Abstracts of technical articles

IRMA - Flowsheet Model Examples of Application   398
J. Link

ULCOS is a large European research project that aims to identify and develop technology that could enable a drastic reduction in CO_2 emissions from ore-based steel production. The IRonMAking flowsheeting model (IRMA) has made a vital contribution to one of the ULCOS subprojects, as IRMA models were used to evaluate the economics and CO_2 reduction potential of a large number of alternative ironmaking routes.

IRMA is a software tool that allows for the use of thermodynamic data relevant to iron- and steelmaking in a flowsheeting environment. It was developed by Corus to serve as a dedicated, flexible and accessible tool to evaluate and compare a wide range of ironmaking routes.

IRMA can be used to calculate consumption figures, product quality and the occurrence and significance of emissions. IRMA can do this for a wide range of operating conditions and raw material compositions.

IRMA is currently being used for benchmarking, design and pilot plant development of the ISARNA process, which was developed in the context of the ULCOS project. ISARNA is one of the four process routes that have been selected for further development within ULCOS.

Modelling of Coal Pyrolysis Using a Twin Screw Reactor   404
M.-K. Roedig, W. Klose

Based on the balance equations of mass, partial mass, momentum and thermal energy, the pyrolysis process of non-coking coals using a counter-rotating twin screw reactor (TSR) is modelled by means of commercial CFD code PhoenicsTM. In favour of good convergence of the mathematical solution, a structured, cylindrical-polar grid is chosen. Variable filling and intermeshing degrees are taken into account by blocking numerical cells in gas domain and intermeshing domain instead of performing two-phase calculations in a body-fitted co-ordinate system. Viscous behaviour of the granular coals is expressed by means of a generalised Newtonian fluid and chemical decomposition is implemented with aid of distributed activation energies.

Biomass sustainability, availability and productivity 410
A. Fallot, L. Saint-André, G. Le Maire, J.-P. Laclau, Y. Nouvellon, C. Marsden, J.-P. Bouillet, T. Silva, M.-G. Piketty, O. Hamel

Research conducted on biomass for Ulcos ("Ultra-Low CO_2 Steelmaking" European Integrated Project) has progressively focused on charcoal supply from tropical eucalyptus plantations. The sustainability of such plantations is being investigated from the viewpoint of their carbon, water and nutrient budgets: they must all be neutral or positive. Field research is producing results at the tree or stand level in several sites of Congo and Brazil, while a spatial model is developed to identify the conditions of biomass neutrality at the scale of the forest ecosystem. The productivity of biomass has been analyzed through the description of practices along the various supply-schemes that competitively feed the steel industry in Brazil and the identification of bottlenecks for further expansion.

ULCORED SP 12 Concept for minimized CO_2 emission 419
K. Knop, M. Hallin, E. Burström

ULCORED is the concept suggested by SP 12 to meet the demand of reduced CO_2 emission using iron ore and gas based direct reduction for steelmaking. The concept includes the use of 100% oxygen, POX (partial oxidation) instead of reformers, shifter for production of CO_2 free reduction/excess gas and the reducing agent being either natural gas or syngas from coal/biomass.

HSC Simulations of coal based DR in ULCORED   422
L. Bergman, M. Larsson

The ULCORED coal based concept is simulated based on the production of syngas using existing coal gasification technology. The shifter gives the option to produce CO_2-lean H_2 from coal/biomass for in plant use. Large CO_2 emissions arise on site from the use of natural gas in heating ovens and from the use of electricity in EAF melting. In the case of these coal based systems, production of "excess gas" to be used as fuel gas in various processes will reduce the CO_2 emission for the total site.

Biomass gasification for DRI production   429
T. Buergler, A. Di Donato

The Direct Reduction process can be carried out using syngas from biomass. Mathematical models of the integrated process gasification plus direct reduction have been used to evaluate flow rate, temperature and composition of the gas in the various steps of the whole process. Fluidised bed gasification and operation with technological oxygen at high pressures is the proposed solution to produce syngas. Best candidates for such application are biomass from forest and wood industry and agricultural residues. Both of such type of biomass are present and distributed in many European areas in such amount to make industrially possible their use, taking into account the logistic requirements. A cost between 30-60 €/t DRI is roughly estimated.

The characteristics of the syngas implies the adoption of purification steps, before the use of the syngas in the shaft furnace, using technologies permitting hot gas cleaning, to save energy efficiency of the process.

Modelling a DR Shaft Operated with Pure Hydrogen using a Physical-chemical and CFD Approach   434
A. Ranzani da Costa, D. Wagner, F. Patisson, D. Ablitzer

The hydrogen-based route could be a valuable way to produce steel considering its low carbon dioxide emissions. In ULCOS, it is regarded as a long-term option, largely dependent on the emergence of a hydrogen economy. To anticipate its possible development, it was decided to check the feasibility of using 100% H_2 in a Direct Reduction shaft furnace and to determine the best operating conditions, through appropriate experimental and modelling work.

We developed from scratch a new model, called REDUCTOR, for simulating this process and predicting its performance. This sophisticated numerical model is based on the mathematical description of the detailed physical, chemical and thermal phenomena occurring. In particular, kinetics were derived from experiments. The current version is suited to the reduction with pure hydrogen, but an extension of the model to CO is planned so that it will also be adapted to the simulation and optimisation of the current DR processes. First results have confirmed that the reduction with hydrogen is much faster than that with CO, making it possible to design a hydrogen-operated shaft reactor quite smaller than current MIDREX and HYL.

Application of Modeling to the Development of an Electrochemical Pilot Cell 440
A. Allanore, H. Lavelaine, Wen Xuan

The hydrodynamics in an electrolysis pilot-cell has been modelled with the aim of upscaling the direct iron production process based on the alkaline electrolysis of an iron oxide suspension. Two dispersed phase flow involved in this three-phase process have been evaluated: the solid and the gas phase hydrodynamics.The suspension flow characteristics are evaluated from existing litterature, and available correlations are applied to the case under study. The minimum velocity required for transportation of finely ground iron oxide along the cathode surface is fairly low, in the laminar regime, corresponding to minimum pressure drop.The behaviour of the oxygen phase produced on the anode is evaluated in at two scales. First, the trajectory of a single bubble sliding on the anode is depicted, predicting possible rising or dragging of the bubbles as a function of its diameter. The gas-phase pattern is then studied from litterature results for gas-liquid flow in pipes. A separation of the gas phase from the liquid is predicted, the lightest phase being in contact with the upper part of the cell. Obtained results confirm the potential of the selected design for transportation of particles and gas recovery with low energy consumption.

Electrowinning of Iron in Aqueous Alkaline Solution Using Rotating Disk Electrode 455
Boyan Yuan, G.-M. Haarberg

In order to develop a new, efficient industrial process for producing high quality iron and steel with significantly reduced carbon dioxide emissions, we investigated the electrowinning of iron from an iron oxide ore in aqueous alkaline solutions. Hematite (Fe_2O_3) solid particles suspended in the concentrated aqueous sodium hydroxide (NaOH) solutions were transferred to the cathode (e.g., a rotating disk graphite electrode) and reduced to iron metal by applying a constant current; oxygen was evolved on the anode (e.g., a nickel screen mesh). Current efficiencies of above 90% with respect to iron deposition were consistently obtained under the specific conditions in a laboratory cell, and the corresponding energy consumptions were calculated to be around 3 $kWh \cdot kg_{-1}$ iron. The deposited iron crystals were the oriented clusters of stacked six-fold twins in a tetrahedron-shape grew growing in a direction perpendicular to the cathode surface. Influences of rotation rates of the cathode, cathodic current densities, contents of the Fe_2O_3 particles in electrolytes, and concentrations of NaOH solutions on current efficiency and morphology of deposits were studied.

Optimized Design of an Iron Electrowinning Cell 460
H. Lavelaine, A. Allanore

In the development of the electrolysis technique for iron, the cell-design step is crucial to ensure that the results obtained on smaller scale experiments are scaled-up to industrial size. Design criteria, based on the theorem of equipartitioned irreversibility, are proposed for the alkaline electrowinning process. One of the specific features of the process is the treatment of a multiphase electrolyte, a genuine breakthrough for electroextraction processes. Each of the unit-operations necessary to obtain the separation of the iron and oxygen from iron oxide are depicted together with the corresponding physical limitations and available technologies. Optimal solutions to obtain uniform and steady variation of each of the involved phenomena can be readily deduced from this approach and a cell-design is proposed.

CFD Modelling and Comparison among Different Configurations of Parallel Plates Iron Electrowinning Cells 472
M. Serna

Within the ULCOS project, a pilot cell for iron electrowinning is being designed. Electrical energy is used to transform iron ore particles (hematite) suspended in a sodium hydroxide solution into iron metal and oxygen. The work developed by Labein-Tecnalia is focused on the study of the fluid flow for different electrolytic cell configurations to get knowledge of the interaction between the oxygen bubbles generated during the process and the electrolyte flow. The numerical algorithm used is the finite volume used in the commercial Computational Fluid Dynamics code FLUENT. The work developed is focused on vertical and horizontal parallel plates configurations, to analyze the removal of oxygen bubbles from the gap between anode and cathode, and the access of iron ore particles to the cathode. A user subroutine has been developed for the CFD code to compute the mass flow rate of oxygen bubbles generated at the anode, as a function of the local current density. A methodology has been developed to analyze the accessibility of the iron ore particles to the cathode. The knowledge obtained from this work has helped for the design of the pilot cell within the ULCOS project.