A cooperation between LTU and Swerea MEFOS.

Due to increasing environmental and product demand, the future iron and steel making technology will be characterised by

- lowest possible CO$_2$-emission
- lowest possible energy consumption
- zero waste production
- high quality steel production
The LTU–MEFOS joint research is focused on the following areas:

• A. Raw materials for ironmaking and interaction with process conditions
• B. Zero waste steel production
• C. Iron carrying raw materials as scrap substitutes
• D. Collaboration with other research organisations
• E. Reports and Publications
Work programme for
A. Raw materials for ironmaking and interaction with process conditions

Emphasis on “Mixed burden layers”
- Use of CCA, Carbon Composite Agglomerates and Ferrocoke
- Incorporation of Activated Nut-Coke
- Improved combustion of coal

Also covered: - Modelling of raceway and hearth conditions
- Study of Raceway conditions, ongoing
- Modelling of BF reactor using SIMUSAGE to model slag formation

Researchers involved:
Bo Björkman, Viswanathan Nurni, Hesham Ahmed, Pär Semberg from Ltu.
Lena Sundqvist and Maria Lundgren from Swerea MEFOS.
CCA, Carbon Composite Agglomerate = Iron ore agglomerate also containing reductant

Reductant = coal, nut coke, residues, charcoal etc.

Important parameters = reactivity, Interaction with iron ore, influence on slag formation, mechanical strength etc.

Addition of CCA

Regeneration of CO in pellet layer increases

\[ C + CO_2 \leftrightarrow 2CO \]

1.) Improved indirect reduction degree

\[ FeO + CO \leftrightarrow Fe_{\text{met}} + CO_2 \]

2.) Coarse coke is saved from solution loss reaction and temperature decreases

Production of high quality CCA

Increased energy efficiency
Examples of projects on ”Mixed burden layers”
Activation of nut coke.
Also within RFCS project INNOCARB

Low reactive coke is produced and used in coke layers and pellet layers

Activation or use of selected reactive coke is suitable for pellet layers

Increased reactivity of coke increases
C +CO₂ ⇌ 2CO

Lowering of temperature in thermal reserve zone leads to increased indirect reduction
FeO + CO ⇌ Fe_{met} +CO₂

1.) Endothermic direct reduction of FeO is minimized
2.) Lowered reaction of CO₂ with C in coarse coke

Improved energy efficiency
Tests in fixed bed reactor and thermal analyses on effect of activation of nut coke

- Tests with original and activated coke in
  - FBR/TA in 100% CO₂ - method for further testing
  - TA 50%CO/ 50%CO₂ (dynamic program)
- Effects on activation energy could not be stated
- Gasification rate of CO₂ with C was increased

Scientific publication is under preparation
Examples of projects on "Mixed burden layers"
Charging of reactive nut coke

Operational trials in cooperation with LKAB

Operational data
Measurement of
- Temperature and gas composition
- Vertical temperature profile
Collection of solid samples

Treatment of coke with slurry (magnetite, hydrated lime)
Charging of nut coke in mixed pellet layers into the LKAB EBF
Examples of projects on ”Mixed burden layers”
Charging of reactive nut coke

Operational trials in cooperation with LKAB

Preliminary results indicates that
• Improved energy efficiency due to increased gas efficiency
• Thermal reserve zone temperature reduced for lime activated coke

Treatment of coke with slurry (magnetite, hydrated lime)
Approx. 2% of coke consists of solids from slurry

Charging of nut coke in mixed pellet layers into the LKAB EBF
Examples of projects on "Injection"
Improved coal combustion under variable BF conditions
RFCS Project IMPCO

• The aim is to improve the energy efficiency in the BF
  – Minimized use of coal for BF ironmaking
  – Increased injection of coal and reduced coke rate
  – High and constant replacement ratio of coal to coke

• Should be reached by
  – Maximized combustion and conversion efficiency of injected coal by
    • Modified lance design for enhanced oxygen supply to the coal plume
    • Optimization of operational parameters
    • Improved characterization and selection of injection coal

• Activities involves laboratory tests, theoretical calculations (CFD, heat and mass balance calc.), technical scale tests (lance design, new measurement technique), pilot scale tests in the LKAB EBF and industrial tests at SSAB
Examples of projects on "Injection"
Improved coal combustion under variable BF conditions
RFCS Project IMPCO

- Master thesis by Adeline Morcel for reaction behavior of various coal types during
  a) Volatilization
  b) Reaction of C with CO₂
  c) Reaction C with oxygen in air
- Injection materials tested
  - MV coal (a, b, c)
  - HV coal (a, b)
  - Activated lignite (a, b)
  - Lignite (a, b, c)
  - Petrol coke (a, b, c)
  - Torrified biomass (a, b)

\[
k = A \exp \left( -\frac{E}{RT} \right)
\]
Examples of projects on "Injection" Improved coal combustion under variable BF conditions RFCS Project IMPCO

- Results are under evaluation and master thesis report prepared
- An example of measurements on thermally pre-treated coal (for volatilization) in CO₂

\[ k = A \exp \left( -\frac{E}{RT} \right) \]
Examples of projects on "Injection" 
Improved coal combustion under variable 
BF conditions 
RFCS Project IMPCO

1. CFD modeling for lance design, boundary conditions with variations as for SSAB Luleå
   - Reference case
   - High injection rate
   - Low production rate
   - Modified lance design

2. Transfer to technical scale for validation of model (Linz University)
   - Possible modifications of model/lance design etc

3. Transfer to EBF scale

Distribution of oxygen at lance tip
Evaluation of method to determine the Lc value of coke samples – a collaboration with UNSW, Australia

- Lc value, the coke graphitization degree, can detect the historical temperature of the coke material
  - Useful for evaluation solid samples taken from the blast furnace
  - Indicates operational conditions
  - Difficulties due to interfering peaks to be solved

- Laboratory tests with coke in controlled high temperature atmosphere have been conducted
  - In N₂ and Ar gas atmosphere
  - with coke and melted hot metal or slag separately to evaluate the effect of melt on coke

- Comparison with coke samples taken out of LKAB Experimental Blast Furnace
  - From the raceway and hearth area

- Collaboration with UNSW
  - XRD data for laboratory and EBF samples sent for corresponding evaluations
  - A publication is under preparation
Interaction between iron ore and additives during reduction. The case with olivine

Carried out together with LKAB, financed from HLRC, Hjalmar Lundbohm Research Centre and now within CAMM.

Phenomena up to 1300°C are studied PhD. Thesis to be presented in June 2013
Work programme for C. Zero waste steel production

• Carbon containing residue agglomerates, in close connection to A and B.
  - Reaction mechanisms in CCA produced with residue materials.
• Injection of ACM (Alternative Carbon Material)
  - Modelling of Raceway conditions when injecting residue materials
• Slag products
  - Minor element distribution in steelmaking slags

Researchers:
Bo Björkman, Hesham Ahmed, Qixing Yang, Fredrik Engström, Ida Strandkvist from Ltu.
Lena Sundqvist, Linda Bergman and Amanda Persson from Swerea MEFOS.
Examples of projects on "Injection"
Injection of ACM, Alternative Carbon Material
Also within a RFCS project Flexinject
Efficiency in use of injected BF dust/sludge preliminary evaluation

- C is used similarly as C in coal or coke
- No use of C in Tornado treated sludge mainly due to segregation causing C deficiency
- Injected Iron oxide is reduced to a reduction degree in-between FeO and Fe_{met}

Based on tests carried out in the LKAB Experimental Blast Furnace
Efficiency in use of injected BF dust
preliminary evaluation

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Based on tests carried out in BF No.4 in Oxelösund
B. Iron carrying raw materials as scrap substitutes and C. Zero waste steel production
Residue recycling to a DRI process, RHF

Recipe for agglomerate
Different choices

Agglomerering (Brikettering, pelletising, granulering)

Exploration heat treatment results by lab. scale tests

Basket samples in the EBF

Choice of energy carrier

RHF, Rotary Hearth Furnace

Briquettes charged at De-S plant after heat treatment

Also carried out together with: Swedish ore based steel industry within a "Jernkontoret" project
Influence of Mineralogy in Steelmaking Slag on the Possibility for Valorisation

Focus on leaching of Cr and Mo. Influenced by
• process conditions
• cooling etc.

Individudal minerals behave differently:

Mainly carried out within CAMM as well as together with the scrap based steel industry in Sweden
Dissolves Chromium(Cr\(^{+3}\))

- Merwinitie  Yes
- Akermanite  No
- B-Ca\(_2\)SiO\(_4\)  No
- MgO  Yes
- Gehlenit  No
- Ca\(_2\)Fe\(_2\)O\(_5\)  Yes
- 3CaO*Al\(_2\)O\(_3\)  No
WP 6 Raw materials for future iron- and steelmaking

Thanks for the attention!