ULCOS: Searching for Breakthrough CO$_2$-lean Steelmaking Routes...

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Ultra Low CO$_2$ Steelmaking

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Ultra Low CO₂ Steelmaking: program's targets

- identify steel production routes with the potential of mitigating CO₂ emissions by a factor 2 or more (European targets for 2020/2050, probably worldwide targets in post-Kyoto negotiations)
- select the most promising ones by passing them all through a sustainability analysis
- develop the technology in order to be ready for a scale-up to commercial size at the end of the 5 year program (ULCOS-I)
- prepare and launch the next step, ULCOS-II

- the program is supported financially by the European Union (RFCS & 6th FP)
Program schedule

Technology development – 5 years

Phase 1
- SP1 - New Blast Furnace
- SP8 - New Advanced C-lean & C-based Route to Steel
- SP2 - New Smelting Reduction
- SP3 - New NG Route to Steel
- SP4 - Hydrogen steel production
- SP5 - Electrolysis steel production
- SP6 - CO₂ Capture & Storage for steelmaking
- SP7 - Biomass-based Steel production

Phase 2
- SP9 - Scenarios, sustainability, innovation, training & dissemination

Phase 3
- SP10 - New C-based Steel production
- SP11 - New adv. C-based Steel production
- SP12 - New Nat Gas-based Steel Production
- SP13 - New Electricity-based Steel Production
- SP14 - ULCOS-Process for Steel Production

ULCOS – RFCS

ULCOS – 6FP

ULCOS

Project Management

59 M€ budget
What is possible in the long term?

Use of C from sustainable biomass

CO₂ capture & storage

Decarbonation

Existing technology

Carbon

Blast Furnace

Coke

Coal

Syngas

Natural gas prereduction

Plasma in Blast Furnace

H₂ prereduction

H₂ by electrolysis of H₂O

Electrons

Electrolysis

Electric Arc Furnace

Other reducing agents: Al dross, etc.

New Technology

Hydrogen
How to tackle the CO₂ issue...

**C-based steel production + CO₂ Capture & Storage**

- **Biomass-based steel production**
- **Electrolysis steel production**
- **Natural Gas-based steel production**
- **Hydrogen-based steel production**
CO₂ emissions - 370g CO₂/kWh

kg CO₂/t HRC

Scope 2

Hydrogen

BF benchmark

BF variants

Smelting Reduction

Direct Reduction

Electrolysis
Conclusions of phase I

- steel production routes can be *designed* to cut CO₂ emissions by a factor 2 or more
- further intensive RTD work is needed before they can *actually become available and used commercially*
- beside these breakthrough routes, we have exhibited other routes, already developed, that can deliver intermediary levels of cuts in CO₂ emissions
- ULCOS has selected 4 breakthrough routes, for further work in phase II, based
  - either on using fossil reducing agents and fuels and pure O₂ operation, on CCS and an original in-process CO₂ capture concept,
  - or on using carbon-lean electricity.
Top Gas Recycling Blast Furnace

Phase II of ULCOS-I
Experimental campaign, Fall 2007

6 week test period from 24 September 2007 on the LKAB EBF in Luleå:
- Production rate constant
- PCI rate constant
- Maximize gas injection rate

Tuyeres

Tuyeres + Shaft
Preliminary conclusions of the ULCOS EBF trial

1. no safety issue with the new process.
2. smooth operation with the new process
3. carbon savings up to 24% at 156 kg/t_{hm} of coal.
4. stable gas efficiency in the shaft & control of thermal stability of the EBF
5. start-up not especially difficult
6. no carbon deposition
7. smooth operation of the VPSA
8. the first EBF campaign with the TGR-BF process has been a great success.
Future plans

- need to start scaling up BF and CCS operation

- the TGR-BF concept is seen as the most realistic one for the middle term, as existing BF can be retrofitted to the ULCOS technology and the BF culture is prevalent in the Steel Industry for mass production.
Melting Reduction: ISARNA

Phase II of ULCOS-I
ISARNA's concept

- pure O$_2$ operation
- CO$_2$ rich off-gas, CCS ready
- no raw material preparation necessary (pulverized coal and pulverized ore)
- very compact cyclone, to feed molten and slightly prereduced iron ore into the bath smelter
- produces hot metal
- rebirth of the Smelting Reduction concept in the new context of CO$_2$-lean ironmaking
Future plans

- *pure oxygen operation, CCS*

- *small experimental plant* under detailed design stage to be built at Saarstahl and experimented with, during 5th and 6th years of the 6FP ULCOS project

- later on (>2010): *commercial size pilot plant*

- then, *commercial deployment…*
New Direct Reduction

Phase II of ULCOS-I
New DR concept

- 100 % Oxygen
- No reformer
- 20 % less energy consumption
- Off gas = CO₂
- Shifter gives high amount of H₂ in the reducing gas = high rate of reduction
- + opportunity to bleed out N₂ and make a H₂ stream which can be used
Future plans

- pure oxygen operation, CCS
- natural gas and syngas can feed the process
- small LKAB DR pilot in Luleå at MEFOS (1 ton of DRI / h), with implementation of the ULCOS-DR technology
- later on, commercial scale pilot.
Electrolysis of iron ore

Phase II of ULCOS-I
Electricity-based Steelmaking

Direct decomposition of iron oxide: \( \text{Fe}_2\text{O}_3 \rightarrow \text{Fe(金属)} + \text{O}_2(\text{气}) \)

Pyroelectrolysis: \( 1600°C \)

Alkaline electrowinning: \( 110°C \)

- Pyroelectrolysis
  - Iron ore
  - Self crucible
  - Molten iron
  - Molten slag
  - Oxygen evolution
  - Rectifier
- Alkaline electrowinning
  - Iron ore
  - Iron oxide
  - Purification
  - Electrowinning
  - Iron metal
- DC EAF analogy
  - Liquid steel
- Aluminum analogy
  - Melting
  - Liquid steel
Future plans - electrolysis

- **the most original route explored within ULCOS, with a potential for "zero emission" in conjunction with the appropriate electricity production (not necessarily nuclear!)**

- project still running at a rather fundamental level, because of the lack of prior experience in the area, although scaling-up takes place rather quickly!

- application is both long-term and a "long shot"

- more laboratory work needed for several more years.
Conclusions

- ULCOS-I has exhibited a series of process technologies with the potential of cutting emissions by a factor 2 to 4
- Full scale implementation still requires much RTD, as carbon-lean technologies are not available off-the-shelf in the steel sector, which has already cut emissions by 50/60% in the last 40 years
- All breakthrough routes need CCS; the concept has to be cleverly adapted to the original features of the sector (shorter-term solution?), except when C-lean electricity is considered (longer-term solution?)
Conclusions

- implementation and deployment can take place from 2015 to 2050, provided the constraints on CO$_2$ are the same everywhere in the world.
- in 2050, the steel industry worldwide might still be short of its targets of reduction, as the increase in production is likely to balance out the reduction in specific CO$_2$ emissions.
- what might be needed, then, are zero-emissions processes, which can also be found in the ULCOS panel of technologies with some more adaptations.
ULCOS-I

- TGR-BF

ULCOS-II (a)

- TGR-BF eng. and construct.
- Demo. tests

ULCOS-II (b)

- Storage step 1
- Additional pilot tests
- Engineering and construct.
- Commercial-scale tests

Steps 2:
- Site sel.
- Injection start-up

Step 3:
- Step 4:
- Industrial storage


ULCOS-II umbrella

ISARNA (early pilot tests)

New DR

Electrolysis

Small pilot (1t/h)

Engineering and Constr.

Commercial-scale tests

Laboratory work

Eng.

Single cell
ULCOS is part of a worldwide initiative…

CO₂ breakthrough program

7TH intermediary
COORDINATION COMMITTEE MEETING

Brussels, Belgium

9-Mar-08