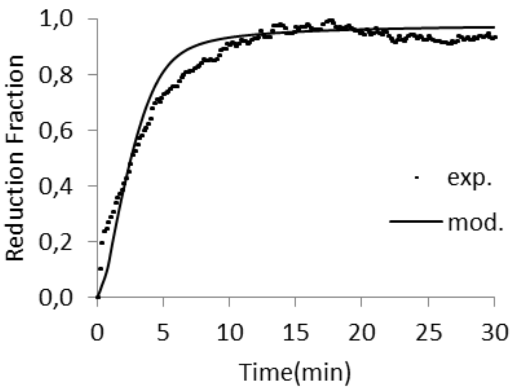

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Measurements and simulation of the isothermal reduction of a single hematite iron ore pellet in mixtures of hydrogen and carbon monoxide

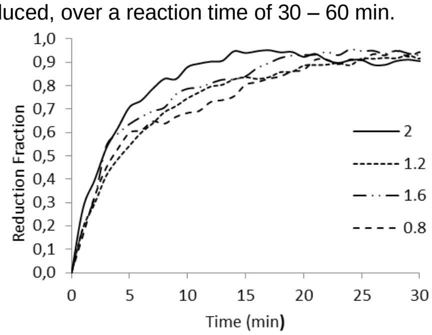
An isothermal simulation of the reduction of a single hematite pellet has been developed. The model allows for the description of the chemical reactions taking place and the mass transfer conditions existing for each of the gas species present within the pellet. The model predictions are in reasonable agreement with the experimental results obtained from laboratory experiments. The model predicts that an increase in the gas ratio and/or reduction temperature, as well as the porosity of the pellet, resulted in an increase in the reduction rate. Moreover, pellets with a larger diameter need more time to reach complete reduction, *i.e.* the diffusion length path is important.

The production volume of direct reduced iron has increased from 0,8 to 74 M tonne per year between 1970 and 2012, and is expected to increase to 200 M tonne/year by 2030. It offers a lower-emissions alternative to the blast furnace iron. Direction reduction of iron usually utilizes a mixture of hydrogen and carbon monoxide gases as reductants. The reductants react with the oxygen in the Fe_2O_3 iron ore, producing emissions of water and carbon dioxide, respectively while reducing the iron to first wustite (FeO) and then Fe. The interaction between the gas mixture and the solid ore pellet was studied with experimental and computational simulation studies.

Reaction kinetics

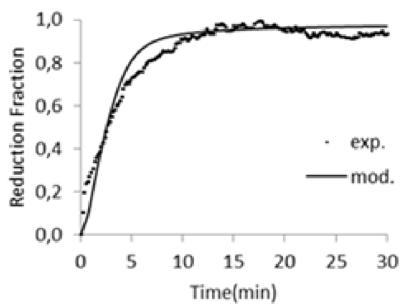
The kinetics of the controlling steps for the reduction of a single hematite pellet has been reported to includes the following steps: (i) the convection mass transfer of the gaseous reactant from the bulk flow to the pellet surface, (ii) the diffusion of H_2 and/or CO through the porous solid layer, (iii) the chemical reaction with the solid reactant at the reaction interface, (iv) the diffusion of the much larger molecules of produced H_2O and CO_2 away from the reaction surface through the solid porous layer, and (v) the convection mass transfer of the product through the gas film surrounding the solid pellet into the bulk flow [1-3].

Experimental work was performed using a laboratory scale Thermo-Gravimetric Analyser (TGA). The sample was placed in a crucible and held at the target temperature while exposed to the reductant gas mixture. The progress of the reaction was monitored by measuring the weight loss from the pellets and presented as a plot of fraction reduced, over a reaction time of 30 – 60 min.



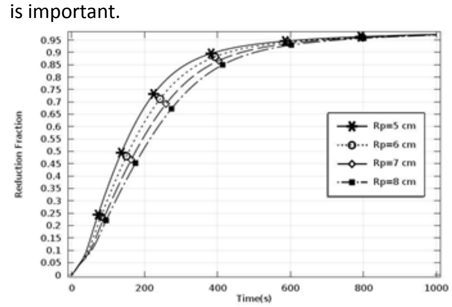
Experimental results for the reduction fraction versus time for different gas mixture ratios of H2/CO.

Computational simulation The reduction of an iron ore pellet can be estimated using the "Shrinking Core Model" where the reaction is described as proceeding progressively through concentric layers, from the outside to the centre of the pellet. The simulation was implemented in COMSOL Multiphysics® software version 4.3b.



Example of progression of reduction with time, from experiments and computational simulation.

Effect of variables The reduction rate increased as the proportion of hydrogen was increased, at constant temperature. A decrease in the temperature or an increase in the pellet porosity also gave an increase in reaction rate. Larger pellets need longer reaction time, indicating the diffusion length is important.



Larger pellets required longer reaction times.

Further work The experimental work is now being extended to a bed of pellet particles using the reduction furnace at LKAB CK laboratory in Maalmberget. These results will be used to validate a simulation model of the bed of particles, and extend the studies of the effect of variables on the reduction. The final goal is to provide guidance on the optimisation of the process with regard to emissions, with regard to an implementation in cold climate regions.

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