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SIMULATIVE ANALYSIS OF THE SUSTAINABILITY DRIVEN TRANSFORMATION OF CASTING PLANTS

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ABSTRACT

The current energy crisis and high fossil fuel costs are challenging energy intensive industries such as non-ferrous foundries. It is therefore important to promote the transition to renewable energy sources with the electrification of melting units. This pilot study is the first to simulate the transition of conventional foundries to sustainable technologies. For this purpose, a simulation model based on a selected example company is developed. It takes into account the energy consumption and the logistical effects of a converted operation. The simulation model is implemented as a hybrid simulation combining a discrete event simulation at the plant level and a process simulation within the furnaces. The study shows how a sustainable energy supply can be achieved in foundries. The effects of efficiency as well as energy costs and emissions are also taken into account.

1 INTRODUCTION

The sharp rise in the cost of fossil fuels poses major challenges for energy-intensive industries. To counter this cost pressure, it is important to push ahead with the switch to renewable energy sources. In addition to process and material advantages, the electrification of melting aggregates also offers the potential to substitute fossil fuels, similar to electric mobility. However, decarbonisation with the switch to sustainable technologies is associated with challenges in the industry. In particular, the switch involves significant changes in logistical operations and requires huge investments. Mathematical modelling can be used to demonstrate the feasibility and potential of this transformation. With the help of simulations, new and sustainable technologies as well as their integration into the operational process can be analysed in advance.

In the context of this pilot study, the technology shift towards sustainable foundries is being simulated for the first time. Based on a selected foundry, the necessary change is considered, starting from the existing conventional infrastructure. The simulation models of the selected foundry with the existing and the transformed infrastructure including the associated control module are implemented in Matlab/Simulink. Based on a simulation study, the energy consumption and the effects on the operational energy costs in a transformed operation are considered and the feasibility of a sustainable energy supply is demonstrated. The consideration of the optimal operational design plays an essential role in this.

2 SIMULATION MODEL

The hybrid simulation model includes the material and energy flows in the production process of a sustainable casting operation. One challenge in modelling a melting and casting operation is that the operation has both discrete-event and continuous processes. While the material flow contains both discrete (e.g. forklift transport) and continuous (e.g. melting process) components, the energy flow is modelled purely continuously. At the factory level, the material flow is simulated discretely in terms of events, while the melting furnaces are represented by a finite automaton for the machine states and a continuous process simulation for the internal material and energy flow. The melting process is complex and requires the continuous consideration of the interaction between material and energy flow. The mapping of the continuous material flow during the melting process is done with the help of ordinary differential equations. These are bidirectionally coupled with differential equations of the energy flow to take into account the interaction between energy and mass during the melting process. The modelling process and the schematic implementation are shown in Figure 1.

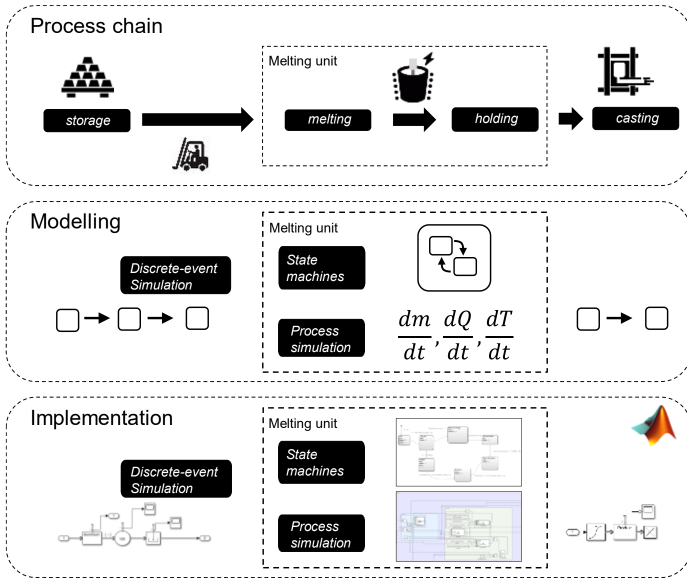

Figure 1: Implementation of the simulation model.

3 SIMULATION STUDY

Within the framework of a simulation study, the feasibility of the sustainable transformation process as well as implementation options are demonstrated. The modelled conventional casting operation with gas-fired melting furnaces serves as a reference, which was validated using data from two real operations (Schlüter 2017). In a first step, the feasibility of the transformation is demonstrated. Using different variations for capacity and electrical power of the melting units as well as different numbers of forklifts, the effects, especially on the operating sequence, are analysed and evaluated. The production quantity, energy consumption and an operating indicator for fault susceptibility are used as evaluation criteria, which are generated as output values from the simulation. Based on these criteria, an optimal plant and forklift configuration could be determined using a brute force approach. The simulation framework can therefore be used to examine plants for transformation and to show the implementation possibilities.

It could be shown for the operation investigated that productivity is also guaranteed with the converted process. The energy input is reduced by 54.3% compared to conventional operation, but different forms of energy are used with natural gas in conventional operation and electrical energy in transformed operation. The conversion into energy costs shows that no savings are achieved at current energy prices (German energy market). In terms of CO2 emissions, it can be seen that with the current electricity mix, a reduction in emissions of 24% can already be achieved compared to conventional operation.

REFERENCES

Schlüter, W., M. Henninger, A. Buswell, and J. Schmidt. 2017. „Schwachstellenanalyse und Prozessverbesserung in Nichteisen-Schmelz- und Druckgussbetrieben durch bidirektionale Kopplung eines Materialflussmodells mit einem Energiemodell“. In *Simulation in Produktion und Logistik,* edited by Wenzel, S., and T. Peter, 19–28. Kassel.