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PROCESS INTEGRATION IN THE IRON AND STEEL INDUSTRY

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Introduction

The iron and steel industry is one of the most energy intensive, as the processes operate at high temperatures. The increasing concerns about energy consumption and climate change have led to the need to refocus on energy efficiency and new technologies for a lower energy consumption and lower CO_2 emissions from steel production.

Process integration (PI) is a common name for system-oriented methods and integrated approaches to complex industrial process and plant design. In process integration, interactions in the industrial system are taken into account during process design and optimization via their material and energy flows. The use of systematic methodologies is a very effective approach to improve the energy and material efficiency of large and complex industrial facilities.

Since process integration primarily is a system-oriented methodology, the largest benefits and savings are expected for complex processes or plants such as oil refineries, chemical and petrochemical factories, etc. The last few years, sparse reports on application of process integration in the iron and steel industry have started to come.

Analysing the potential for improving energy use and environmental performance in steelmaking often involves complex interaction between the subunits of the industrial system. In the steel industry, implementation of process integration methods can be further developed to powerful tools for strategic management, which includes decision making in connection with design of new plants, reshape of existing plants, or process development projects. Process constraints and alternative design options can be evaluated on equal terms. The implementation of recommended measures in this type of studies is often closely linked to other strategic decisions.

Guidelines for application of process integration in the steel industry

For the steel industry, process integration builds on three main concepts:

1. The whole picture; consider the production system as an integrated system where the processes are interconnected with both primary and secondary process streams.
2. Process engineering; apply techniques such as thermodynamics, chemistry, mass and heat balancing to analyse the

potential attainable improvements within the scope of material and energy efficiency in the system.

3. Realize performance, finalize and introduce the process designs and retrofit options to realize the identified system improvements.

There is an extensive range of applications of process integration. These include:

- Heat integration, Pinch analysis, exergy analysis.
- Mathematical modelling, optimization and simulation.

The separation and upgrading processes in the steel industry are primarily very high-temperature metallurgical processes, namely blast furnace and basic oxygen furnace processes or electric arc furnace systems surrounded by extensive material handling of solids including coal, iron ores, slags and steel as well as dusts and sludges. The applicability of the traditional process integrations techniques within this industry depends on the question at hand.

For successful application of process integration in the steel industry the mass and energy interaction in processes must be taken into account. Mathematical modelling is a suitable method to analyse the complex material and energy interaction within the steelmaking system. Pinch and exergy analysis is suitable to analyse the heat recovery possibilities. In the pinch analysis method, the system is analysed with respect to heat transfer possibilities between different streams within the network. Possibilities for minimization of the external heating and cooling demand for the system are analysed. This method is preferably used in systems with heat exchange possibilities between different process streams, e.g. in heat and steam networks but also for heating ovens etc. A similar analysis technique for the blast furnace, the Reichhardt diagram, has been used in the steel industry since the 1920s. This method of analysis is a way of characterizing the energy balance in the blast furnace based on the heat transfer possibilities between the burden materials and the reduction gas.

In the exergy analysis method, the processes and process steps are analysed based on energy quality levels (usefulness). The processes can be analysed with respect to the energy losses and from this, different practices can be compared. In mathematical programming (also called optimization), different mathematical models are used to analyse and optimize the system. This method is suitable for defining process behavior and the interplay between different processes, as well as for analysing the total system effect of changes in a sub-system. Simulation models are widely used in the industry for total system analyses.

An optimization problem often consists of a set of independent variables or parameters, and also conditions or restrictions/constraints that define acceptable values of the variables. The solution of an optimization problem is a set of allowed values of the variables for which the objective function assumes an optimal value. Different algorithms for solving the optimization problem are used depending on the type of problem. A linear problem is solved by linear programming (LP). A problem using both continuous and discrete variables, i.e. binary variables, to represent the system requires mixed integer linear programming (MILP). The use of discrete variables makes the modelling more flexible (e.g. possibilities to approximate non-linearities, discrete choices between processes routes, or in situations where real values do not make sense). However, the problem and the technique to solve the problem increase in complexity. Non-linear programming (NLP) and mixed integer non-linear programming (MINLP) increase the flexibility in modelling even more. The complexity on the other hand also increases.

Simulation models are widely used in the industry for total system analyses. To choose the right system boundary and decide an appropriate system boundary is necessary. If the system boundary is chosen incorrectly, important effects may be overlooked and omitted. It is important that the system boundary is set appropriately to handle the aims of the study. According to the systems approach, variables inside the system boundary are those that can be affected and those that might be affected by the system (e.g. material and energy variables). Outside the system boundary are those variables that affect the system but cannot be affected by the system (e.g. taxes and legislation). Two different system boundaries can be set for the system, one including only steelmaking parameters and processes (process and plant level) and one including the interplay with the surroundings (community level).

Validation is important in order to determine if the model description is sufficient to solve the problems formulated. Both the model and model results need to be validated. In order to perform model validation, known cases can be modelled and used as basis for comparison, i.e. black-box validation. In this approach it is possible to validate both model and model result. In the case of optimization the model result needs to be discussed in the industry context.

About IETS

The IEA TCP on Industrial Energy-Related Technologies and Systems (IETS), founded in 2005, is dealing with new industrial energy technologies and systems.

The mission of IETS is to foster international cooperation among OECD and non-OECD countries for accelerated research and technology development of industrial energy-related technologies and systems. In doing so, IETS seeks to enhance knowledge and facilitate deployment of cost-effective new industrial technologies and system layouts that enable increased productivity and better product quality while improving energy efficiency and sustainability.

Through its activities, IETS will increase awareness of technology and energy efficiency opportunities in industry, contribute to synergy between different systems and technologies, and enhance international cooperation related to sustainable development.

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