Alternative coke for up-scaling – Successful development for laboratory-pilot-industrial and implementation

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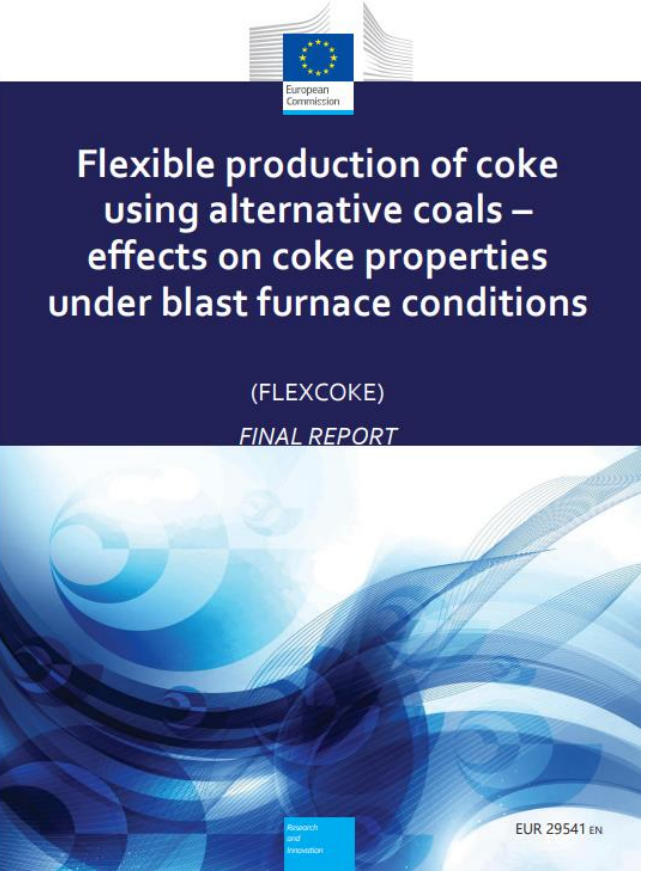
European Commission

Research Fund for Coal & Steel

SWERIM

Project time
01/07/2013 – 31/12/2017



Project partners

Swerim AB (Swerea MEFOS), coordinator	Sweden
THYSSENKRUPP STEEL EUROPE AG (TKSE)	Germany
SSAB EMEA	Sweden
LUOSSAVAARA-KIIRUNAVAARA AB (LKAB)	Sweden
Tata Steel UK	United Kingdom

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Overview

WP1
Laboratory coke making

MEFOS, Tata, SSAB, TKSE

WP2
Laboratory characterisation of coke relative blast furnace conditions
TKSE, MEFOS, ~~Tata~~, SSAB, LKAB

WP3
Technical and pilot scale test of coke relative blast furnace conditions
~~**Tata**~~, MEFOS, TKSE, SSAB, LKAB

WP4
Operational tests in coke plant and in BF

SSAB, MEFOS, LKAB, TKSE

WP5

Coordination, documentation and reporting

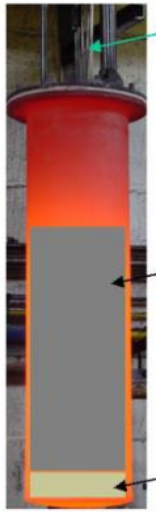
MEFOS, TKSE,

Tata, SSAB, LKAB

WP1 & WP3 coke making tests at DMT

Final coke temperature:
1030 - 1040 °C

Coking time:
approx. 4 hours



D. Gajic et. Al. New Findings from the DMT Small-Scale Coking Test Retort Regarding Coke Quality and Coke Oven Wall Safety, AisTech 2012 conf. proc., Atlanta USA, p. 237-246

10 kg retort

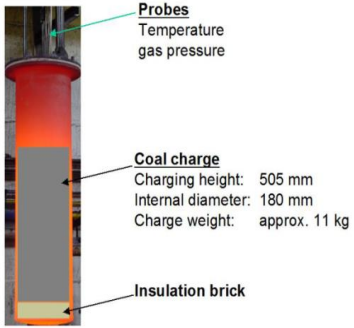
http://www.dmt.de/en/dienstleistungen/kokereitechnik/kohle_koksuntersuchungen.html

500 kg semi-industrial coke oven with movable walls

Laboratory coke making

Final coke temperature: 1030 - 1040 °C

Coking time: approx. 4 hours



- 10 coke making tests at DMT 10 kg retort
- Base blend, coking coals from SSAB
- Particle distribution, bulk densities etc. as for SSAB coking coal mix

No.	"Coal" Blend %	LV coal	MV coal	HV coal	TC HV high FSI	TC HV no FSI	Pet coke	Anthracite	Char coal	TW, high temp.	TW, medium temp.
1	Base Blend	40	32	28							
2	Base Blend + HV TC high FSI	40	25	25	10						
3	Base Blend + HV TC no FSI	40	25	25		10					
4	Base Blend + Anthracite	40	30	25				5			
5	Base Blend + Charcoal	40	30	25					5		
6	Base Blend + TW, high temp.	40	30	25						5	
7	Base Blend + TW, medium temp.	40	30	25							5
8	Base Blend + HV TC no FSI + Anthracite	40	25	25		5		5			
9	Base Blend + HV TC No FSI + Pet coke	40	25	25		5	5				
10	Base Blend + HV TC no FSI + Charcoal	40	25	25		5			5		

Thermal coal, anthracite, charcoal and torrefied wood were selected for coking tests and mixtures with thermal coal and anthracite, pet coke or charcoal were made

Based on characterization results in WP2, some test mixes were selected for pilot scale

DMT 500 kg semi-industrial coke oven

Cokemaking tests at DMT 500 kg pilot coke oven

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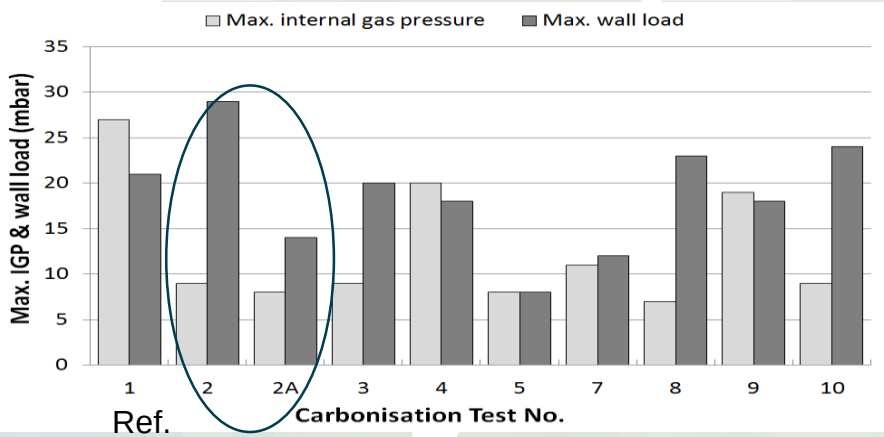
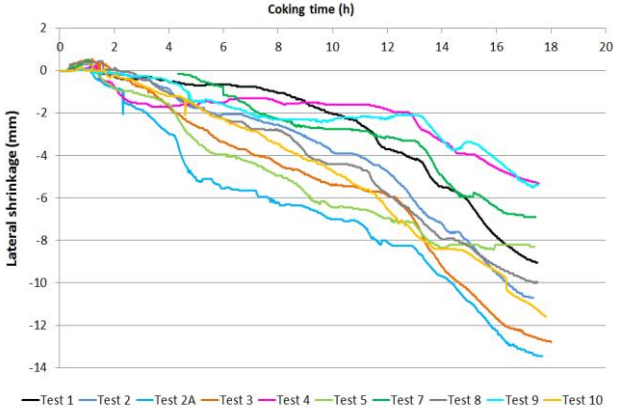
No.	"Coal" Blend %	LV coal	MV coal	HV coal	TC HV no FSI	Pet coke	Anthracite	Charcoal	TW wood medium
1	Base Blend	40	32	28					
2	Base Blend + HV TC no FSI	40	25	25	10				
2A	Base Blend + HV TC no FSI, **lower content**	40	30	25	**5**				
3	Base Blend + 5 % Anthracite	40	30	25			5		
4	Base Blend + Charcoal	40	30	27				3	
5	Base Blend + Pet coke + Charcoal	40	29	25		3		3	
7	Base Blend + HV TC no FSI + Pet coke	40	29	25	3	3			
8	Base Blend + HV TC no FSI + Anthracite	40	29	25	3		3		
9	Base Blend + 3 % HV TC no FSI	40	30	27	3				
10	Base Blend + 3 % Anthracite	40	30	27			3		





Important parameter at SSAB coke oven: ***Low pressures on the coke oven walls!***

10% addition of thermal coal showed unexpectedly high wall pressure compared with the retort test → the recipe was changed to 5% addition in the mix (2A)

The coke shrinkage was enough for all tests and could easily be pushed out of the coke oven

WP2 Laboratory characterisation – DMT 500 kg coke oven

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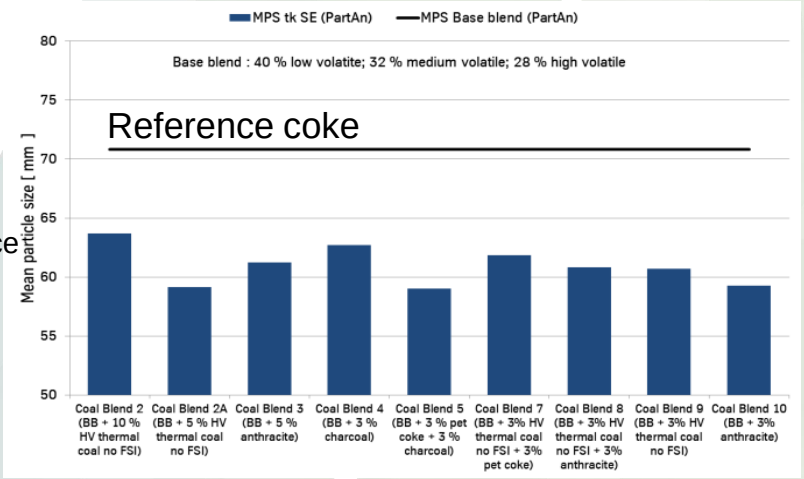
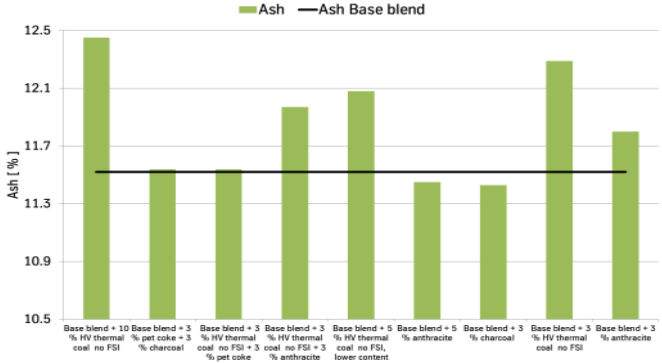
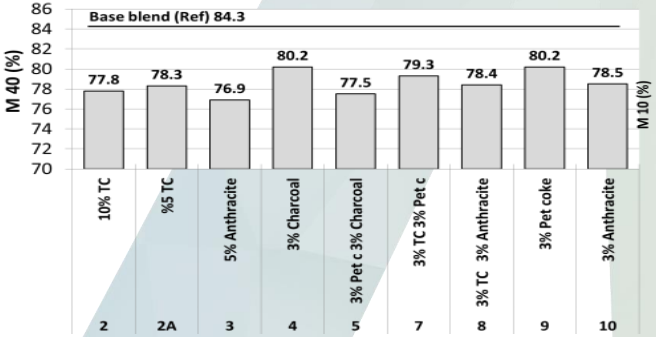
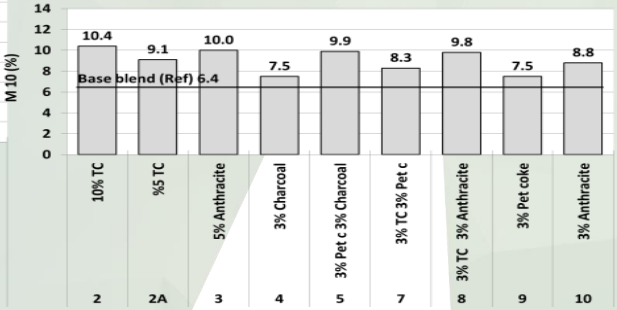
- **Particle size – Optical measurements (PanAn) at thyssenkrupp**
  - Smaller coke pieces (mean particle size) with addition of alternative C-containing material
- **Mechanical strength, Micum (M)**
  - M 40 (breakage) decreases and M10 (wear) increases compared to reference coke
- **Ash content**
  - Addition of thermal coal increases the ash content, especially with 10 %
  - Addition of biomass (charcoal) or anthracite gives lower ash contents









WP2 CRI/CSR DMT 500 kg coke oven

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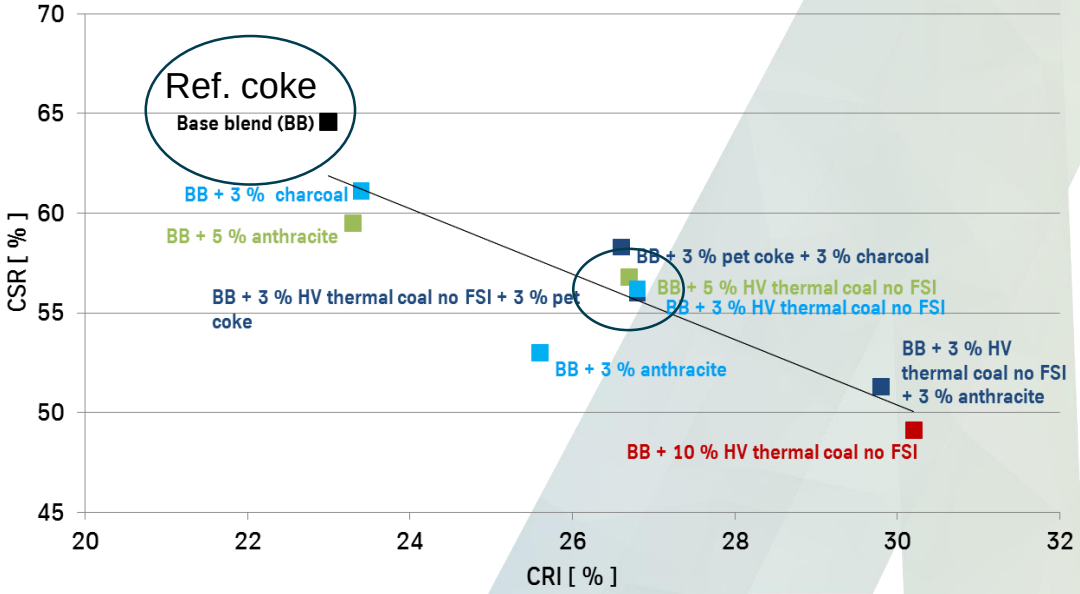
CRI – coke reactivity index & CSR – coke strength after reaction

Standard quality tests of coke reacted at 1100 ºC for 2 hours in 100 % CO_2 gas, $C + CO_2 = 2\ CO$

High CSR & low CRI is desirable



- **Alternative coke gives higher CRI and lower CSR compared to reference**

Project group decided to go ahead with 2 types of blends for industrial scale coke making tests

WP4 Operational tests in coke plant and in the blast furnace

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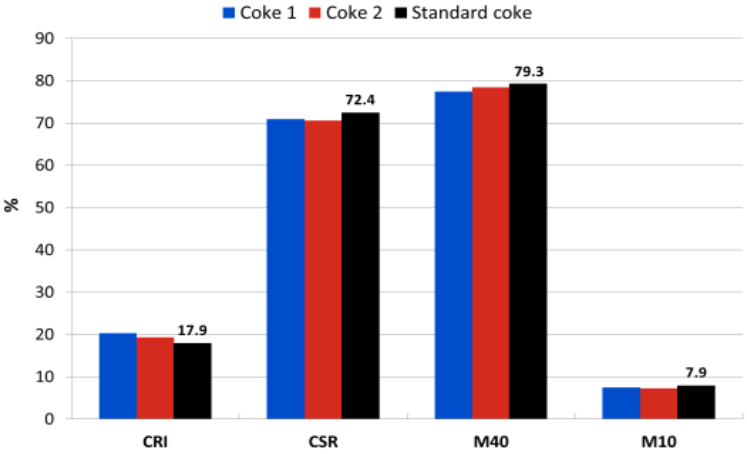
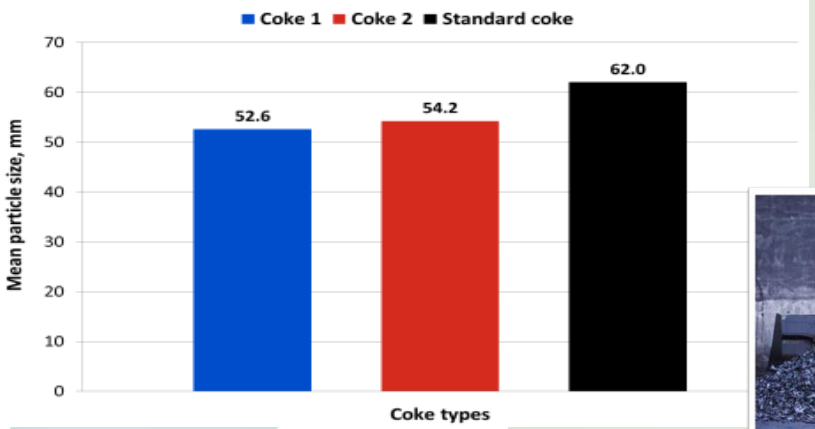
SSAB 1:st industrial coke making – production av alt. coke for blast furnace pilot trials (EBF)

Mix name:	LV part	MV part	HV part	Non-coking part
Mix 2a DMT	40%	30%	25%	5% thermal coal
Mix 1 EBF® trial coke	43%	32%	20%	5% thermal coal 400 t prod.
Mix 7 DMT	40%	29%	25%	3% thermal coal + 3% pet coke
Mix 2 EBF® trial coke	39%	33%	22%	3% thermal coal + 3% pet coke 400 t prod.

WP2 Characterization



Micum & CRI/CSR (DMT)



Average particle size (SSAB)

WP4 Operational tests in coke plant and in the blast furnace

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Tests in LKAB Experimental blast furnace (EBF)

Working volume	8.2 m3
Working height	5.9 m
Hearth diameter	1.4 m
Tuyeres	3
Top pressure	1.5 bar
Productivity	3-5 tHM/m3, 24 h
Total red. rate	510-530 kg/tHM

November 1st - 11th 2016 testing Coke 1 and Coke 2

- A large number of samples were taken during the trial (shaft probes) and after stopping/quenching and excavation of the EBF
- After evaluation of the EBF trial the result showed that there was no significant difference of Coke 1 or Coke 2 regarding C-consumption and performance in the blast furnace
- The project group chose to use Coke 1, with 5% addition of thermal coal to the blend, in SSAB full scale simultaneously operational trials in coke plant and in blast furnace No. 3.

WP4 SSAB 2nd industrial coke making trial – prod. of alternative coke for simultaneous industrial blast furnace trials at SSAB BF No. 3 (9th of May - 24th of June 2017)

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No deviating or disturbing effects were noted during coke making with FLEXCOKE trial coke, 5% thermal coal addition

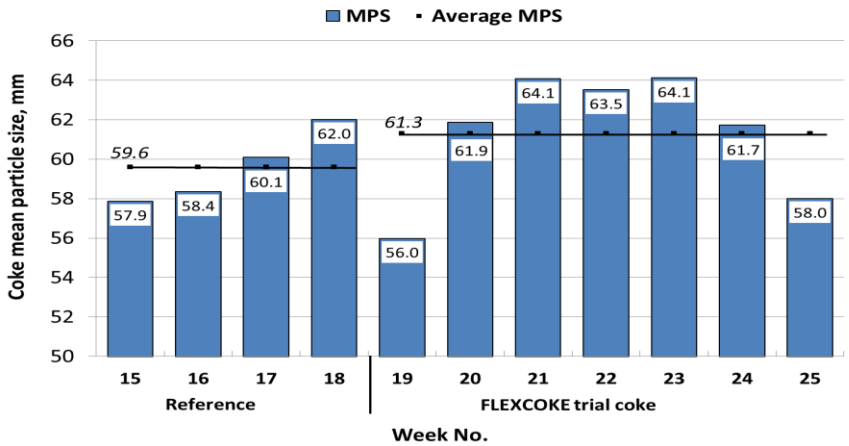
Name:	LV part	MV part	HV part	Non-coking part
FLEXCOKE trial mix	42%	36%	17%	5% thermal coal
Standard (Reference) mix	42%	36%	22%	

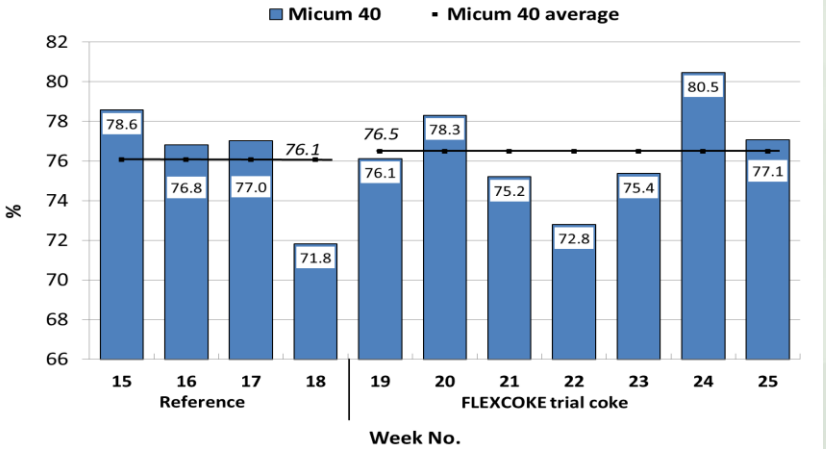
Ramping up; 20%, 40%, 80% and 100% (June)

WP2 characterization

No smaller coke medium particle size was noted, unlike previous tests!

Mechanical strength (Micum) significantly better than DMT 500 kg tests
→ **Improved results in industrial coke ovens!**





WP4 SSAB 2nd industrial coke making trial – prod. of alternative coke for simultaneous industrial blast furnace trials at SSAB BF No. 3 (9th of May - 24th of June 2017)

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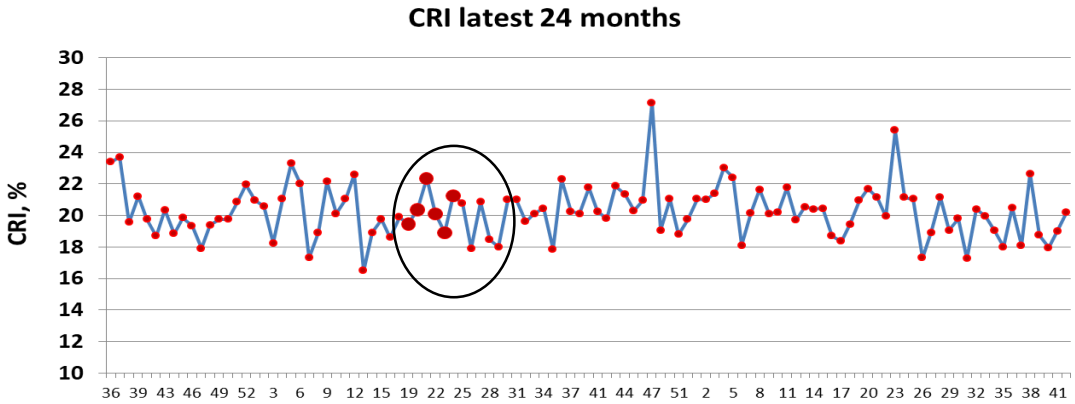

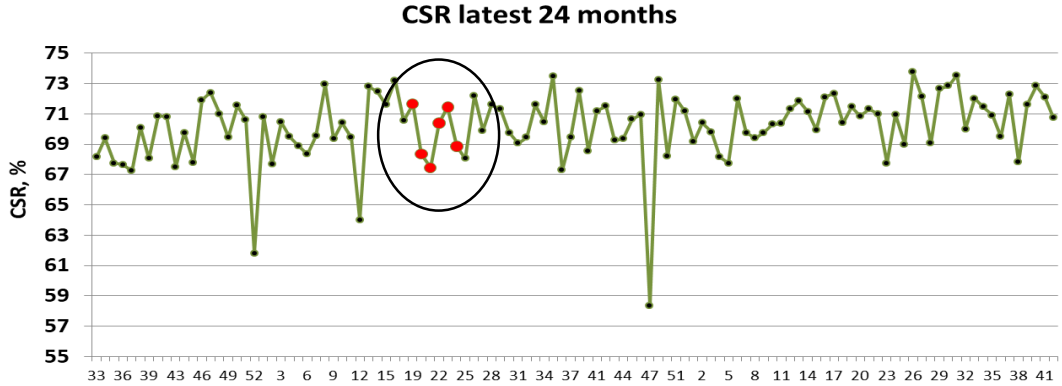

CRI (coke reactivity index) and CSR (coke strength after reaction), lays with the ***normal deviation of standard production coke***

Production in industrial coke plant gives better results with several units compared to coking in pilot scale when alternative C-containing materials are used in the mix

WP4 SSAB industrial blast furnace trial at BF No. 3 in Luleå 9th of May - 24th of June 2017

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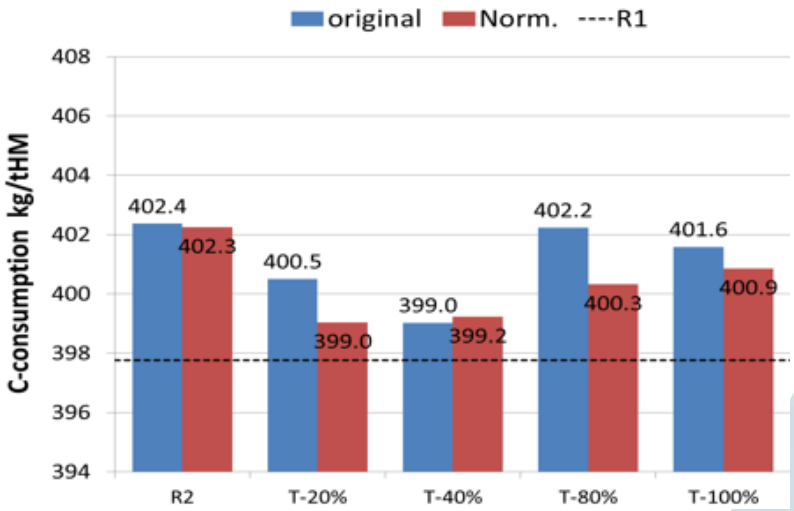
- **No negative effects** was noted by observations from blast furnace operators
- **No higher C-consumption**, based on the heat-and mass balance model (MASMOD)



To fully investigate the effect of FLEXCOKE test coke on coking plant and in blast furnace operation, a longer time frame for production and operation was required.

Therefore, a new test period to produce coke with 5% of thermal coal in the coke mix was planned by SSAB outside the project

was successfully made for 10 weeks during 2018

SSAB implementation at coke plant and blast furnace

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- SSAB is running with 5% thermal coal addition right now – June 2019 to February 2020
- Will be implemented as standard from 2020
  - Tests with other thermal coals
- Experience – No harmful effects (~ higher ash content in the coke)

Thank you!

Photo Stig-Göran Nilsson, Jernkontorets bildbank

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