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EFFICIENT MANUFACTURING OF ELECTROLYZER CELLS FOR GREEN HYDROGEN PRODUCTION

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ABSTRACT

Many countries and companies are pursuing the goal of climate neutrality, which is increasing the importance of green hydrogen. However, due to high electricity and capital costs—particularly for electrolyzers—the production of green hydrogen remains expensive. As part of the StaR research project, a novel stack for alkaline electrolyzers was developed, along with a scalable production concept. To reduce investment risk, a semi-automated pilot production facility was established at the Dortmund site. The production processes and workforce allocation were modeled using a discrete-event simulation and analyzed with regard to productivity and resource assignment. A generic control logic enables flexible evaluation of various scenarios for work plan optimization. Real-world process data are continuously collected and integrated into the simulation model for ongoing updates.

1 DEVELOPMENT AND SCALING OF A PILOT LINE FOR ELECTROLYZER CELL PRODUCTION

Many companies and countries are aiming for climate neutrality (Kachi et al. 2025; IPCC 2022). However, since not all energy demands can be met by electricity from renewable sources, the demand for green hydrogen has been rising steadily in recent years—a trend that is expected to continue (Wappler et al. 2022). Currently, the production of green hydrogen remains costly, primarily due to high electricity prices and substantial investment costs, particularly for electrolyzers (Basma et al. 2022).

To reduce the production costs of electrolyzers, a novel stack for alkaline water electrolyzers was developed within the StaR research project. The stack represents the central functional unit of the electrolyzer and consists of multiple electrochemical cells, which are stacked and firmly connected. The objective was to design an economically viable production concept for industrial-scale manufacturing of this key component. Innovative manufacturing approaches were developed to enable largely automated mass production at high volumes.

Figure 1: (right) Pilot production line in Dortmund; (left) Positioning gantry.

As the establishment of a highly automated production line involves significant capital expenditures, a semi-automated pilot production facility was first implemented at the Dortmund site to minimize financial risks. This facility serves as a technological test platform to evaluate and gradually automate the newly developed manufacturing processes under real-world conditions. This step-by-step approach allows for a gradual increase in production capacity while distributing the investment burden over a longer period.

The performance of the pilot line is not solely determined by the current level of automation, but also significantly influenced by the number of personnel deployed and the allocation of tasks to individual workers. Purely analytical evaluations reach their limits in this context, as some process steps require collaborative work by multiple operators and certain equipment is used across different process stages.

For this reason, a discrete-event simulation model was developed to represent the pilot production system. The goal was to systematically analyze and evaluate system performance as a function of the number of operators and the specific task assignments (work plans).

2 SIMULATION-BASED ANALYSIS OF TASK ASSIGNMENT IN PILOT PRODUCTION

To optimize work plans based on the number of available operators, the pilot production line was modeled using the simulation software Plant Simulation. The model represents the core assembly process, which primarily consists of a positioning gantry used to accurately place large-scale components onto workpiece carriers. For each cell, two stacks - top and bottom - are created. Subsequently, these two stacks are brought together at a so-called "marriage station," where the top part must first be rotated 180° before the two halves are joined. After joining, the top part's workpiece carrier is removed, and the completed cell is transported to the test station. There, the cell is lifted off the carrier using a crane and inserted into the testing station. Upon successful testing, the cell is transferred to the stacking station. A central focus during modeling was the flexible representation of workers and their assigned tasks. Tasks are defined via a configurable table containing parameters such as process times and required resources. A separate dependency matrix maps logical task relationships (precedence and succession), and an assignment table allows tasks to be flexibly allocated to individual workers. To control the simulation, a generic logic was implemented that dynamically manages process flow and worker allocation based on the input data. This setup enables low-effort evaluation of different task assignment scenarios. Using the simulation tool, the output of the pilot line can be increased by more than 25%. Simulation results include, among other metrics, the output of the pilot line and the workload distribution across workers. The simulation model is continuously updated to reflect changes in the real production environment. For example, current process times are regularly recorded using a real-time location system (RTLS) and transferred to the model for parameter updates.

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