Dynamic Operation of a Power-to-Gas System for Integrated Steelworks

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Introduction

Integrated steelworks are major contributors to global emissions of carbon sources such as carbon dioxide (CO_2). Consequently, it is key to work on possibilities to reduce such emissions in the framework of emerging volatile markets, the energy transition and the challenging goals of the Paris climate agreement. A significant reduction until 2050 may only be achieved through e.g. cycle management resp. utilization of CO_2 as well as by substituting fossil energy sources with ones from renewable energy.

The project – i3upgrade

By-product gases from integrated steelworks such as blast furnace gas (BFG), basic oxygen furnace gas (BOFG, converter gas) and coke oven gas (COG) have a rich content of CO_2 and CO (carbon monoxide). One way of reusing certain gas streams would be through well-known synthesis processes like methanation where CO_2 and CO react with hydrogen (H_2), preferably gathered from green energy sources, to methane (CH_4) and vapor. [1]

The reaction kinetics of such syntheses under dynamic and transient conditions are yet to be investigated. This is especially important for steelworks processes, as the concentrations and the total volume flow of the produced gases vary frequently due to the related operational work steps. Even more, the amount of available H_2 required for the methanation synthesis is dynamically available too. The energy required by the electrolyzing unit to produce the necessary H_2 is linked to the online electricity price and of course only driven economically. Consequently, the reaction behavior of a dynamically driven methanation plant and its applicability for upscaling need to be investigated to provide a fundamental base for its implementation in an integrated steelworks plant. This investigation is carried out within the EU-funded project "i3upgrade" (Fig. 1). [2]

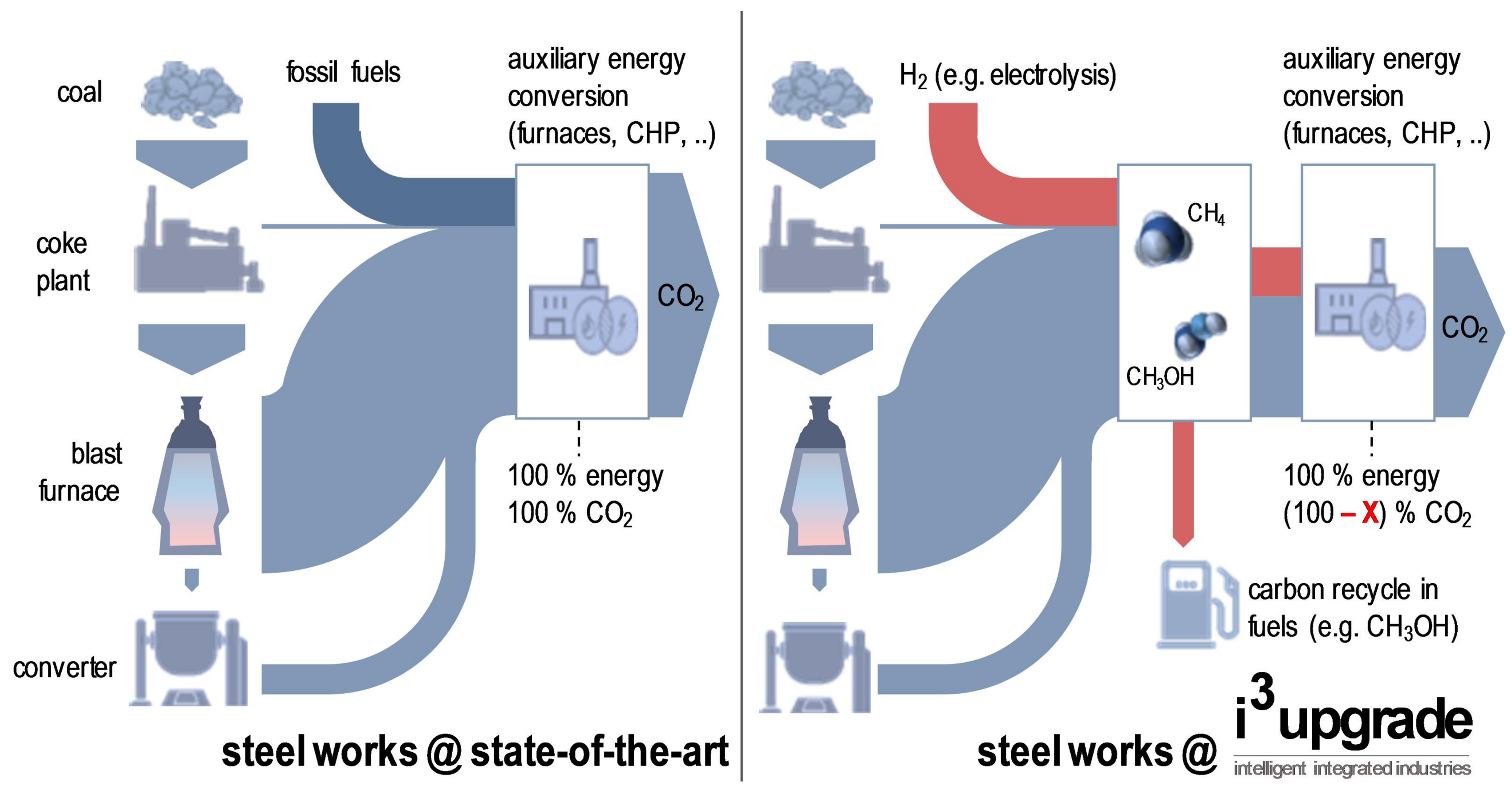

Fig. 1: Schematic carbon flow inside an integrated steelworks (left: state-of-the art, right: approach in i3upgrade)

Dynamic operation

For the necessary experiments under dynamic conditions, the existing pilot rig at the Chair of Process Technology and Industrial Environmental Protection at the Montanuniversitaet Leoben (MUL) is used (Fig. 2), which consists of three reactors with an inner diameter of 80mm and a length of 300mm each. The reactors are filled with the commercial bulk catalyst Meth 134® as well as with inert material up- and downstream. [3]

Fig. 2: Methanation test rig at MUL

A series of experiments with synthetic BFG and BOFG (p = 4 bar, GHSV = 4,000 h^{-1}) has been carried out.
To achieve the reaction goal of 100% CO_x conversion, an H_2 excess rate of 5% to stoichiometry was used. Once steady-state was achieved, the assumption was made that less H_2 would be available for the synthesis due to an increase in the electricity price, resulting in CO_x conversion rates below the target value. Consequently, the flow rates of the injected steelworks gases had to be decreased automatically to maintain a 100% CO_x conversion rate (Fig. 3).

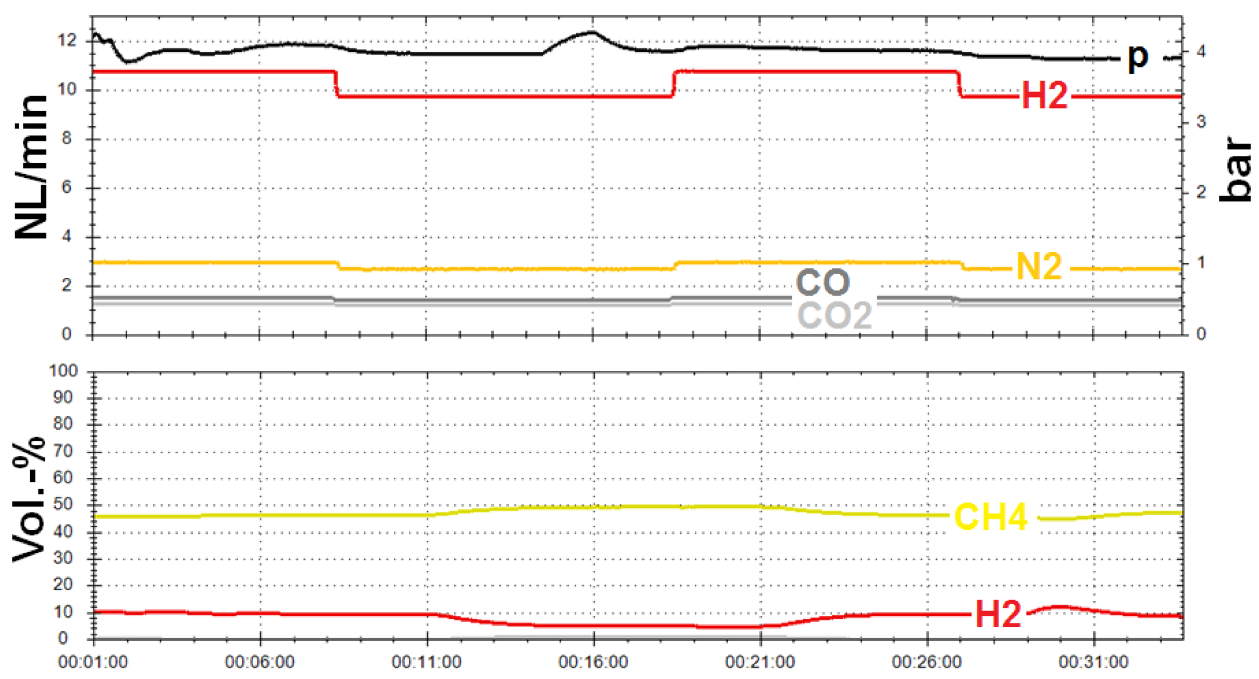

Fig. 3: Dynamic experiment with synthetic BFG (top: educt gas [NL/min], pressure [bar]; bottom: product gas [Vol.-%])

Wash-coated honeycombs for dynamic methanation

The dynamic experiments made with the commercial bulk catalyst will also be carried out with monolithic honeycombs which have been wash-coated with Boehmite/Al_2O_3 and Nickel nitrate (Fig. 4).
The advantages of such honeycombs in terms of pressure drop and load flexibility are subject to tests for their applicability in a dynamically driven methanation synthesis of an integrated steelworks plant. [3]

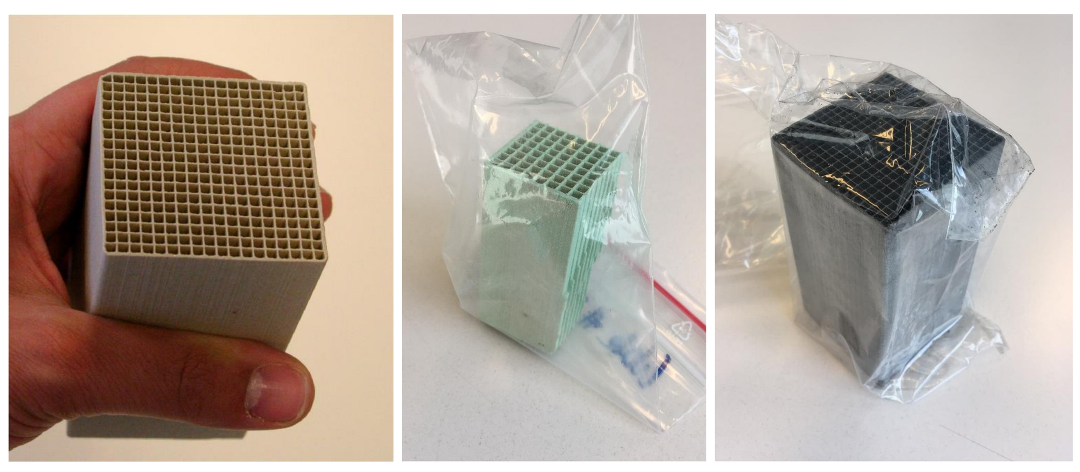

Fig. 4: Honeycombs used for catalytic methanation (from left to right: raw, wash-coated, used)

Summary & outlook

Dynamic methanation experiments with by-product gases from the steelworks industry showed an achievable goal of constant 100% CO_x conversion with varying availability of hydrogen.
Further experiments will be carried out to compare the performance of wash-coated honeycombs with the commercial bulk catalyst. Synthetic as well as bottled real gases from the steelworks industry will be used for these experiments.


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Literature:
[1] Sabatier, P. et al. "New methane synthesis". Compt. Rend. Acad. Sci., 134:514-516, 1902.
[2] Hauser, A. "i3upgrade – intelligent integrated industries". URL: https://www.i3upgrade.eu, 02.04.2019.
[3] Biegger, P. "Keramische Wabenkatalysatoren zur chemischen Methanisierung von CO_2". PhD thesis; Austria, 2017.

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