ESTAD Symposium HYBRIT

1 September 2021, 08:30 – 12:00

Moderators: Åsa Bäcklin and Mattias Elfwing, Hybrit Development AB

PROGRAM

1. The HYBRIT initiative

Presented by Eva Vitell, General Manager Hybrit Development AB

The HYBRIT initiative started in 2016 when SSAB, LKAB and Vattenfall joined forces. The initiative endeavors to revolutionize steel-making by replacing coking coal with fossil-free hydrogen. The result will be the world's first fossil-free steelmaking technology, with virtually no carbon footprint.

HYBRIT Research Project 1 was initiated 2017 as a four-years research project and is a joint initiative between academia, research institutes and industry and is conducted with financial support from the Swedish Energy Agency (Energimyndigheten). HYBRIT Research Project 1 has been conducting research across the entire fossil-free energy-mining-iron-steel value chain, providing a basis for industrial development activities and future transformative change.

The HYBRIT initiative is presented along with how the HYBRIT Research Project 1 has explored and assessed pathways to produce fossil-free steel and laid the foundation for the continued development of the HYBRIT concept.

2. Fossil-free iron ore pellets production

Presented by Sofia Nordqvist, Hybrit Development AB

The ore-based steelmaking value chain starts at the iron ore mine. After mining, the iron ore is processed, and a product rich in iron oxides is produced in the form of pellets, or fines. The purpose of the pellet process is to create an iron ore product suitable for the subsequent ore reduction where the iron oxides are converted to metallic iron. To create a fossil-free iron ore-based steelmaking process, the fossil fuels currently used in ore processing needs to be eliminated with increased energy efficiency and by switching to fossil-free sources of energy.

HYBRIT Research Project 1 has investigated ways towards fossil-free pellet production through analysis of alternative heating sources such as renewable fuels and plasma heating technologies, regarding their usability in the pelletizing process. Furthermore, the potential use of the oxygen by-product from the hydrogen production, to decrease the energy consumption and improve product quality in the pellet process, is investigated both on an applied and fundamental level. The possibilities for improved energy and material

efficiency of the complete system are investigated through detailed analysis of heat and/or mass integration between the pellet induration and iron reduction processes.

3. Hydrogen based iron ore reduction

Presented by Johan Riesbeck, Hybrit Development AB

The reduction reactions in ironmaking represent around 85 to 90 per cent of the total carbon dioxide emissions in the ore-based steelmaking value chain. In the case of HYBRIT, iron metal is produced by using hydrogen gas as the main reductant. The production route is similar to existing direct reduction processes using natural gas, except for the carbon dioxide emissions: hydrogen reacts with iron oxides to form water instead of carbon dioxide.

HYBRIT Research Project 1 aims to clarify the possibilities to produce direct-reduced iron with a hydrogen-rich reduction gas. Influence of the reduction gas properties and influence of the composition of pellets on the process has been investigated. Fundamental studies on iron ore reduction with hydrogen-rich gases as a function of temperature and pellet composition has been conducted. Mass and heat balance of the shaft furnace has been reviewed and models designed of the reduction shaft and process.

4. Steelmaking from hydrogen reduced iron

Presented by Carl Allertz, SSAB

The Electric Arc Furnace (EAF) is used for heating and melting charged materials by means of electric current. The use of EAFs allows steel to be made from up to 100 per cent scrap metal, or as in the HYBRIT concept, from a mix of direct reduced iron and scrap. Carbon plays a vital role in iron- and steelmaking to control oxygen potential, to stir the steel, to purge residuals, to foam the slag by CO-gas formed, and as an alloying element. In the HYBRIT scenario, iron with no or very low carbon content will be produced in the hydrogen based direct reduction process and used as EAF feedstock.

HYBRIT Research Project 1 has undertaken fundamental, theoretical and experimental studies on how carbon and vanadium oxide affect reaction kinetics at the different temperatures, oxygen potentials and steel/slag compositions that prevails in an EAF when using low-carbon DRI feedstock. The understanding of vanadium's role in a future EAF process will enable the control of slag foaming operation, which is vital to achieve sufficient process thermal efficiency. In addition, increased knowledge about the vanadium behavior in the new process route could in the future improve recirculation and usage of vanadium-rich slag.

5. Providing energy for fossil-free steel production and the effects on the electrical power system

Presented by Tobias Rehnholm, Vattenfall AB

Iron and steel production based on hydrogen from electrolysis instead of coal as a reducing

agent will require large amounts of electricity and would mean a major change for the Swedish and Nordic energy system. The introduction of HYBRIT must therefore take place in a well-thought-out way and consideration must be given to how the rest of the electricity and energy system will develop in the coming decades.

HYBRIT Research Project 1 has studied the integration of the HYBRIT project in the Swedish power system and simulated the techno-economic setup of hydrogen production flexibility, to minimize hydrogen and steel production cost. The project has also investigated power system balancing and power grid stability for the fossil-free steel production in the Swedish power system, and the potential as provider of large-scale demand flexibility in the power system.

6. Hydrogen production and storage

Presented by Nicklas Simonsson, Vattenfall AB

Large-scale hydrogen production and storage will allow for flexibility in power consumption, which will favor the implementation of intermittent renewable energy sources for electricity production. Safe and reliable delivery of hydrogen at competitive price levels is critical for the whole HYBRIT concept and the economic prospects of the concept. There is a need to identify, evaluate and develop feasible hydrogen value chains. Commercial technology for hydrogen production exists today but has yet to be proven on a large scale in terms of process functionality and economics. Hydrogen storage plays an important role in the value chain economics and integration, but technology for large-scale hydrogen storage is still untested.

HYBRIT Research Project 1 has studied the design and layout of the hydrogen process value chain - from the input of renewable electricity to safe, reliable, and cost-effective hydrogen supply to the end-users. This includes exploring suitable design and performance for large scale water electrolysis plants, based on current state of the art and future developments. Large scale underground hydrogen storage feasible for Swedish geological conditions as well as alternative storage options have been evaluated.

7. System integration, transition pathways and policy strategies

Presented by Max Åhman, Lund University

Electrical infrastructure expansions and regional transformation support are fundamental requirements for the HYBRIT concept. Competence and capacity building will support the future value chain production systems and business models. Political instruments, e.g. emission trading, will affect the industrial transition period and the likelihood of a viable business case. Regional effects on society will be considerable in the areas where transition will take place, requiring further consideration. The industrial transition stages and associated technological and economic effects represent considerable risks and costs for the companies involved, which need to be resolved.

HYBRIT Research Project 1 has explored and analyzed pathways and governance strategies for the transition to hydrogen-based iron and steelmaking utilizing renewable electricity. Such a transition requires co-evolution of technologies, infrastructure, fossil-free steel and energy markets, as well as supportive policy and governance structures. An important part is exploring and understanding the integration between different systems (i.e. steel production, electricity system, iron ore pellets production and hydrogen system) and new flows (e.g. oxygen from electrolysis). The project also includes in-depth analyses of strategies for the energy and industry and climate policy in a few selected countries, as well as broader analyses of other important countries and international climate policy developments.

8. The way forward

Presented by Eva Vitell, General Manager Hybrit Development AB

With HYBRIT Research Project 1 important steps on the road toward fossil-free steel have been taken. This concluding presentation will address the research going forward, targeting the greatest needs on the path to industrialization and commercialization.

The commissioning of HYBRIT's pilot plants for fossil-free pellet production and fossil-free direct reduction in 2020 has created new opportunities for the continued research and development, enabling HYBRIT to conduct R&D on a pilot scale for key parts of the value chain. Hybrit will also conduct research in selected areas, internally and together with external partners. The continuing technology development supports the planning for the next step – a HYBRIT demonstration plant.