PROCESS INTEGRATION IN IRON AND STEEL

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CURRENT STATUS

For the steel industry processes, mathematical modelling is a suitable technique to handle the complex material and energy interactions. The success of using the tools and modelling approaches described for process integration depends on the ability to mathematically describe the industrial system. System modeling of diverse metallurgical processes requires integration of different types of models. System models have been developed in different organizations and different modelling frameworks. There is currently no commercially available modelling software designed for steelmaking with standardized unit operations, for example. A general development of modelling framework that allows model sharing and sharing the development cost for modelling packages and models is needed. Pooling of resources across the industry including universities and institutes will facilitate efficient innovation environment to improve the industry resource efficiency.

Because PI is an emerging field in iron and steelmaking, efforts are needed to educate personnel to gain acceptance and successfully implement PI in the industry. Education is required using a multidisciplinary approach at all management levels. PI is not only about methods and tools, it is about implementing a way of working within companies where PI is a natural part of everyday work. Although there are several good examples from industrial applications, there is still a lack, or insufficient reporting of, success stories. Hence, a lack of awareness of the benefits results in low probability to launch PI projects. This is important in order to overcome the hurdles of acceptance and understanding the potential of the techniques.

IEA IETS Annex XIV concluded the following current state of PI in the iron and steel industry:[1]

- Static site models are quite well developed, good for scenario modelling. E.g. change in one processes unit can be analyzed on total site, average description of the system.
- Lack of industry standard tools for making process metallurgy modelling.
- Lack of model interconnectivity inhibit cooperation between stakeholders:
    - Further development of process integration in steelmaking should focus on model design frameworks for enabling process model interconnectivity.
    - The future development of process integration for steel industry should go towards tools providing multi domain, multi physics and interconnectivity possibilities.
- Methods are more designed for strategic analysis, not developed for day-to-day optimization of the production sites.
- Guidance system for optimization of energy use requires further method development, on-line real time modeling, dynamic modelling.
- Site and process models can be further developed and used as operator training tools
- Acceptance of models and model results are important hurdles to overcome for successful implementation.
- To pool resources for development on common development platforms, taking competition between companies from development of modeling of different processes towards the ability to adapt and use the model framework.
- Develop PI educational tools for different stakeholder groups to increase competence and acceptance

GREENHOUSE GASES FROM STEELMAKING

The majority of steel, around two-thirds globally, is produced from virgin (mined) iron ores via the BF-BOF route (integrated steelmaking) which is energy and CO_2 intensive, at circa 20 GJ/t steel and 2 t CO_2/t Steel. The majority of carbon that is emitted is carried via process gases which are recovered from coking, blast furnace and basic oxygen furnace which are then combusted at the power plant, hot stoves of the blast furnace, reheating furnaces, coke oven heating, sinter plant and other heating applications. Although a number of flue gas streams are relatively concentrated in CO_2, 15-25%, the most promising target for removal of CO_2 is from the three processes gases which account for about 90% of all carbon emissions (Figure 1). The process gases contain varying quantities of CO, CO_2, H_2 which have the potential to be shifted to H_2 which could replace the process gas in the metallurgical processes, and CO_2 which could go to CCS or reacted to form various chemicals or fuels (Figure 2). There is energy recovery potential or integration possible with excess heat in the steelworks. The combination of a multitude of potential gas processing options and integration potential comes with numerous challenges in process integration. Of particular importance is the impact of additional energy which must be used for separations and reactions. The ability to integrate and optimize systems covering both metallurgical operations for core steelmaking, energy production and chemical operations for carbon use or carbon capture is a vital role for PI. Today, Swerea MEFOS often take results from chemical system modelling, e.g. Aspen, Protreat, and simplify or linearize these for given operating windows and then integrate into static spreadsheet-based model of all units.

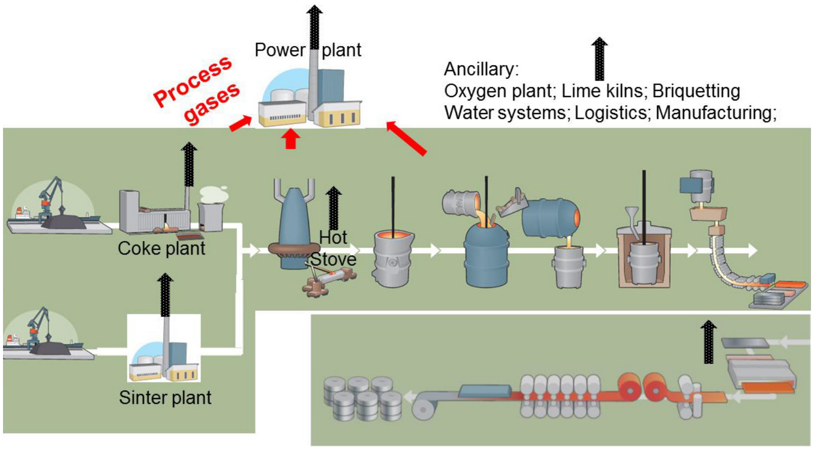

Figure 1. integrated steelmaking

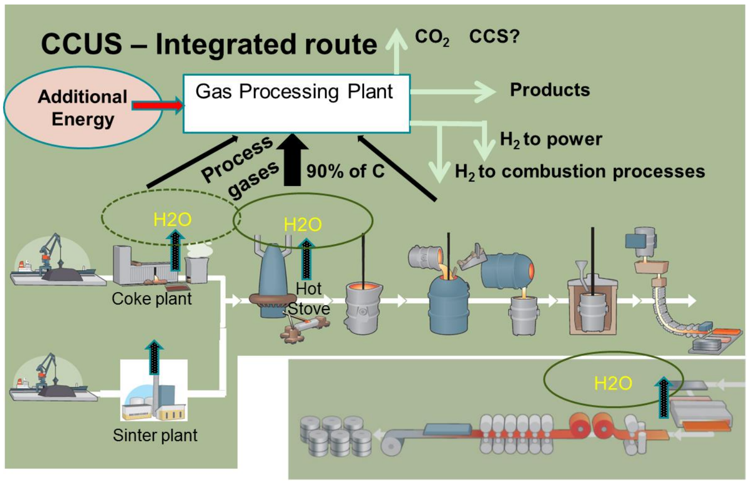

Figure 2. Integrated steelmaking with CCU/CCS

Two examples of ongoing projects at Swerea MEFOS are STEPWISE and FReSMe projects, both are EU-funded via H2020.[2] The projects include constructing and operating large pilot plants of gas reforming and chemical production from process gas, and also include Process Integration in the projects to evaluate various options and increase impact. In FReSMe, methanol will be tested as fuel in a Stena's ferry Stena Germanica.

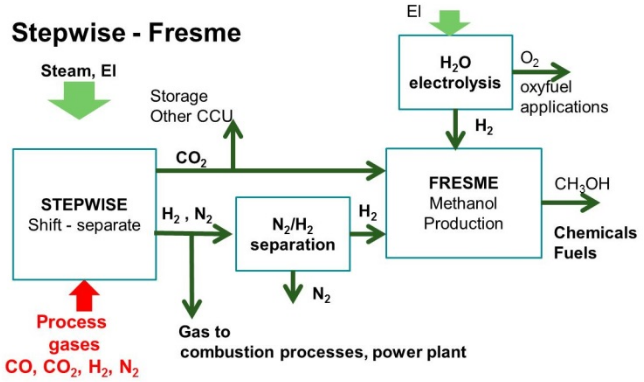

Figure 3. Integration of gas reforming and chemicals production from steelplant process gas

In the long term, fossil fuels will have to be replaced by renewables. Figure 4 shows a possible route, using fossil-free electricity and biomass. Interesting from a PI perspective is that the core metallurgical process – Direct reduction via gas and then smelting in electric arc furnace – will need to be developed somewhat further but already are commercial processes. Of course there may be other options for reduction, e.g. direct electrolysis. The aspects of integration of energy supply and transformation to make the system feasible is a particular challenge. Swedish industry led by SSAB, Vattenfall and LKAB, has recently launched HYBRIT programme to develop and then demonstrate this type of system to help meet Sweden's climate goals.[3]

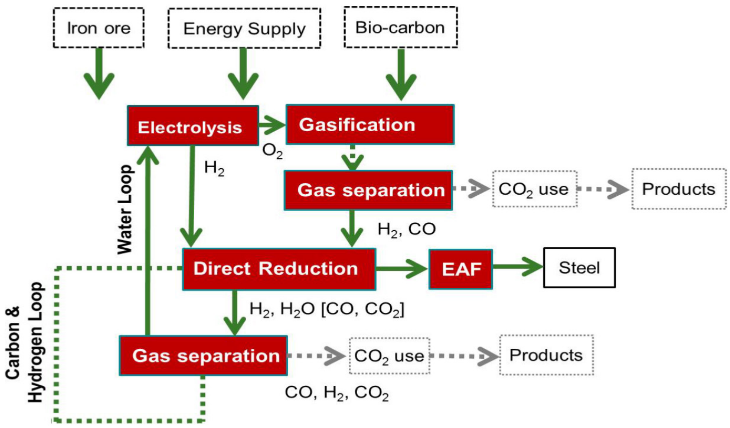

Figure 4. Example routes for changing energy input into steelmaking

PI has a vital role to play in evaluating the feasibility and optimizing the efficiency of these new and broad systems.

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[1] Annex XIV Technical Report (2014). Available at: http://www.iea-industry.org/images/Annex14/mef14064-iets%20annex%20xiv%20technical%20report_2014.pdf
[2] www.stepwise.eu and http://carbonrecycling.is/fresme-project/
[3] SSAB Press Release (4 April, 2016): http://www.ssab.com/GlobalData/News-Center/2016/04/04/05/32/SSAB-LKAB-and-Vattenfall-launch-initiative-for-a-carbondioxidefree-steel-industry;
Swedish Energy Agency Press Release (27 Feb, 2017): http://www.energimyndigheten.se/en/news/2017/the-swedish-energy-agency-is-investing-heavily-in-a-carbon-dioxide-free-steel-industry/