PRONTO

PROcess NeTwork Optimization for efficient and sustainable operation of Europe's process industries taking machinery condition and process performance into account

PRONTO — PROcess NeTwork Optimization

Condition-aware operation and scheduling

ABB Corporate Research Germany, Accai Speciali Terni, BASF, Equinor, Norwegian University of Science and Technology, Technical University Dortmund

Condition-aware operation and scheduling

Motivation and Objective: Taking **equipment condition** and **performance** into account in **scheduling and operations** allows for more accurate optimization affecting **safety, reliability, and profit.**

Conclusion: For **improved operation** it is important to take equipment condition into consideration. Computationally efficient optimization formulations have been developed for **large-scale systems** for such purposes.

Frederik Schulze Spüntrup

(NTNU, Equinor/ABB DE)
Model-based optimization for scheduling and operation of energy networks

Giancarlo Dalle Ave

(ABB DE/TU Dortmund, AST)
Investigation of energy and production synergies

Egidio Leo

(TU Dortmund/Ineos, CMU)
Energy-aware operation taking account of stress on equipment

Jesus Hernandez

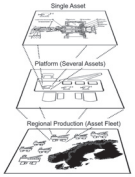
(AST/TU Dortmund, ABB DE)
Optimization of materials and energy flows in the stainless steel industry

Ouyang Wu

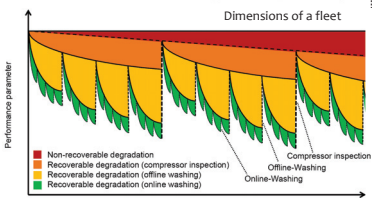
(BASF/NTNU)
Monitoring and operation of batch reactors with consideration of degradation effects

Combined Maintenance Scheduling and Planning

- Perform maintenance **because of degradation,** not just because of approaching asset failure
- Discrete-time model based on Resource-Task Network approach (**MILP**)
- Consider various types of **maintenances**
- Novel enumerator formulation
- Applicable to **large asset fleets** (e.g. compressors)
- Improvement of operational profit

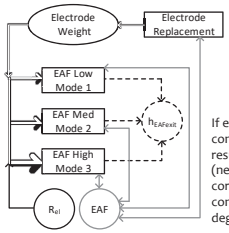


Dimensions of a fleet



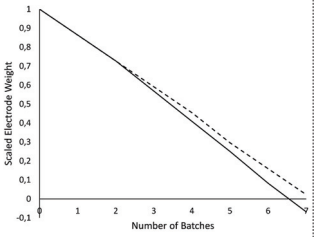
Performance degradation of compressors over time

Demand-Side Management and Equipment Condition



Operating modes of an electric act furnace (EAF) and their impact on electricity consumption and electrode lifetime (thicker line denotes higher consumption)

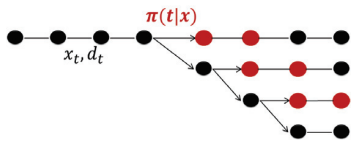
If electrode degradation is not considered (solid line), the resulting solution is infeasible (negative final weight). This is corrected by explicitly considering electrode degradation (dashed line)



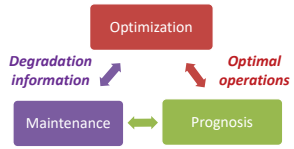
- The goal of steel plant scheduling is to **balance the complex trade-offs** between **electricity usage** (and the associated time-based price), **electrode degradation**, and **task timings**
- Discrete-time approach based on the **Resource-Task Network** (MILP) with the goal of minimizing total production cost

Integrated Prognosis and Operation

- Novel **Condition-based maintenance** formulation accounting for degradation uncertainty
- Integration **prognosis** and **operation** optimization
- Stochastic programming and **endogenous uncertainty**
- Dynamic interaction between the scenario tree and the health of the equipment via prognostic models.



Scenario tree with endogenous uncertainty

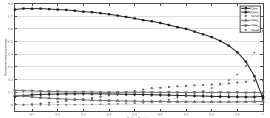


The proposed approach

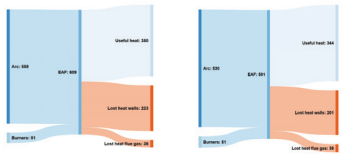
Optimization of energy consumption in the EAF process

The first step in the stainless-steel production process from recycled material, the melting process, is the most **energy intensive.** Its efficiency changes according the properties of the raw materials.

- A **novel optimal control problem** that calculates the setpoint of the melting furnace was explored in this work.
- Novel **models** of the process were **developed and validated**



Dynamic Efficiency of the process

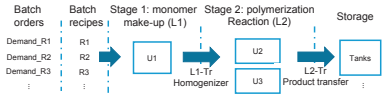


Energy flows. Left – Base case. Right – Optimal Case.

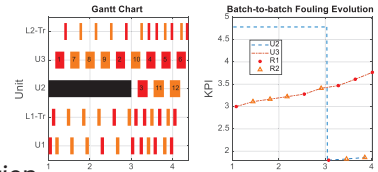
Short-term scheduling of multi-product batch plant

The aim is to improve batch scheduling in a **multi-product batch plant** by explicit consideration of batch-to-batch **evolution of fouling**

- Novel formulation for condition-aware batch scheduling
- Continuous-time precedence based approach (MILP)
- Integrate **with prognosis model** for sequence-dependent fouling evolution



Topology of multi-product batch process



Optimal solution of 12-order (2 recipes) scheduling

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska Curie grant agreement No 675215