June 2024

MaxH2DR newsletter

ISSUE n°3

—

Maximise H2 Enrichment in Direct Reduction Shaft furnaces

The project falls under the funding programme of Horizon Europe – Clean Steel Partnership.

The call topic is related to Carbon Direct Avoidance in steel: electricity and hydrogen-based metallurgy.

—

This project has received funding from the European Union under grant agreement n°101058429

PROJECT KEY FACTS

Max H2 DR

Maximise H2 Enrichment in Direct Reduction Shaft Furnaces

GRANT AGREEMENT ID : 101058429

Hydrogen-based direct reduction as ground-breaking technology for climate neutral steelmaking

DURATION 4 YEARS
Start: 01 June 2022
End: 31 May 2026

BUDGET
Total cost : 4 476 585 €

FUNDED UNDER
Horizon Europe Clean Steel Partnership

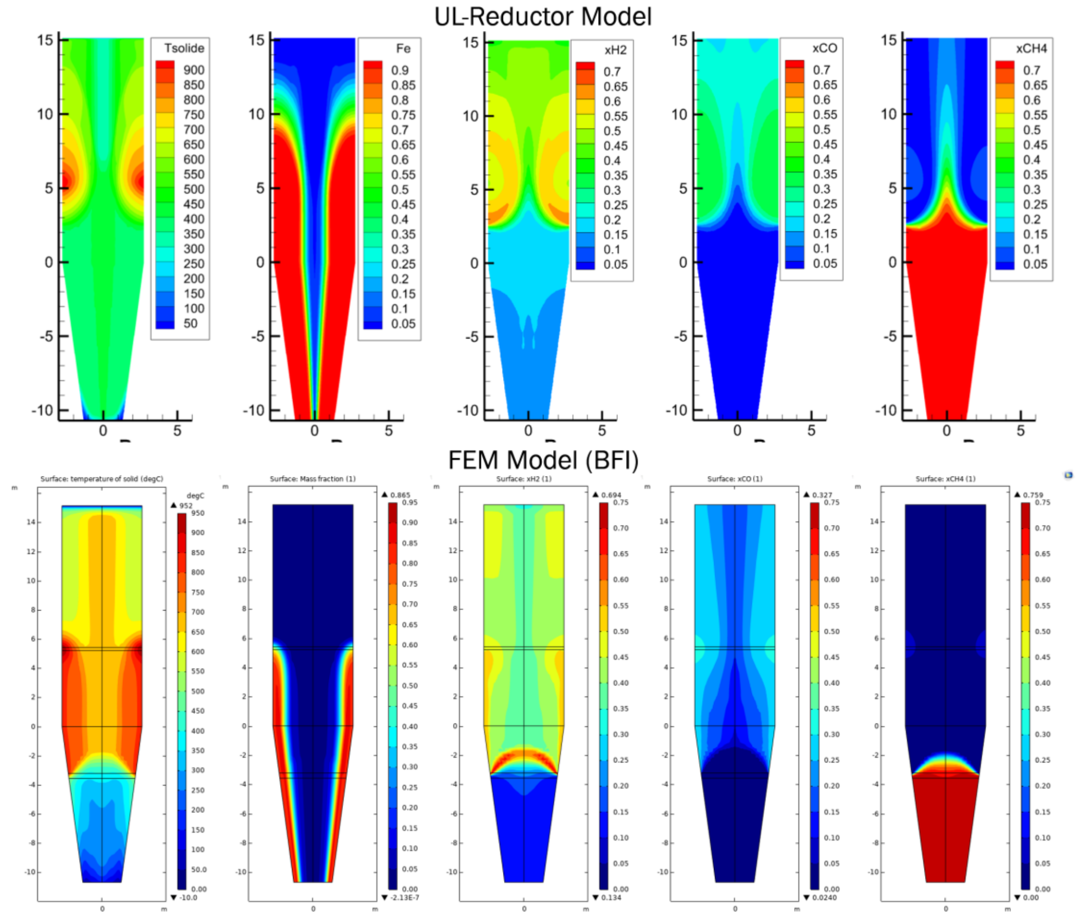
COORDINATOR
SSSA - Suola Superiore di Studi Universitari e di Perfezionamento Sant' Anna (IT)

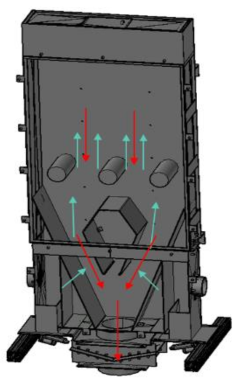
CONSORTIUM
10 Partners from 7 EU countries

TARGET MAXH2DR
Raise the maturity of the relevant toolkits from TRL 5 to TRL 8

Development of over-all process model for a Direct Reduction shaft furnace

An over-all process model for DR shaft furnace reactors has been developed using the finite element method (FEM) by BFI. A shrinking core kinetics with 3 interfaces is used. FEM-based model adopts it for pellets and reductor model adopts it for the grains within pellets. Initial benchmarking of model against the UL-Reductor model indicates that the reaction kinetics in the FEM model needs to be further calibrated, this will be achieved by exploiting the reduction experiment results. A rheological sub-model has been also developed for the solid particle flow which will be tuned by DEM and experimental findings. The FEM model by BFI will be used for the process optimization in later stages of the project.





First Coupled DEM/CFD simulations of the physical demonstrator

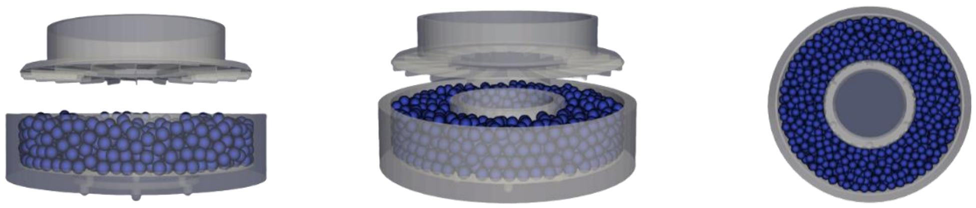
The first set of simulations involves coupled Discrete Element Method (DEM) and Computational Fluid Dynamics (CFD) simulations using an in-house code developed at LEAT and OpenFOAM from Ruhr-University Bochum (RUB). The focus is on analyzing a shaft furnace configured according to the Midrex geometry, standing at a height of 2.2 meters. Pellets are dropped from the top while air flows from the bottom of the shaft furnace. In order to reduce the computational effort, the particle shape is simplified to be spherical. This simplification is reasonable for DR since the fresh pellets coarsely resembles spheres. The radius of hematite (Fe_2O_3) pellets is consistent at 10 mm for accurate comparison.

The primary objective is to investigate pressure loss within this system. Three different test cases are explored:

1. In the initial case, cold simulations (ambient temperature) are performed using two different gas compositions: air (77% N_2 and 23% O_2) and pure hydrogen (100%). Both simulations maintained a constant volume flow. The emphasis here was on determining pressure loss over the furnace's height under these varying gas compositions.
2. The second test case involves a comparison between air flow set at 0.1 m/s through the inlet and hydrogen flow at 2 m/s. Both scenarios maintained a constant mass.

3. For the third test case, a modification was introduced to the shaft furnace model, akin to a "Christmas tree" addition. The comparison focused on pressure loss/height using hydrogen for two geometries: with the added Christmas tree modification and without it.

The second set of simulations is aimed at replicating the shear cell experiments with wooden pellets done by the University of Salerno. The DEM simulations performed at LEAT aim to recreate these experiments and their results regarding the normal force, shear force and displacement of the pellets.



Simulation and first results of the REDUCTOR model

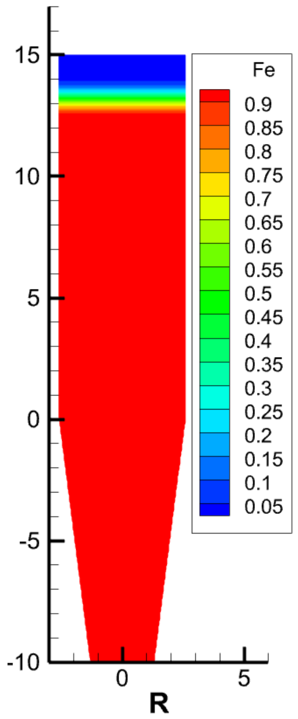


Figure 1 : REDUCTOR results showing iron solid mass fraction in the furnace. The entirety of the initial hematite is converted to iron after a 2-meter long descent. (Solid load : 150 t/h at T = 25°C. Gas flow : 2800 mol/s at T = 900°C)

A typical Direct Reduction shaft furnace, but fed with H_2, has been simulated with the REDUCTOR model. The model shows that iron ore can be completely reduced (Figure 1) with hydrogen at usual DR shaft furnace working temperatures (800 - 1000 °C).

A parametric study is currently being led to determine which factors are of utmost importance in the reduction of the ore. The first results highlight the major influence of both inlet gas temperature and solid flow rate on the metallization, while gas pressure seems to play little to no effect in this matter. Pre-heating the solid before it enters the furnace does not seem to enhance the process either.

The next steps regarding modelling are to improve the overall balances of the simulations and to refine the description of the solid flow. Indeed, since the REDUCTOR model incorporates both a cylindrical section and a hopper, a traditional plug flow model is incomplete to describe the flow of the granular solid bed. A review of continuum solid flow models is ongoing to find which one to introduce in our future simulations.

Stay updated by following the MaxH2DR project on LinkedIn and Twitter

Co-funded by the European Union