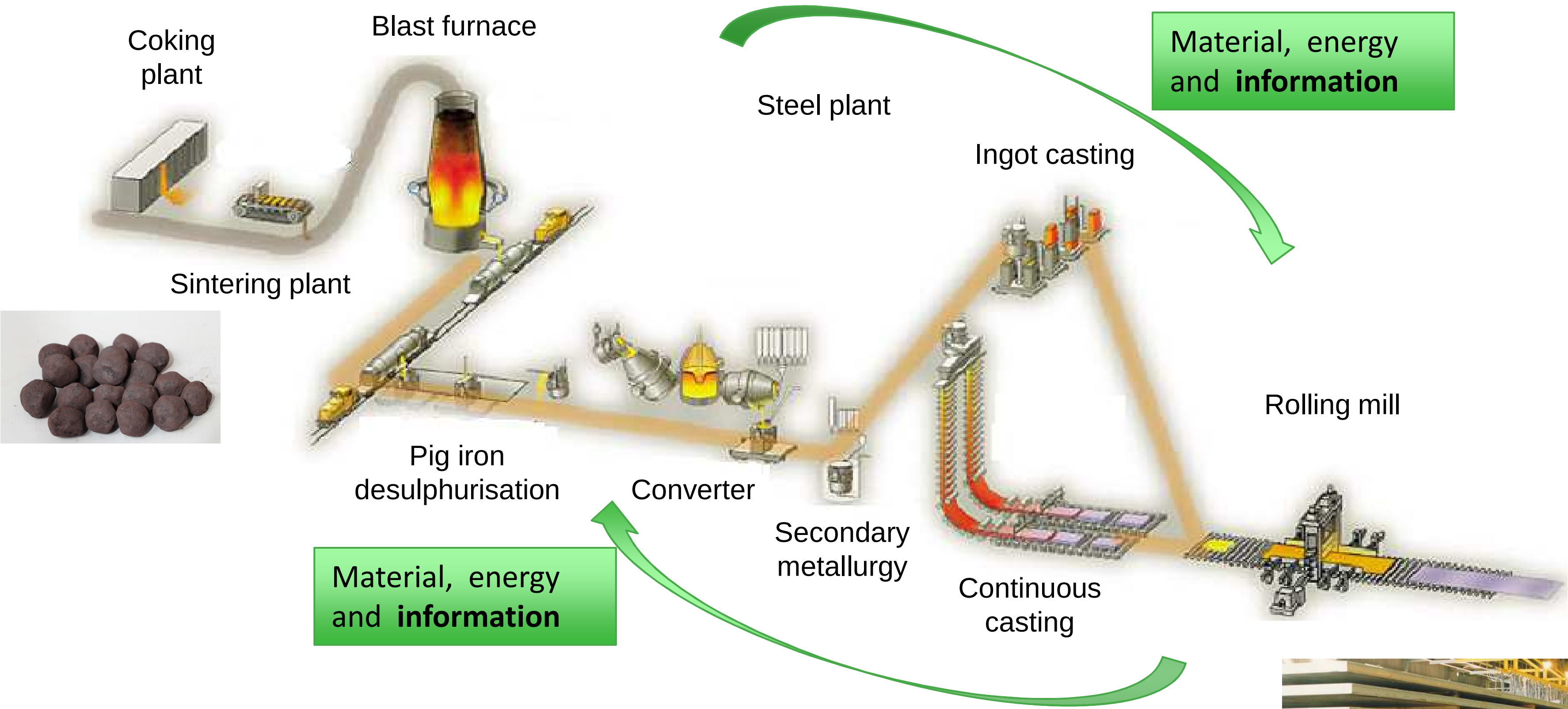




Cyber-Physical Systems (CPS)

- Development of “smart plate production”: Industry 4.0
- Production process as a network of interacting elements with physical input and output instead of as standalone devices

Cyber-Physical Systems (CPS) in an integrated plant



Building up a network and use of information to control and improve

- Process and production reliability
- Process and energy efficiency
- Final plate quality and delivery time

Thank you