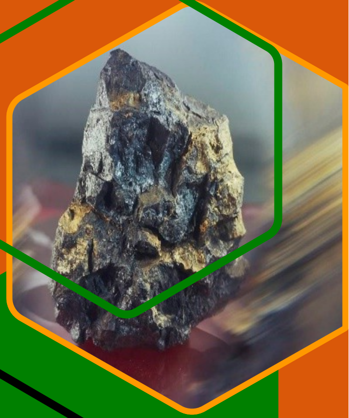
A joint workshop of PREMA and BIOCOKE4FAI projects
11-12 January 2023 Dolný Kubín, Slovakia
Hybrid event

PRÉMA

Alternative reducing agents for the production of ferroalloys - their properties and testing

Jaroslav Legemza, Iveta Vasková, Róbert Findorák

FMMR TUKE



BIOCOKE4FAI

Norway grants
NCBR Narodowe Centrum Badań i Rozwoju

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820561

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FACULTY OF MATERIALS, METALLURGY AND RECYCLING

EVERY SUCCESSFUL JOURNEY BEGINS WITH THE RIGHT DECISION

TECHNICAL UNIVERSITY OF KOSICE

interesting composition of faculties

1. **Mining, Ecology, Process Control and Geotechnology** (1952)
2. **Materials, Metallurgy and Recycling** (1952)
3. **Mechanical Engineering** (1952)
4. **Electrical Engineering and Informatics** (1969)
5. **Civil Engineering** (1977)
6. **Economics** (1992)
7. **Manufacturing Technologies** (campus in Prešov) (1992)
8. **Arts** (1998)
9. **Aeronautics** (former University of military) (2005)

MORE THAN 90.000 ALUMNI

teachers/students

11 238 students

840 pedagogical staff

1495 others (administration, technicians)

Faculty of Materials, Metallurgy and Recycling

FMMR TUKE is created since 2016 three strong, successful and ambitious constitutions

- **INSTITUTE OF METALLURGY**
- **INSTITUTE OF MATERIALS AND QUALITY ENGINEERING**
- **INSTITUTE OF RECYCLING TECHNOLOGIES**

Why FMMR

- **perspective study programs** and attractive content of subjects
- connection with practice and **job opportunities during studies**
- 95% of graduates **found employment** in the field
- excellent conditions for **research and international cooperation**
- **friendly approach** of teachers
- unique team **atmosphere** and rich social **life at the faculty**
- **individual approach** and space for **personal development**

- **Bachelor study**
- **Master study**
- **Doctoral study**

- **Study programmes**

Metallurgy

Materials

Waste treatment and recycling

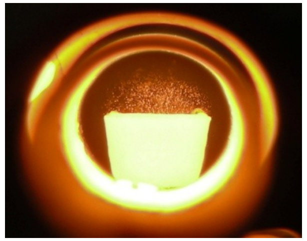
VISIONS AND PERPECTIVES

- **Inovations of study programs** in accordance with events in Slovakia
- **Focus and orientation in the field of digization and automation** of industry also with regard to the indisputable benefits and added value that they bring to the processes.
- **Reflecting on the ambitious environmental aims** of the European Union in reducing CO2 emissions through scientififc projects in cooperation with industrial partners.
- Our next priority is **to arouse interest in young people** and show them the way to the future in a modern world surrounded by digization and green technologies with an emphasis on communication skills and personel development management.
- Last but not least, our further self-education is also important, so we will be ready to respond to tomorrow‘s needs

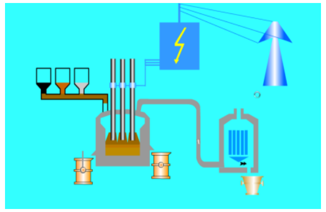
Structure of activities on FMMR TUKE in the ferroalloys

1. • education

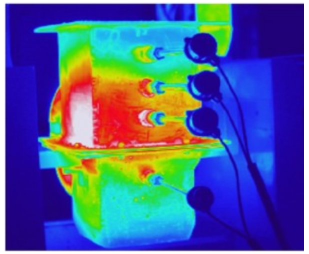
2. • research



3. • creation of software programs



4. • tutorials



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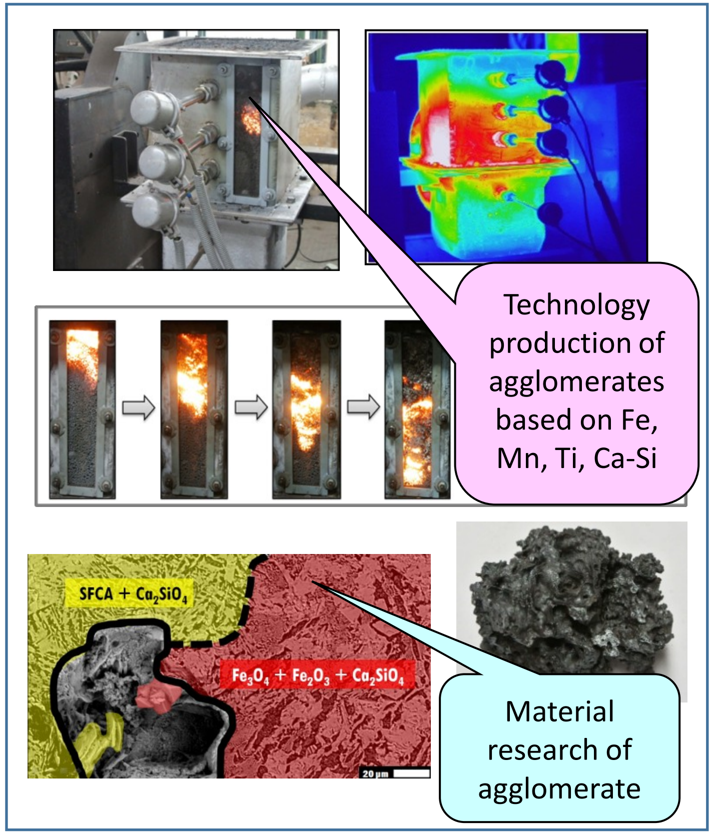
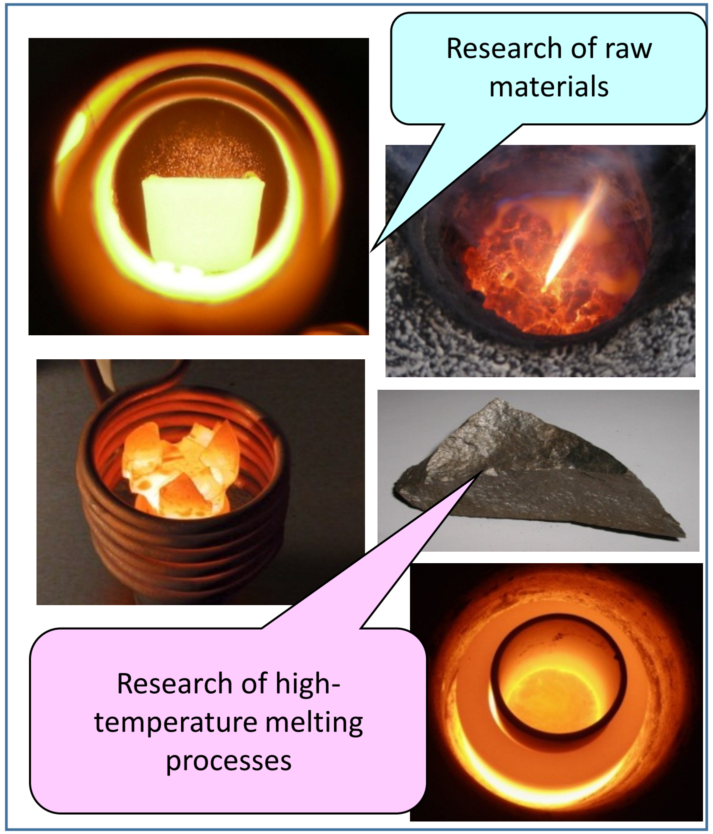
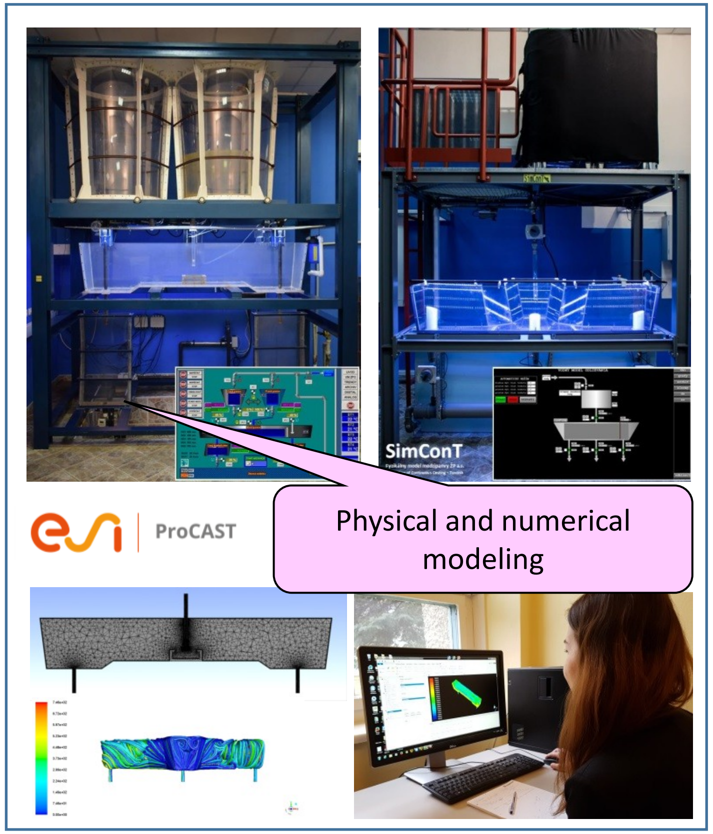
Research on UMET FMMR TUKE







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Organizers:

Research in the ferroalloys production on UMET

1. • testing of input materials and products
2. • sintering technologies
3. • melting technologies

- properties of coal, coke, biomass and electrode paste
- properties of Mn ores
- properties of quartzite, quartz
- production of Mn agglomerate
- simulation of production
- material balances, thermodynamics

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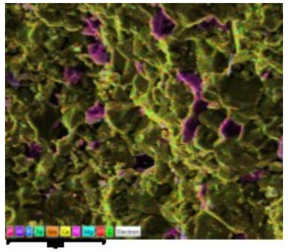
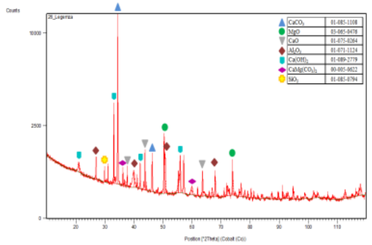
Methodology for testing of Mn ores

chemical composition

physical properties

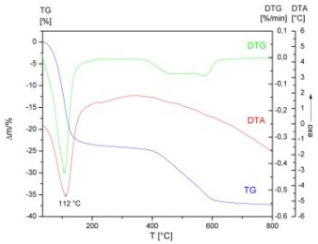


microstructure of grains



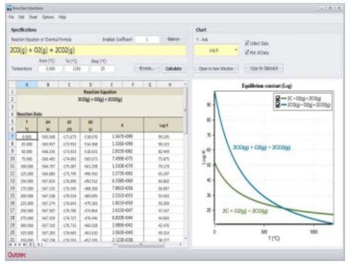
XRD composition

intervals of melting



DTG, DTA analysis

high – temperature of stability



thermodynamics models

reducibility

Production of FeMnC, Mn $_{metal}$

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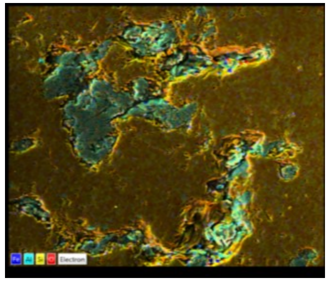
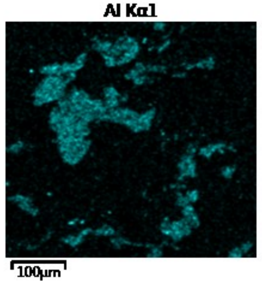
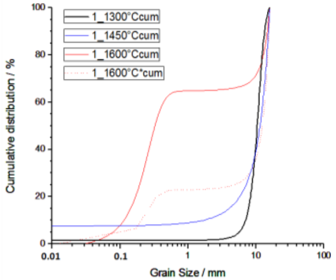
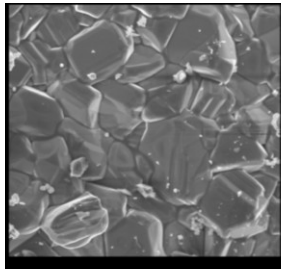
Organizers:

Methods for the evaluation of quartzes or quartzites

 chemical composition	 homogenity	 microstructure of grains	 detail of impurities	 high – temperature of stability
 distribution of grains, HI and TSI index	 reducibility – ground state	 reducibility – grain state	 microstructure of SiC	determination of significance of properties and evaluation

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Organizers:

Goal of the presentation

- specify alternative reductants
- describe selected properties and their determination
- specify thermodynamic models using biomass
- to specify own methodology for determining reactivity

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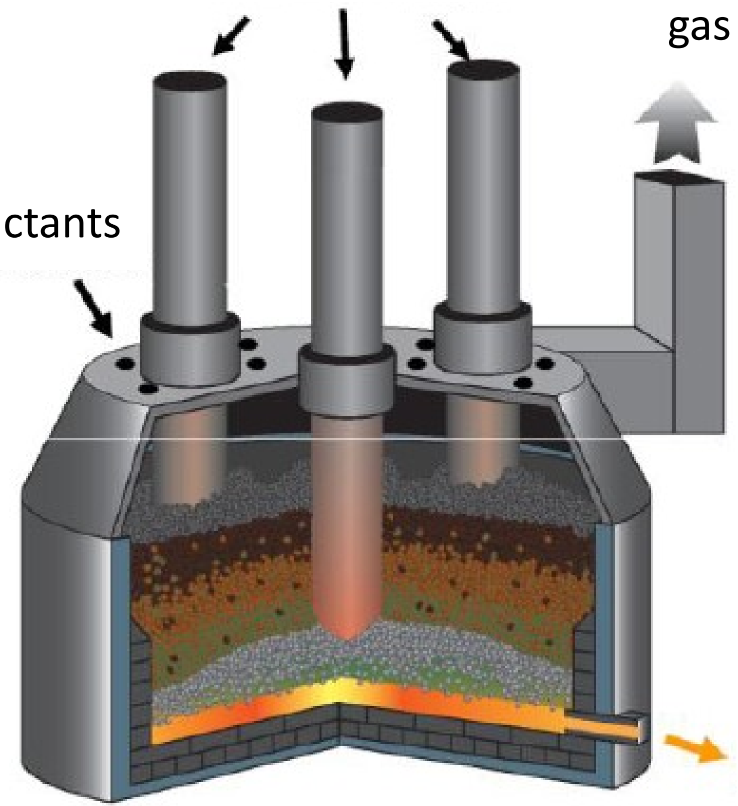
Production of ferroalloys in SAF

electric current

gas

ores +

carbon reductants



ferroalloy + slag

carbon reductants:

coal, coke,

semicoke, charcoal

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Organizers:

Reductants for production of ferroalloys

Carbonaceous reductants for production of ferroalloys

- traditional
  - bituminous coal
  - coke
- alternative
  - brown coal
  - petroleum coke
  - semi-coke
  - charcoal

Others:

lignite
anthracite
wood chips
wood and coal briquettes
hydrogen
syngas, biogas

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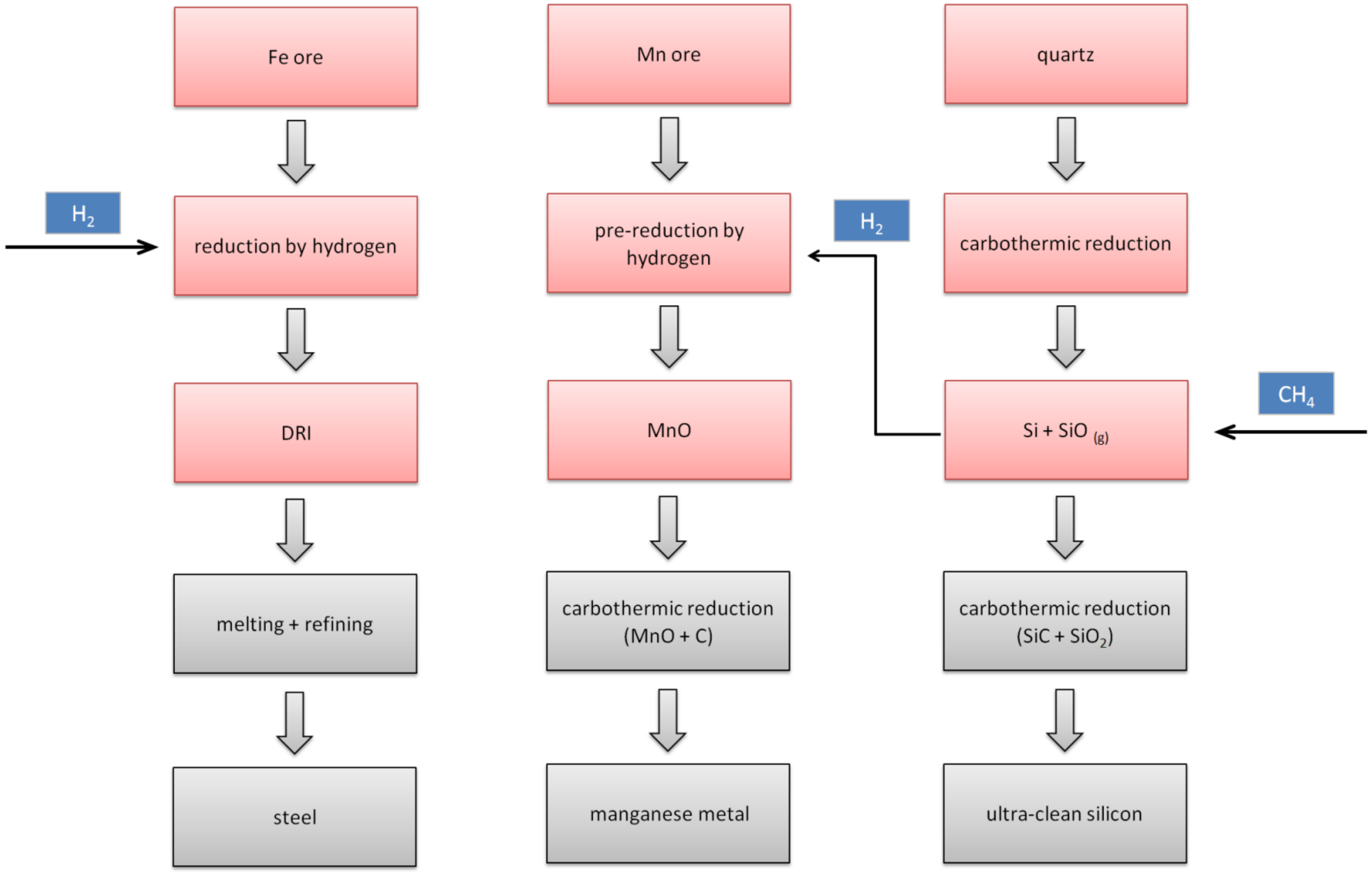
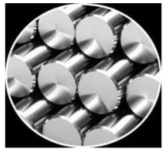
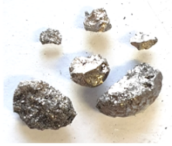
Hydrogen project in Slovakia (2022 – 2025)

The potential of hydrogen utilization in metallurgical industry of SR aimed on decrease of CO_2 production

SLOVAK RESEARCH AND DEVELOPMENT AGENCY







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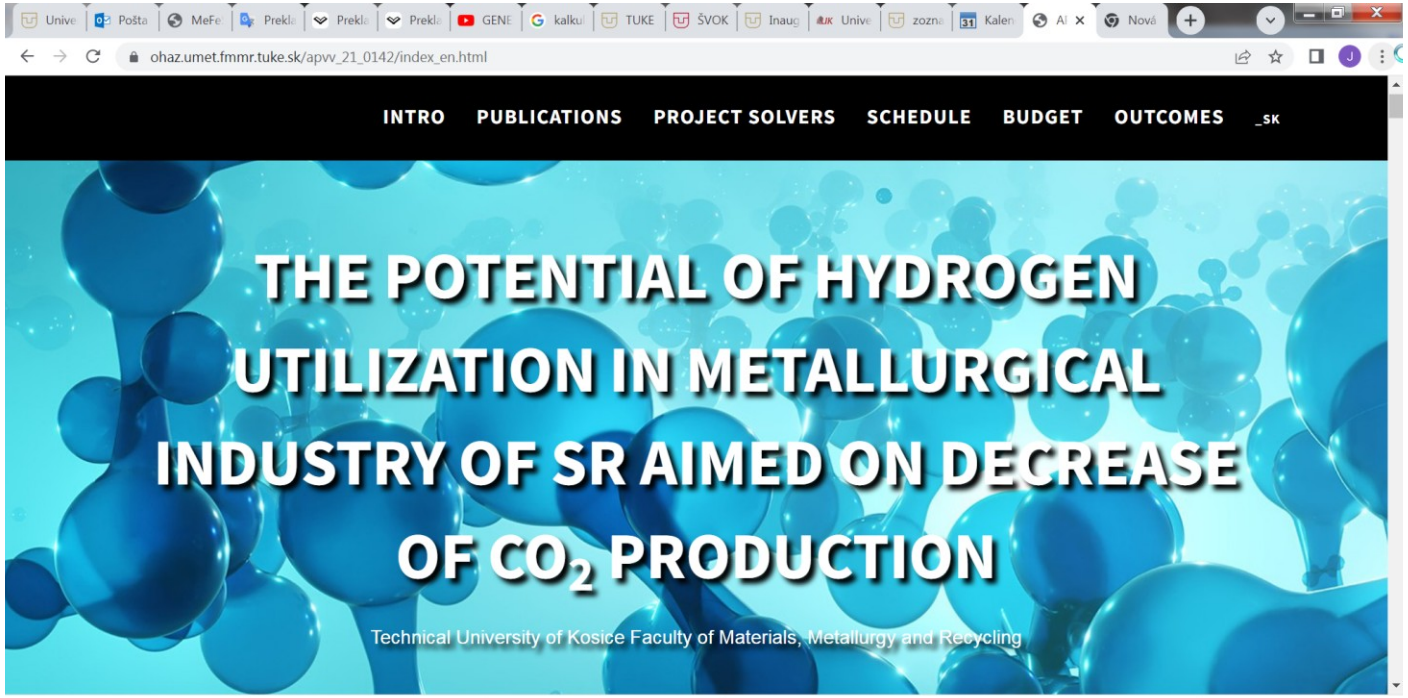

https://ohaz.umet.fmmr.tuke.sk/apvv_21_0142/

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Properties of carbonaceous reductants

Properties of carbonaceous reductants

- chemical and phase composition
  - water (W)
  - volatile matter (VM)
  - fixed carbon (C_{FIX})
  - crude ash (A)
  - chemical composition of ash
  - phase composition of ash
  - element analysis C, H, O, N, S
- physical and mechanical properties
  - grain size composition
  - porosity
  - density
  - ash melting point
  - mechanical strength
- other specific properties
  - maceral analysis
  - reactivity
  - electric resistance
  - calorific value

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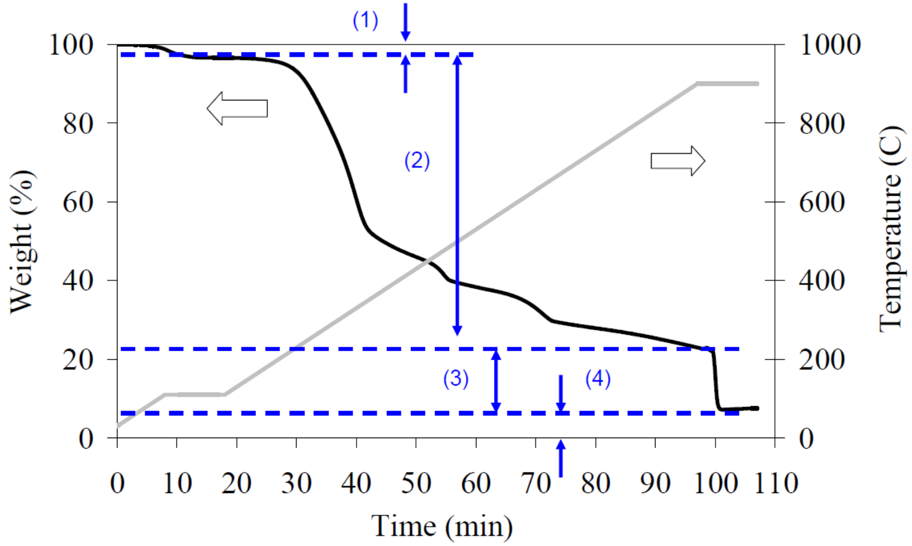
Chemical analysis of carbonaceous reductants

Type of fuel	Proximate analysis – approximate analysis [wt%]				Ultimate – element analysis [wt%]					
	H_2O (W)	Ash (A)	Combustible volatile matter (VM)	Fixed carbon (C_{FIX})	Ash (A)	C	H	O	N	S
Sunflower husks	9.3	3.2	75.5	12.0	3.2	46.8	6.1	43.1	0.7	0.10
Wood sawdust	7.1	1.5	83.4	8.0	1.5	50.6	5.9	41.7	0.2	0.10
Wood	3.1	2.4	77.3	17.2	2.4	55.2	5.7	36.4	0.2	0.10
Charcoal	2.2	1.8	6.4	89.6	1.8	92.4	1.4	3.9	0.4	0.05
Brown coal	12.4	6.8	54.8	26.0	6.8	61.9	3.9	25.1	1.2	1.10
Bituminous coal	6.3	7.3	30.3	56.1	7.3	80.2	5.2	5.5	1.4	0.40
Blast furnace coke	3.5	10.5	0.8	85.2	10.5	87.2	0.3	0.5	1.1	0.40
Coke powder	5.5	12.1	1.5	80.9	12.1	85.4	0.3	0.6	1.3	0.30



(1) moisture (W) — 3 %
(2) combustible volatile matter (VM) — 76 %
(3) fixed carbon (C_{FIX}) — 15 %
(4) ash — 6 %

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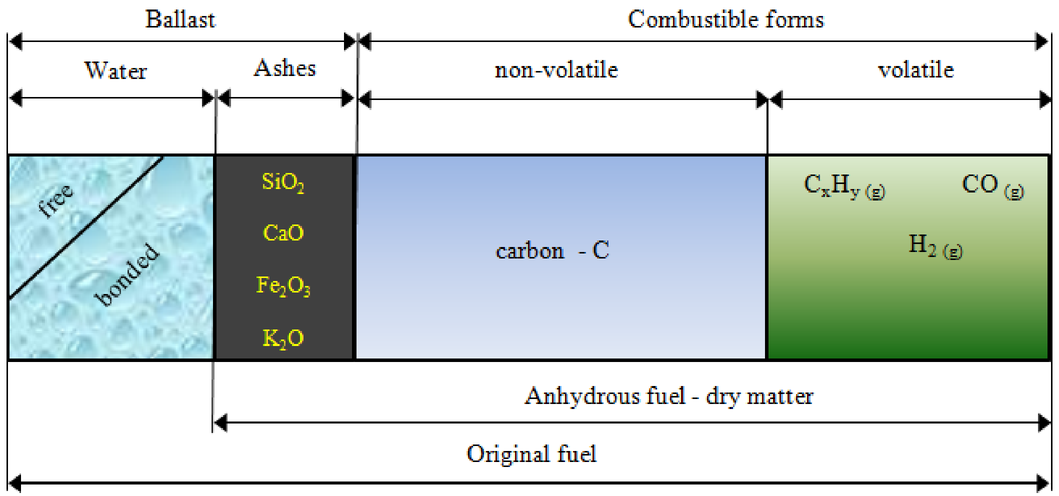
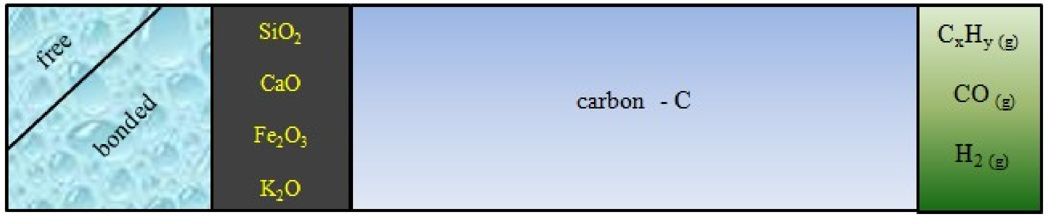
Organizers:

Proximate analysis of carbonaceous reductants

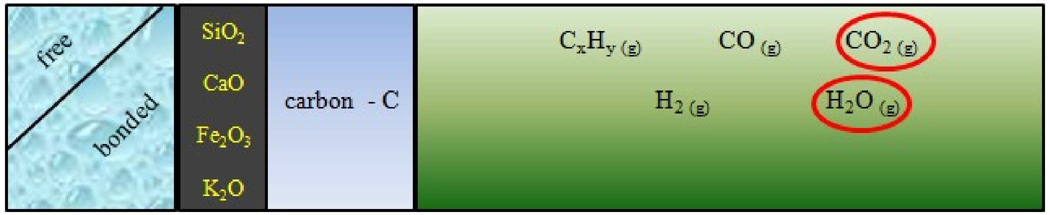
basic specification of carbonaceous reductant



composition of coke



composition of biomass – wood



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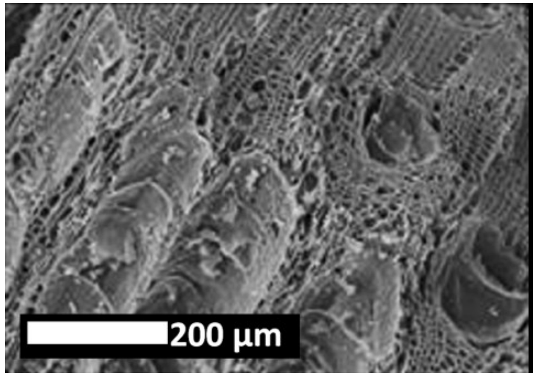
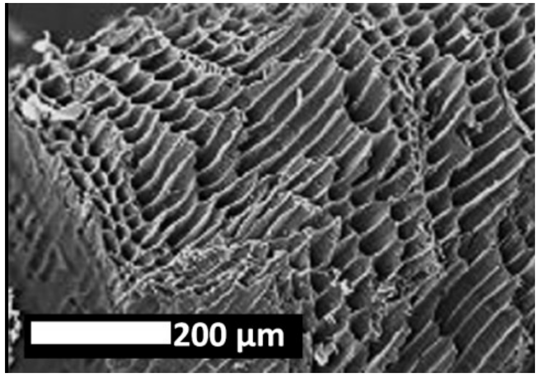
Organizers:

Composition of ash in the carbonaceous fuels

Type of fuel	Ash content [%]	Chemical composition of ash* [%]						
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5
Coke powder	14.5	34.7	21.1	27.2	6.8	2.8	1.6	0.6
Walnut shells	0.7	2.8	1.0	4.2	33.1	5.2	17.8	3.7
Spruce bark	3.0	34.4	6.9	5.0	39.5	4.8	7.1	-
Beech sawdust	0.3	9.2	5.0	24.6	40.0	8.5	6.6	-
Oak sawdust	1.5	41.1	6.7	4.5	23.8	2.6	9.3	0.72
Pine sawdust	0.9	46.6	11.7	6.5	15.2	3.0	5.6	0.85
Corn	1.6	41.1	1.6	2.1	2.6	7.8	37.6	-
Charcoal 1	6.1	22.9	3.2	31.9	28.8	3.0	8.7	-
Charcoal 2	3.5	6.3	0.85	1.47	37.0	12.5	11.42	1.65



charcoal 1



charcoal 2

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Composition of ash in the carbonaceous fuels

Identified phase composition		Coke	Charcoal	Oak sawdust
Chemical formula	**Mineral name**	[wt%]	[wt%]	[wt%]
$(Ca_{0.94}Mg_{0.06})CO_3$	Calcite	-	57.3	-
$MgCO_3$	Magnesite	-	26.8	12.1
$Ca_6Mn_6O_{16}$	-	-	15.9	-
$Al_{1.25}Si_{0.75}O_{4.87}$	Mullite	50.4	-	-
$CaFeSi_2O_6$	Hedenbergite	4.3	-	-
$CaSO_4$	Anhydrite	8.0	-	-
SiO_2	Quartz	16.9	-	10.2
$Ca_2Fe_{1.54}Al_{0.46}O_5$	Brownmillerite		-	-
Fe_2O_3	Hematite	16.5	-	-
Fe_3O_4	Magnetite	4.9	-	-
MgO	Periclase	-	-	-
$CaCO_3$	Calcite	-	-	56.0
CaO	Calcium oxide	-	-	19.8
Amorphous share	-	**19.6**	**41.0**	**84.0**

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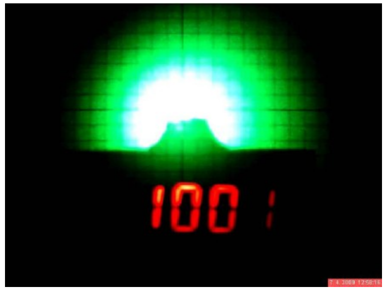
Melting point of ash in the carbonaceous fuels

Solid fuels	Ash content (A) [%]	Melting point of ash [°C]
Pasture grass	8.8	1150
Wheat grain	2.7	687
Rape straw	6.2	1273
Wheat straw	5.7	998
Rye straw	4.8	1002
Barley straw	4.8	980
Agricultural hay	5.7	1061
Beechwood	0.5	1350
Willow wood	2.0	1283
Poplar wood	1.8	1335
Spruce wood	0.6	1426
Bark from coniferous wood	3.8	1440
Brown coal	5.1	1050
Bituminous coal	8.2	1250
Anthracite	5.3	1340
Coke	11.0	1380
Charcoal	5.3	1280

coke ash

charcoal ash



barley straw ash

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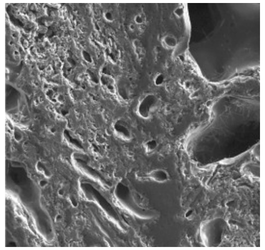
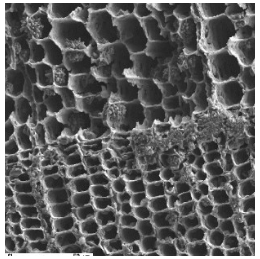
Organizers:

Typical properties of charcoal and coke used for ferroalloys

Properties	Industrial charcoal	High-quality charcoal	Metallurgical coke	Microstructure
Carbon [%]	65–85	92–94	86–88	coke
Volatile matter [%]	15–35	3.8	0.5–2	
Ash [%]	0.4–4.0	2.0–2.5	10–12	
Analysis of ash [%]				
SiO_2	5–25	23	25–55	
Fe_2O_3	1–13	5	5–40	
Al_2O_3	2–12	5	13–30	charcoal
CaO	20–40	11–30	3–6	
MgO	5–12	6	1–5	
CO_2 reactivity at 1060 °C [%C/s]	2.1–2.3.10^{-2}	2.8–3.2.10^{-2}	0.2–0.5.10^{-2}	
Specific electric resistance at 1000 °C log [Ω.m]	0.014–0.023	0.015–0.030	0.003–0.008	

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Organizers:

Comparison of biomass and coke

Individual types of biomass have (compared to coke):

- higher moisture
- lower total and fixed carbon content
- higher content of volatile matter
- significantly lower ash content
- lower sulfur and phosphorus content
- higher content of alkali
- higher CaO and MgO content, higher basicity
- higher reactivity and electrical resistivity
- lower thermal stability

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Organizers:

Impact of biomass on production of ferroalloys

How the properties of biomass will affect the technology of production of ferroalloys?

↓

the optimal way is to combine coke with charcoal (10 – 30 %)

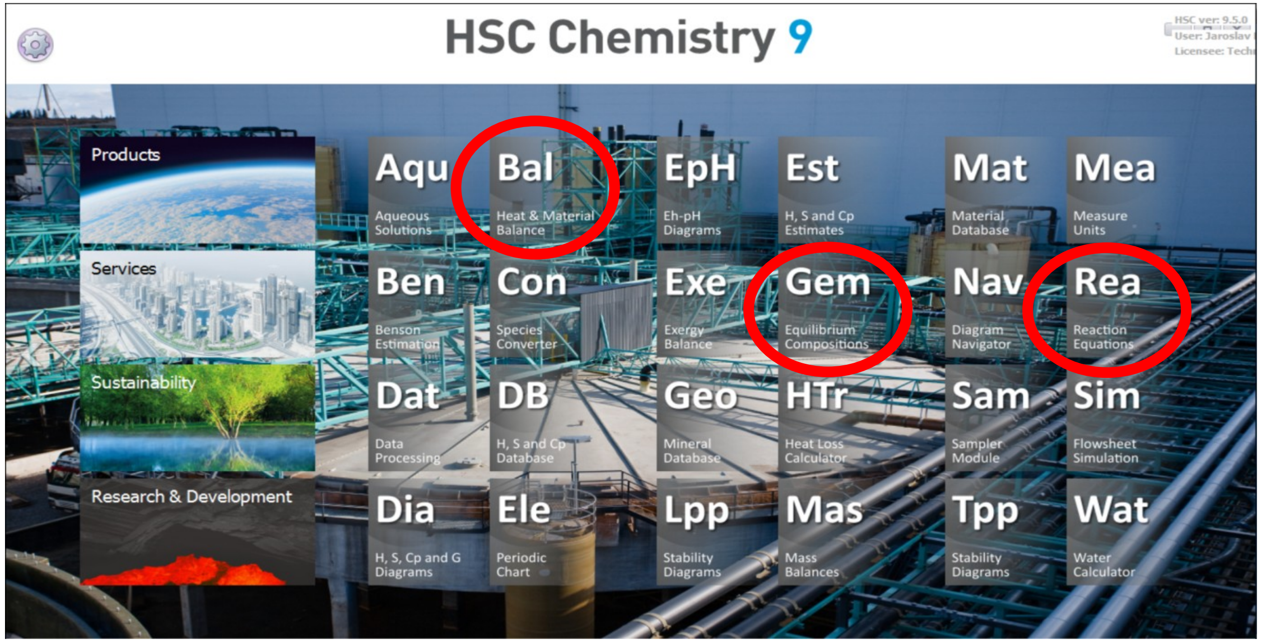
↓

lower electricity consumption, higher yield of metals, lower emissions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820561

Thermodynamics for reductants

Thermodynamics modelling was realised using thermodynamic software “HSC Chemistry 9”, Outokumpu Research Oy, Pori, Finland) that allows one to predict the output parameters based on the initial composition analysis. For mathematical modelling the basic chemical reactions with standard Gibbs energy and mass and thermal balance were calculated.



Bal - Heat & Material Balance **Gem** - Equilibrium Composition **Rea** - Reaction Equations

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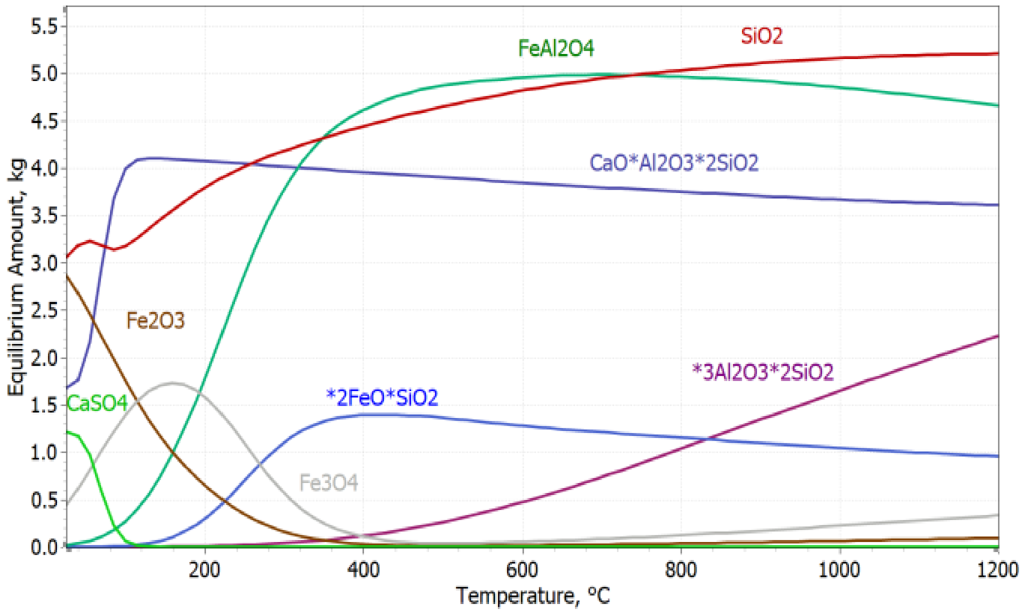
Correlation of properties between model and experiment

Gibbs diagram from HSC simulation



the predicted mineralogical composition of ash allows the output parameters to be calculated

Parameter	Fuel	Modelling HSC Program	Experimental Analysis
Caloric value (MJ/kg)	coke 1	28.02	28.16
	coke 2	28.57	28.87
	lignin	22.87	23.14
	oak sawdust	16.43	16.56
	pine sawdust	19.07	18.93
	walnut shells	16.31	16.90
	charcoal 1	31.86	32.66
	charcoal 2	29.85	29.07
Ash content (wt%)	coke 1	12.43	12.10
	coke 2	14.12	13.15
	lignin	3.38	3.40
	oak sawdust	1.59	1.50
	pine sawdust	1.08	0.91
	walnut shells	0.68	0.72
	charcoal 1	2.33	2.30
	charcoal 2	4.97	5.08

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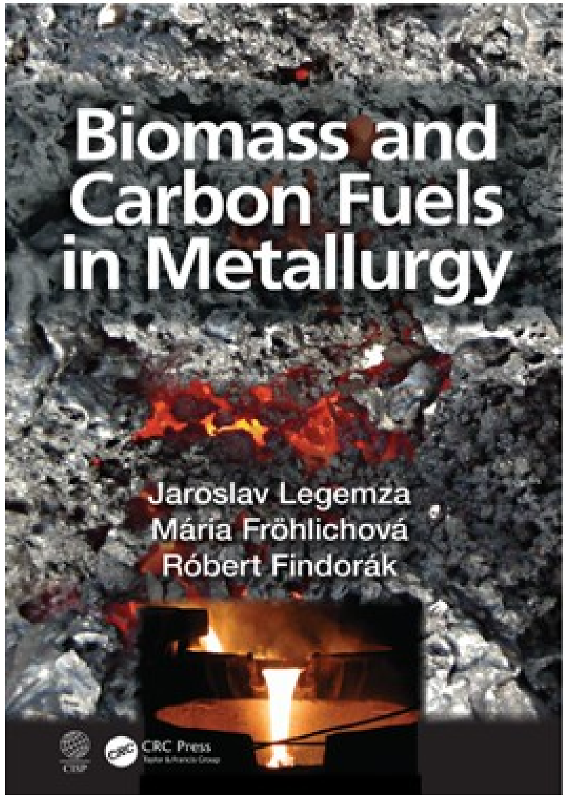
Organizers:

Science book



A significant part of the publication is oriented on alternative fuels – particularly biomass and its utilisation for metallurgical purposes. It describes characteristics of biomass, techniques of its treatment and the possibilities of its use in the production of charge for blast furnaces, pig iron, steel and ferro-alloys.

Taylor & Francis, USA
Cambridge International Science Publishing, Great Britain, 2020

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Reactivity:

- play an important role in the assessment of the quality of reduction materials for metallurgical applications
- based on the gasification of carbonaceous materials in the presence of some oxidizing gas such as carbon dioxide, oxygen, air or steam
- there is no universally accepted standard procedure

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Methodology for determining reactivity

Test results / Výsledky testov

Requester [name, addresse] / Názov a adresa zákazníka:	
Requested tests / Požadované testy	CSR/CRI
Identification of sample / Identifikácia vzorky:	Groszek, čierne uhlie PCG, Kuzbas
Date [sample delivery] / Dátum doručenia vzorky:	*24.9.2018
Issue of protocol / Dátum vystavenia protokolu	*27.9.2018
Number of protocol / Číslo protokolu:	ES/32/2018

	Sample identification	CRI [%]	CSR [%]	AV [%]
1.	Zenmar č. 1. EKO I	89	43	43
2.	Zenmar č. 2. EKO II	90	7	55
3.	Kuzbas - čierne uhlie, Rusko 62009	87	2	55
4.	Murcki - čierne uhlie, 62008	66	15	33

test date: 24.-26.9.2018

Note:
**Determination CSR, CRI in accordance ISO 18894:2006; Sieve 10 mm.*
The relative precision of this test method for the determination of CSR and CRI of coke covers the range CRI 10-60, 30-80** for CSR.*

Reactivity test of coke towards CO2 (ASTM standard procedure)

- developed at Nippon Steel Corporation in Japan in early seventies is widely recognised around the world and was adopted by ASTM
- a sample (200 g of 20 mm particle size) is exposed to CO2 flow for two hours at 1100°C.
- the percentage of mass loss is referred to as reactivity (CRI)

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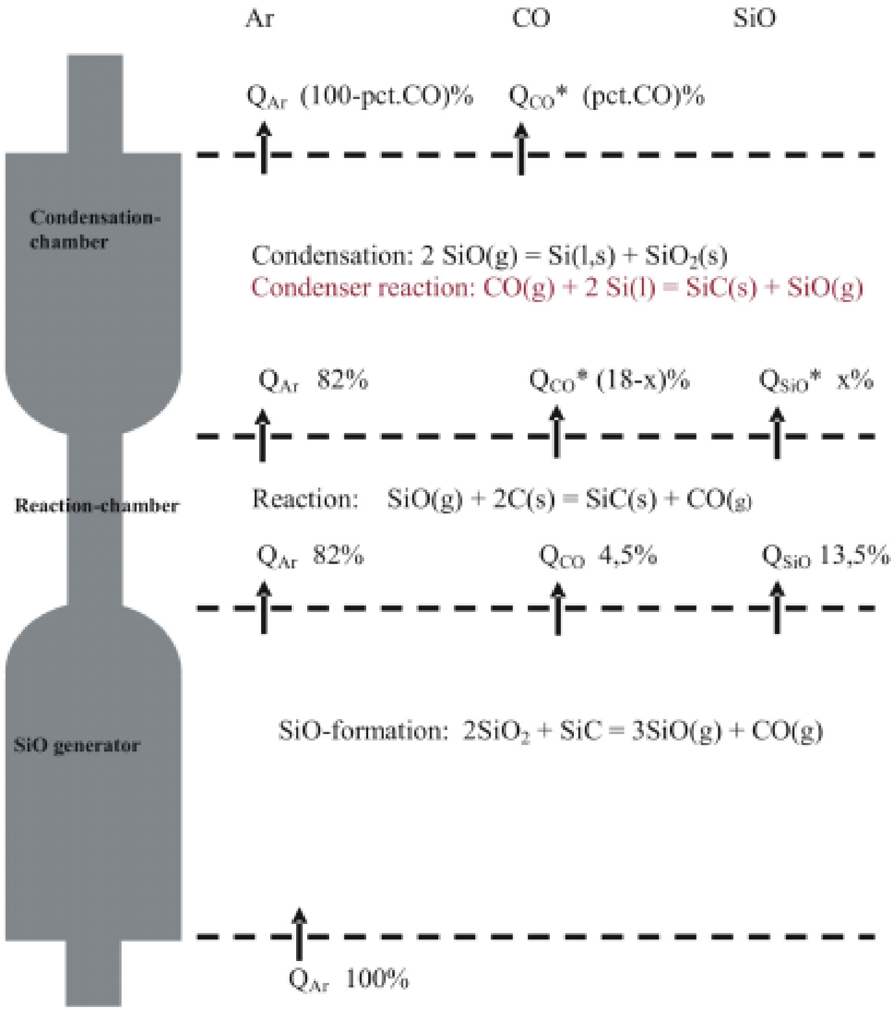
Organizers:

Methodology for determining reactivity



Additional Test specific to ferroalloys:

SINTEF test developed in the 1970's by Tuset and Raaness

quantify the SiO reactivity

SiO(g) + 2 C(s) = SiC(s) + CO (g)

$$R10 = \sum_{18\rightarrow 10} \frac{Q_{Ar}(18 - pctCO)}{82 - 0.82.pctCO}.\Delta t$$

If free carbon is not available in sufficient amounts or does not react fast enough, SiO will be lost by the reaction

2 SiO(g) = SiO2(s) + Si(l)

A high R10 indicates a low reactivity, while a low value indicates high reactivity.

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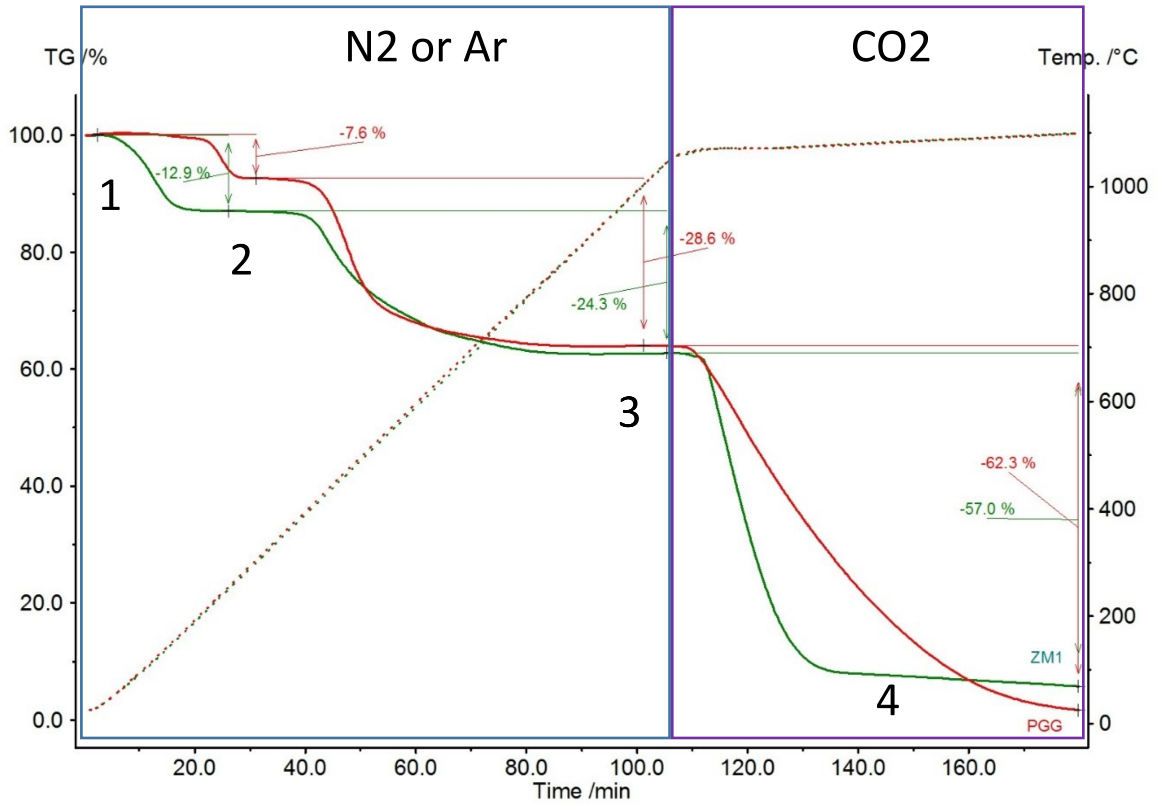
Methodology for determining reactivity

Reactivity by Thermogravimetric analysis



CRI ZM1= 89%
CRI PGG= 66%

- (TGA-DTA) is a widely used technique to study gasification process due to its simplicity and accurate measurements
- gives more complex information about thermal stability and reactivity
- allow the understanding of the reaction mechanism and kinetics

Derivatograph C/PC, Paulik and Erdey, MOM, Hungary)

Sample grains 1-3mm
1. Linear heating (5-15K/min) up to 1070°C (or 1170°C) in Ar
2. Quasi isothermal (0.5K/min) up to 1100°C (or 1200°C) in CO2

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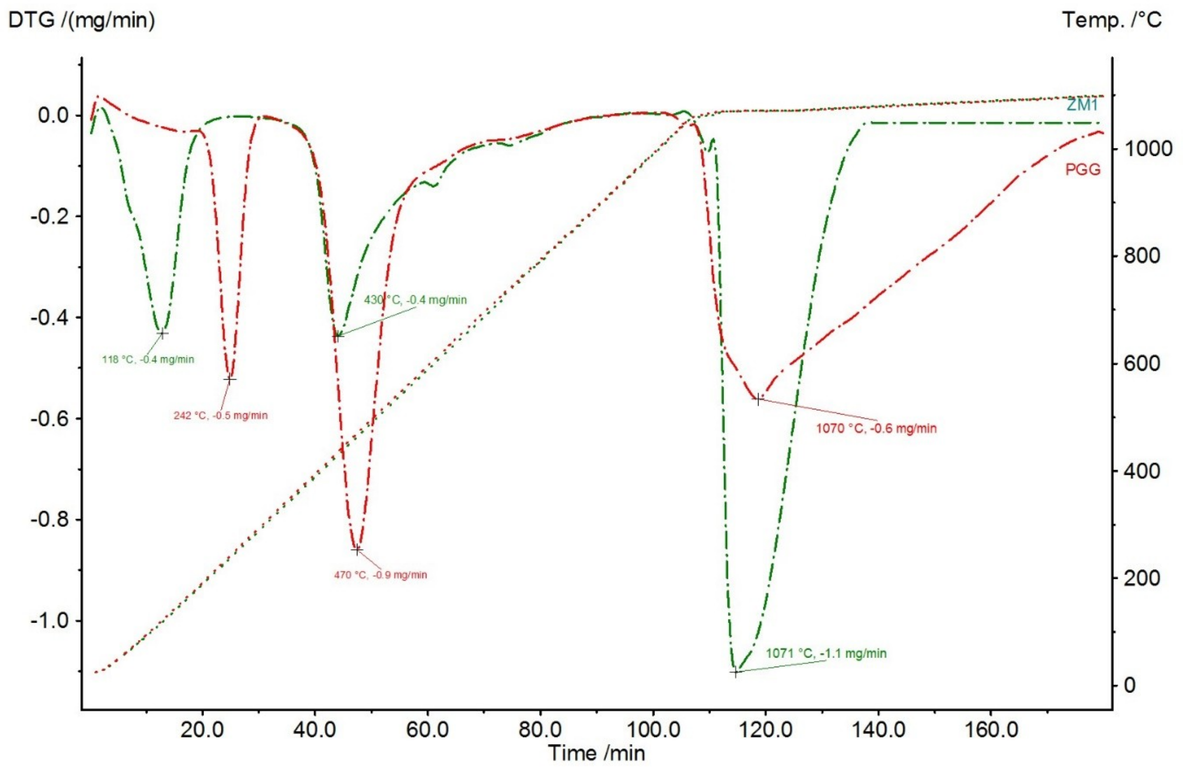
Methodology for determining reactivity



- Determination of different rate of mass loss (defines the kinetics of decomposition)
- Observation the region of stability during linear heating in an inert atmosphere
- Data for calculation of reactivity

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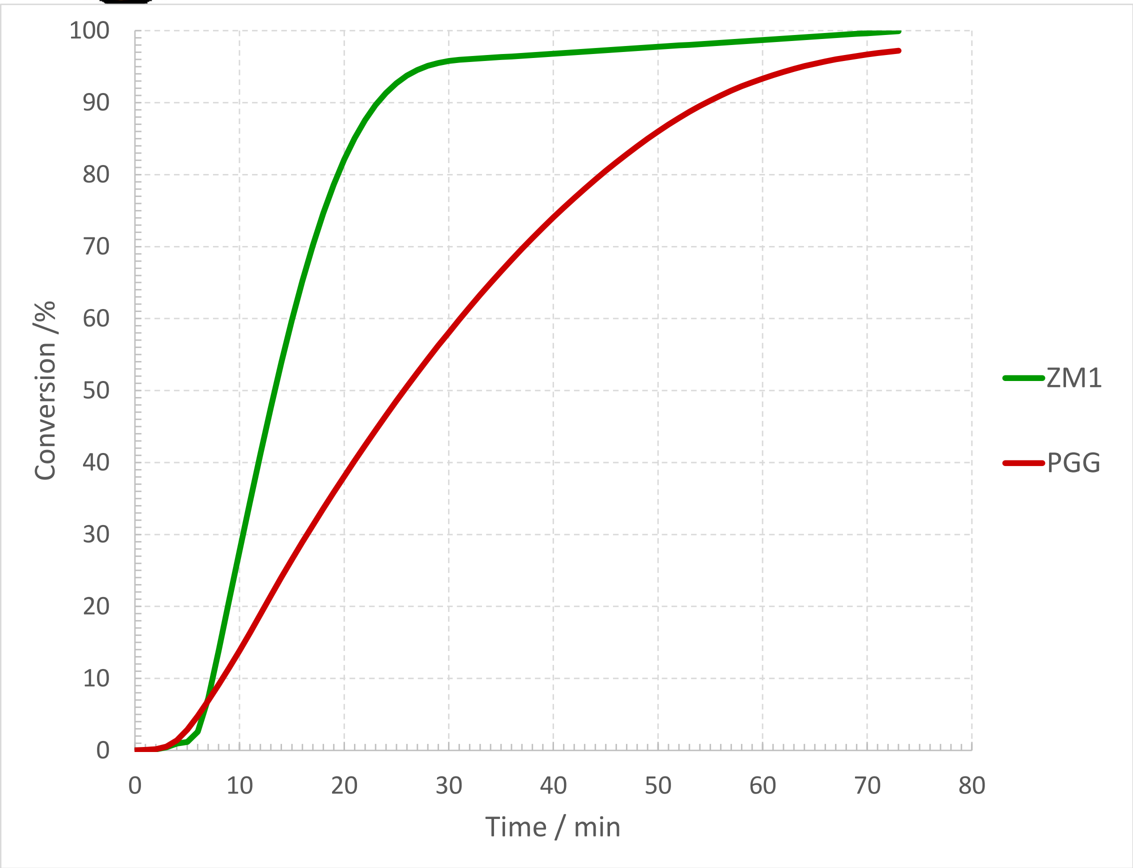
Methodology for determining reactivity



Identification	Sample	r_A / °.min^{-1}	t_{rA} / min	t_{X50} / min
ZM1	Zenmar č.1 EKO I	0,072	9	13,5
PGG	Murcki-čierne uhlie, 62008	0,027	12	26

The assessing parameters for the reactivity:

- maximum reaction rate (rA)
- time to reach rA (with the isothermal heating in CO_2)
- degree of conversion (X)
- time to reach the 50 % conversion during reactivity

$X=1-(W/W_0)$

Where: W- char weight of fixed carbon loss
W_0- initial char weight
dW/dt- the maximum rate of fixed carbon loss

$$r_A = \frac{1}{W_0} \cdot \frac{dW}{dt}$$

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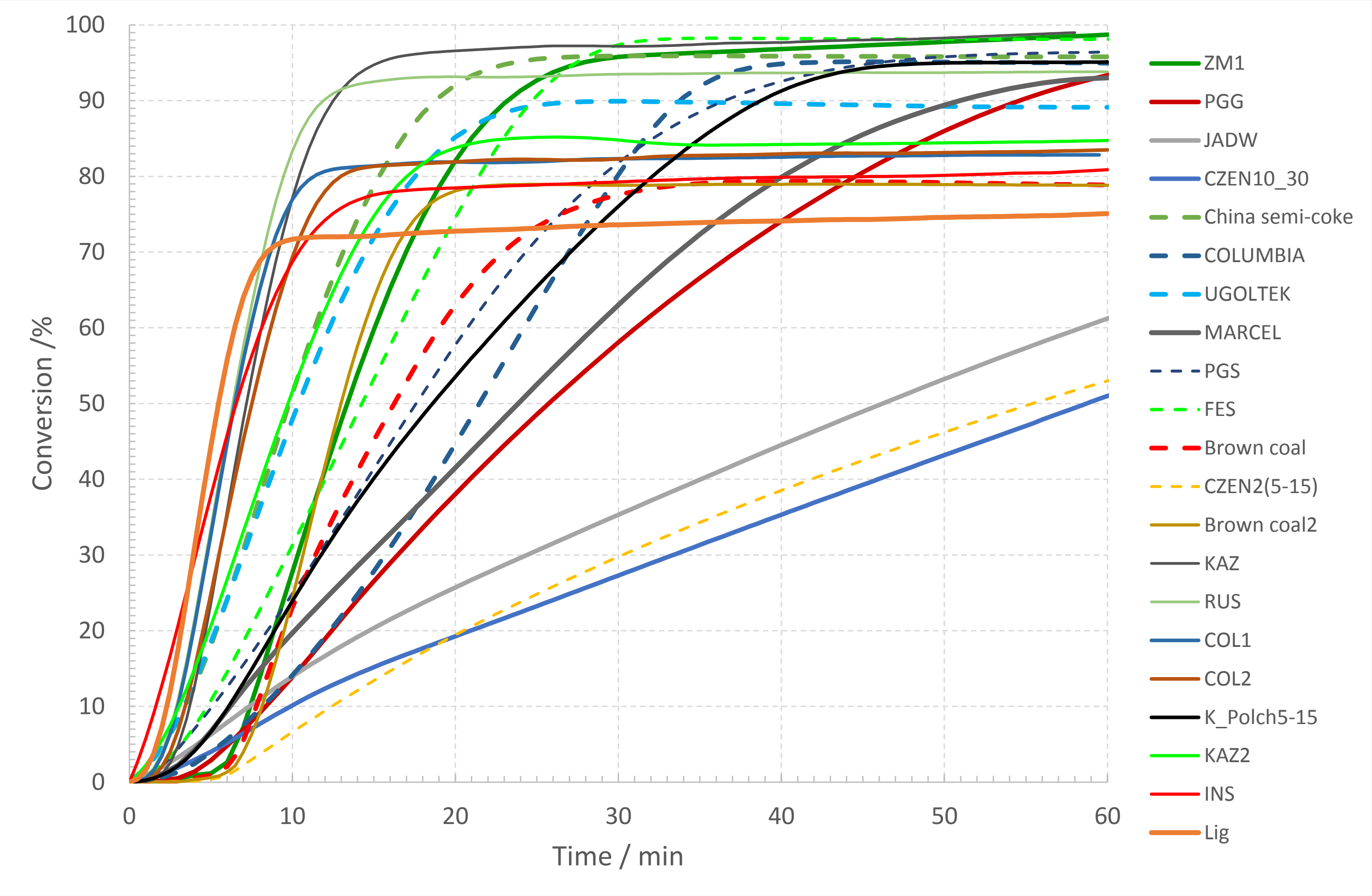
Methodology for determining reactivity

Reactivity of used reducing agents for ferroalloys



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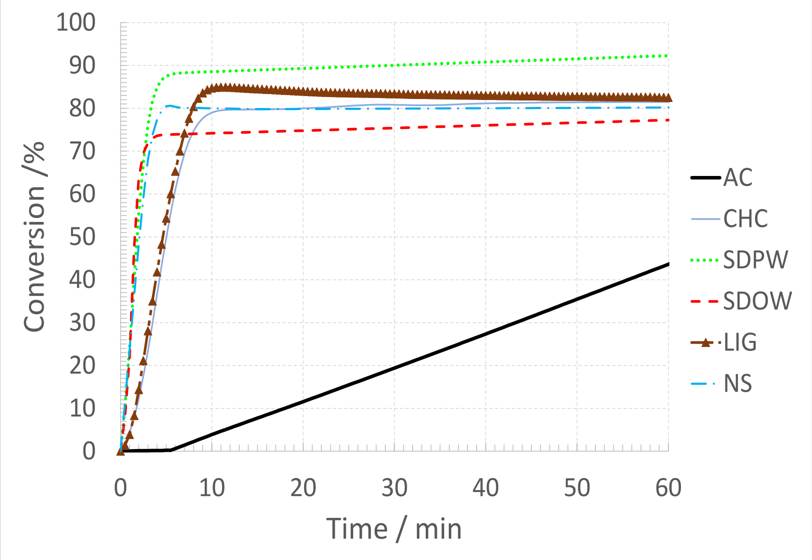
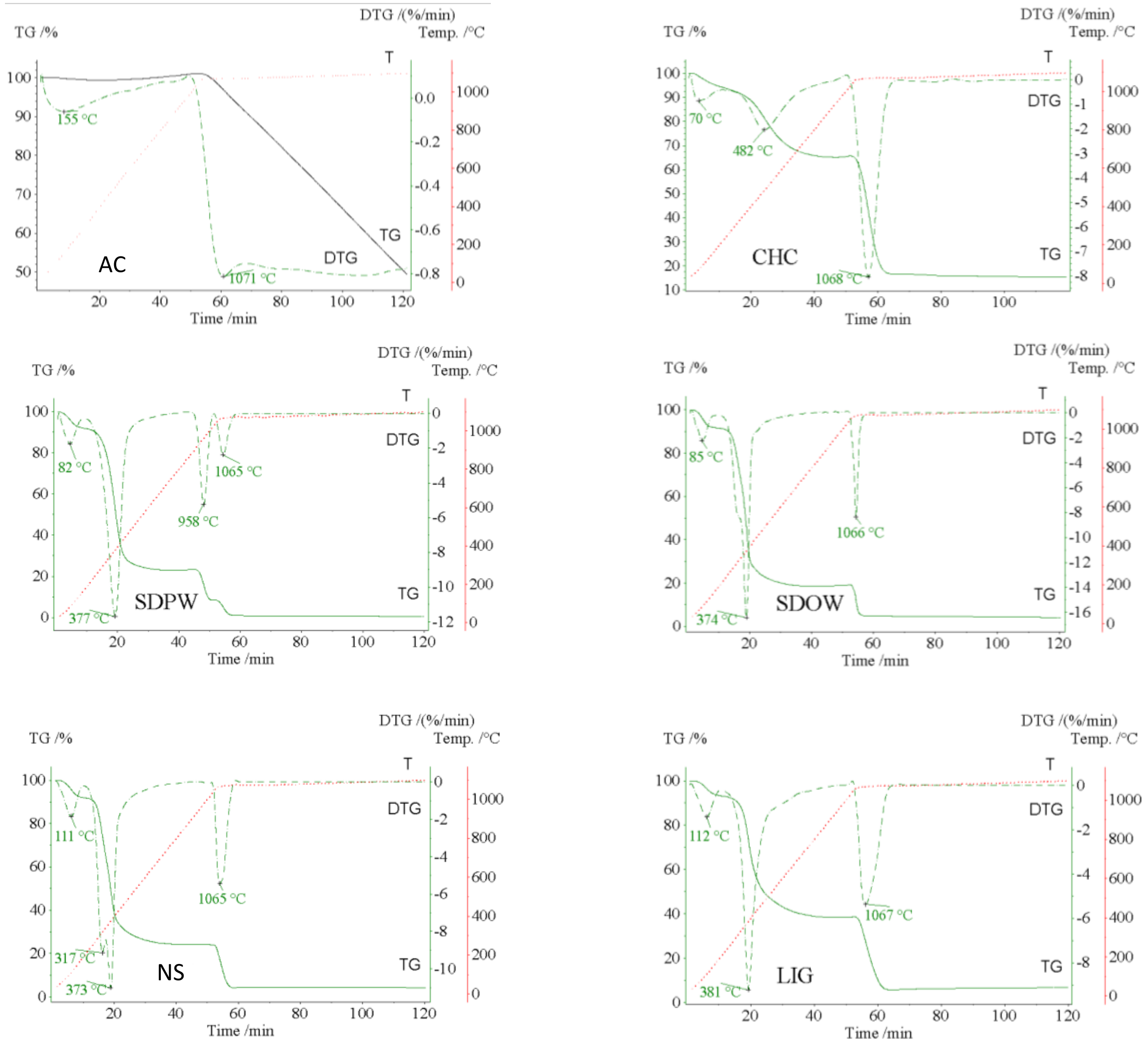
Methodology for determining reactivity

Fosil fuels vs.biomass



sample	r_A / min^{-1}	t_{rA} / min	t_{X50} / min
AC	0.0156	7.5	68.08*
CHC	0.1643	4.0	5.03
LIG	0.1688	3.0	5.18
NS	0.3086	1.0	2.09
SDPW	0.3302	1.5	1.83
SDOW	0.5364	1.5	1.57



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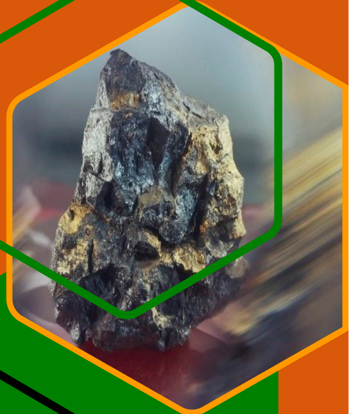
PREMA

BIOCOKE4FAI

The impact of biomass on ecological aspects of iron, steel and ferroalloy production



Jaroslav Legemza, Róbert Findorák

TUKE FMMR

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Goal of the presentation

- specify emissions from metallurgical technologies
- specify model of heat and material balance
- impact of biomass on ecological aspects of FeMnC production

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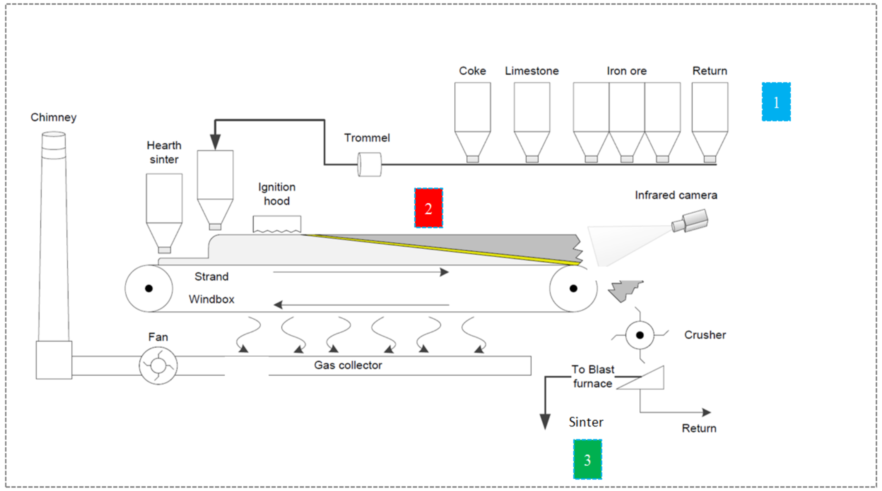
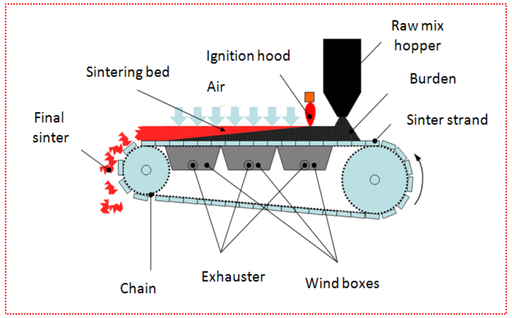
Emissions resulting from production of Fe and Mn agglomerate

1



3



2

Parameter	SI unit	Min	Max
Agglomeration gas	Nm^3/t of agglomerate	1500	2500
Dust	kg/t of agglomerate	0.4	15
PM_{10}	g/t of agglomerate	66	177
NO_x	g/t of agglomerate	300	1030
SO_2	g/t of agglomerate	219	970
CO_2	kg/t of agglomerate	160	360
CO	kg/t of agglomerate	9	38
Methane (CH_4)	g/t of agglomerate	35	400
VOC	g/t of agglomerate	1.5	260
PAH	mg/t of agglomerate	0.2	590
PCDD	µg/t of agglomerate	0.15	16

VOC – volatile organic compounds
PAH – polycyclic aromatic hydrocarbons
PCCD – polychlorinated dibenzo-p-dioxins

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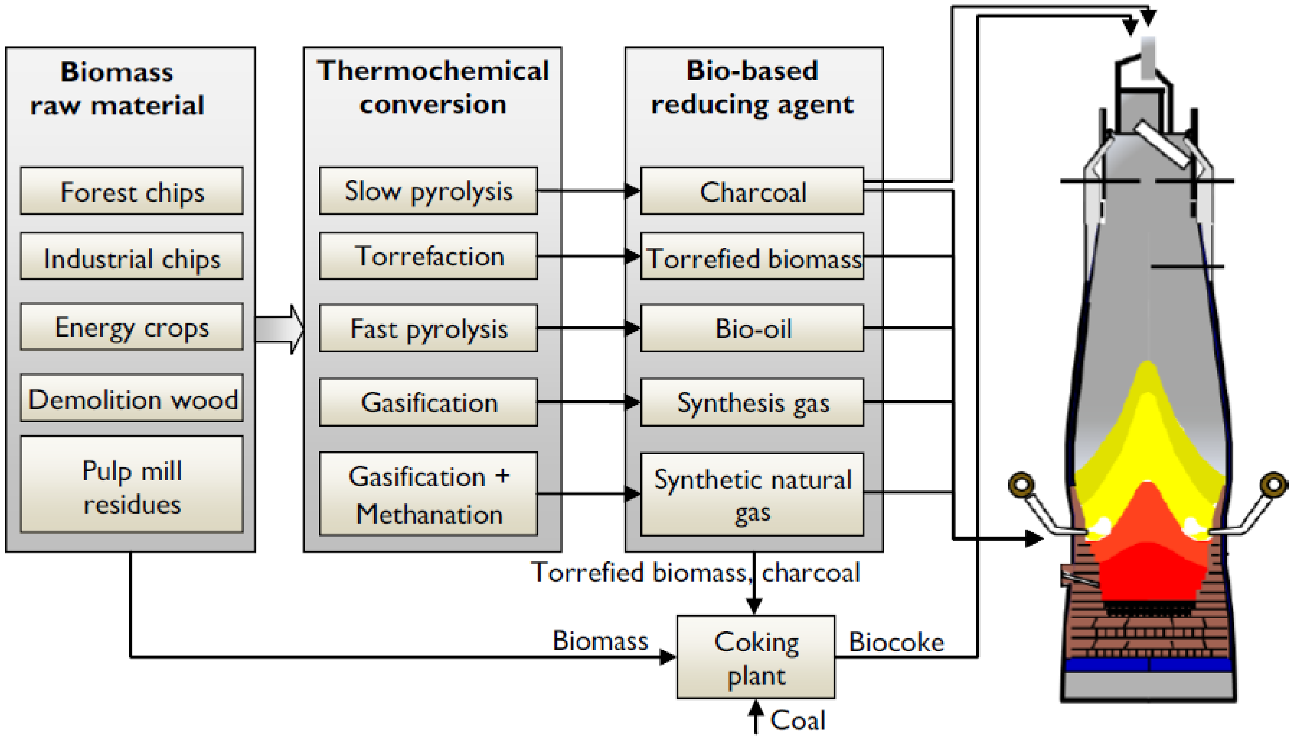
Emissions resulting from production of pig iron in BF



Parameter	SI unit	Min	Max
Blast furnace gas	Nm^3/t p.i.	1200	2000
Dust	kg/t p.i.	7	40
NO_x	g/t p.i.	30	120
SO_2	g/t p.i.	20	230
CO_2	kg/t p.i.	400	900
CO	kg/t p.i.	300	700
Hydrocarbons	g/t p.i.	130	330
Hydrogen	kg/t p.i.	1.0	7.5
PCDD	µg/t p.i.	0.001	0.004

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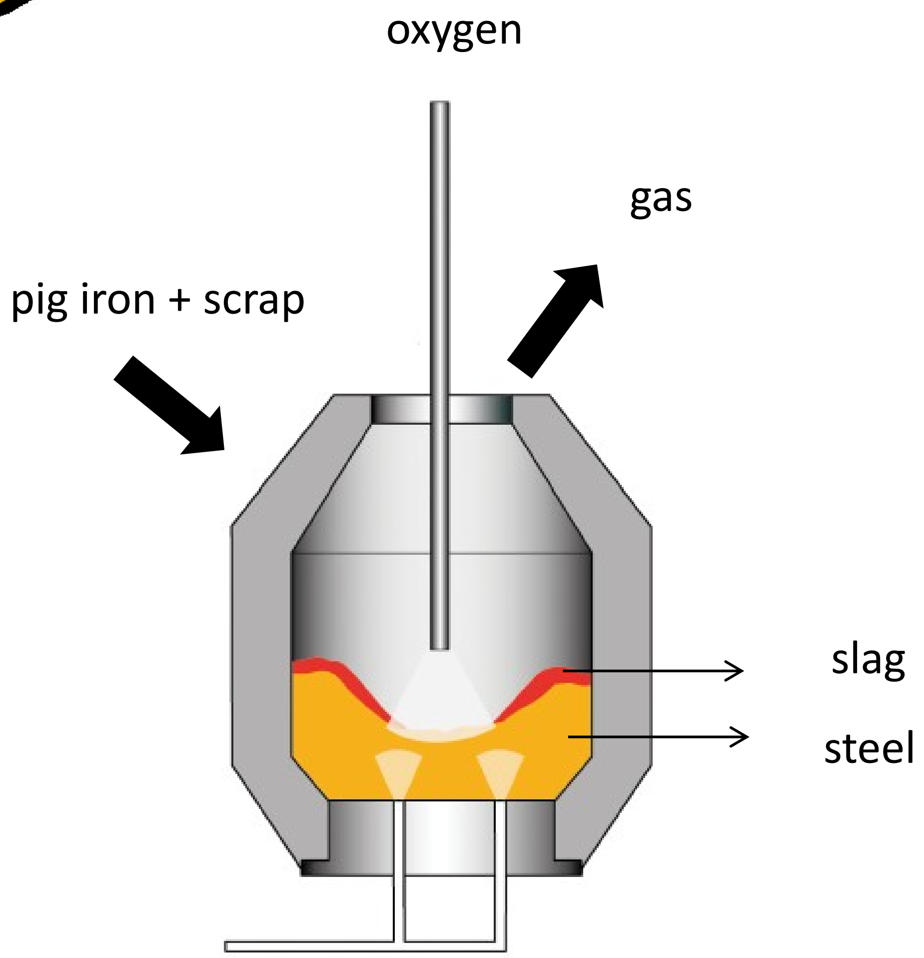
Emissions resulting from production of steel in BOF



Parameter	SI unit	Min	Max
Converter gas	Nm^3/t steel	500	1000
Dust	kg/t steel	12	23
NO_x	g/t steel	5	20
SO_2	g/t steel	0.4	5.5
CO_2	kg/t steel	11	140
CO	kg/t steel	7	16
PAH	mg/t steel	0.08	0.16
PCDD	µg/t steel	0.001	0.110

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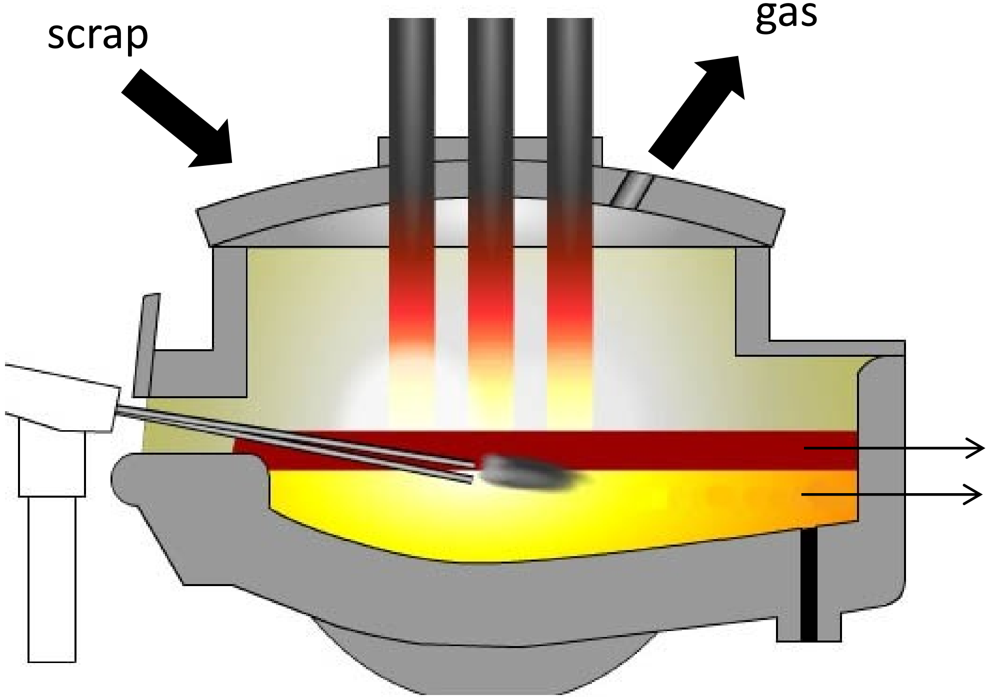
Emissions resulting from production of steel in EAF



Parameter	SI unit	Min	Max
EAF gas	Nm^3/t steel	200	1200
Dust	kg/t steel	5	30
NO_x	g/t steel	120	240
SO_2	g/t steel	24	130
CO_2	kg/t steel	2	50
CO	kg/t steel	0.7	4
PAH	mg/t steel	3.5	71
PCDD	µg/t steel	0.07	9

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Potential for reducing CO_2 emissions using biomass in metallurgy of iron and steel

Process	Substitution by biomass	Decrease of CO_2 emissions	
		t CO_2/t steel	% CO_2
Agglomeration process	50–100 % coke powder substitution (consumption of 45–60 kg of coke powder/t agglomerate)	0.12–0.32	5–15
Coking process	2–10 % coal substitution (consumption of 300–350 kg of coke/t pig iron)	0.02–0.11	1–5
Blast furnace process	100 % injected coal substitution (consumption of 150–200 kg of coal/t pig iron)	0.41–0.55	19–25
Blast furnace process	50–100 % coke nut substitution (consumption of 45 kg of coke nut/t pig iron)	0.08–0.16	3–7
Steelmaking process (BOF)	100 % anthracite substitution (carburiser) (consumption of 0.25 kg of anthracite/t steel)	0.001	0.04
Steelmaking process (EAF)	50–100 % coke substitution (carburiser) (consumption of 12 kg of coke/t steel)	0.019–0.037	3.8–7.5
Steelmaking process (EAF)	50–100 % coke substitution (frother) (consumption of 5 kg of coke/t steel)	0.008–0.016	1.6–3.1

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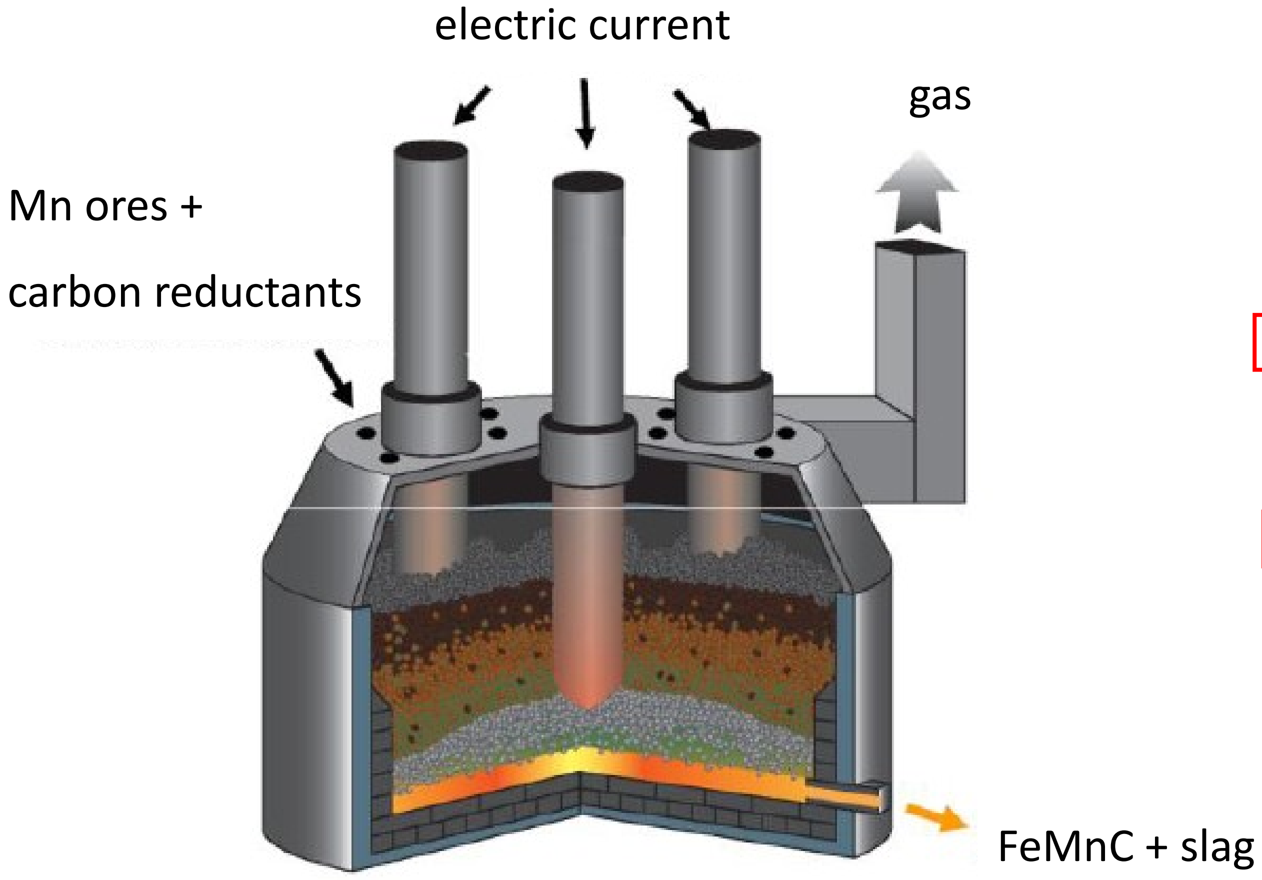
Organizers:

Emissions resulting from production of FeMnC in SAF



Parameter	SI unit	Min	Max
SAF gas	Nm^3/t FeMnC	800	1200
Dust	kg/t FeMnC	40	120
NO_x	kg/t FeMnC	0.5	1.5
SO_2	kg/t FeMnC	0.2	10
CO_2	kg/t FeMnC	1000	1500
PAH	mg/t FeMnC	2	60
PCCD	µg/t FeMnC	0.02	4

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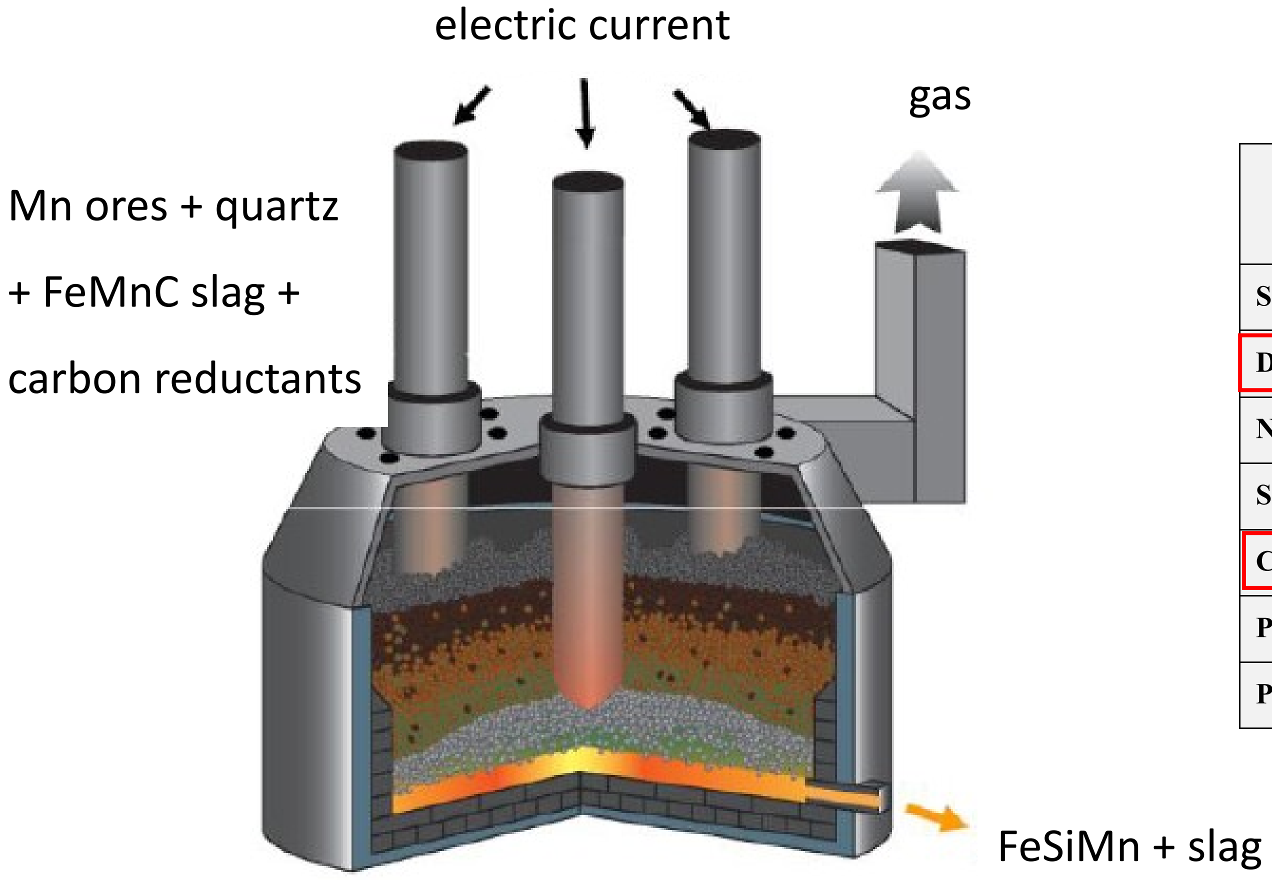
Emissions resulting from production of FeSiMn in SAF



Parameter	SI unit	Min	Max
SAF gas	Nm^3/t FeSiMn	1000	1600
Dust	kg/t FeSiMn	80	300
NO_x	kg/t FeSiMn	0.8	2.2
SO_2	kg/t FeSiMn	0.1	10
CO_2	kg/t FeSiMn	1100	1800
PAH	mg/t FeSiMn	4	70
PCCD	µg/t FeSiMn	0.03	5

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Organizers:

How emissions will change when biomass is used?

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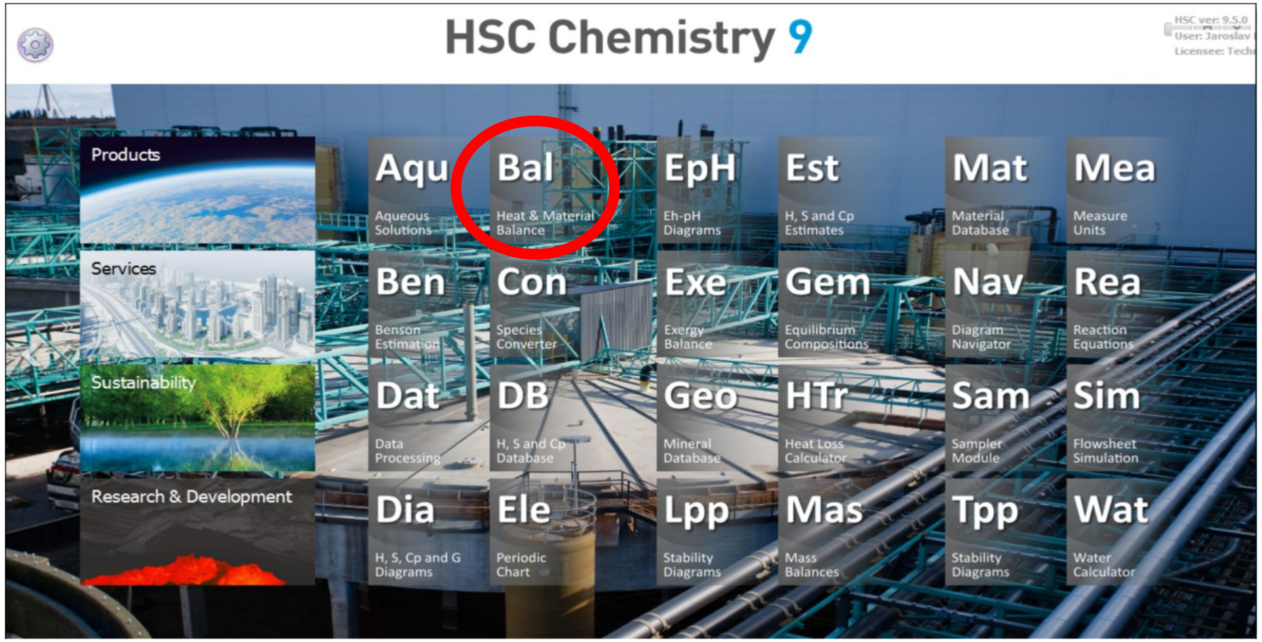
Thermodynamic model of heat and material balance

Thermodynamics modelling was realised using thermodynamic software “HSC Chemistry 9”, Outokumpu Research Oy, Pori, Finland) that allows one to predict the output parameters based on the initial composition analysis. For mathematical modelling mass and thermal balance were calculated.



Bal - Heat & Material Balance

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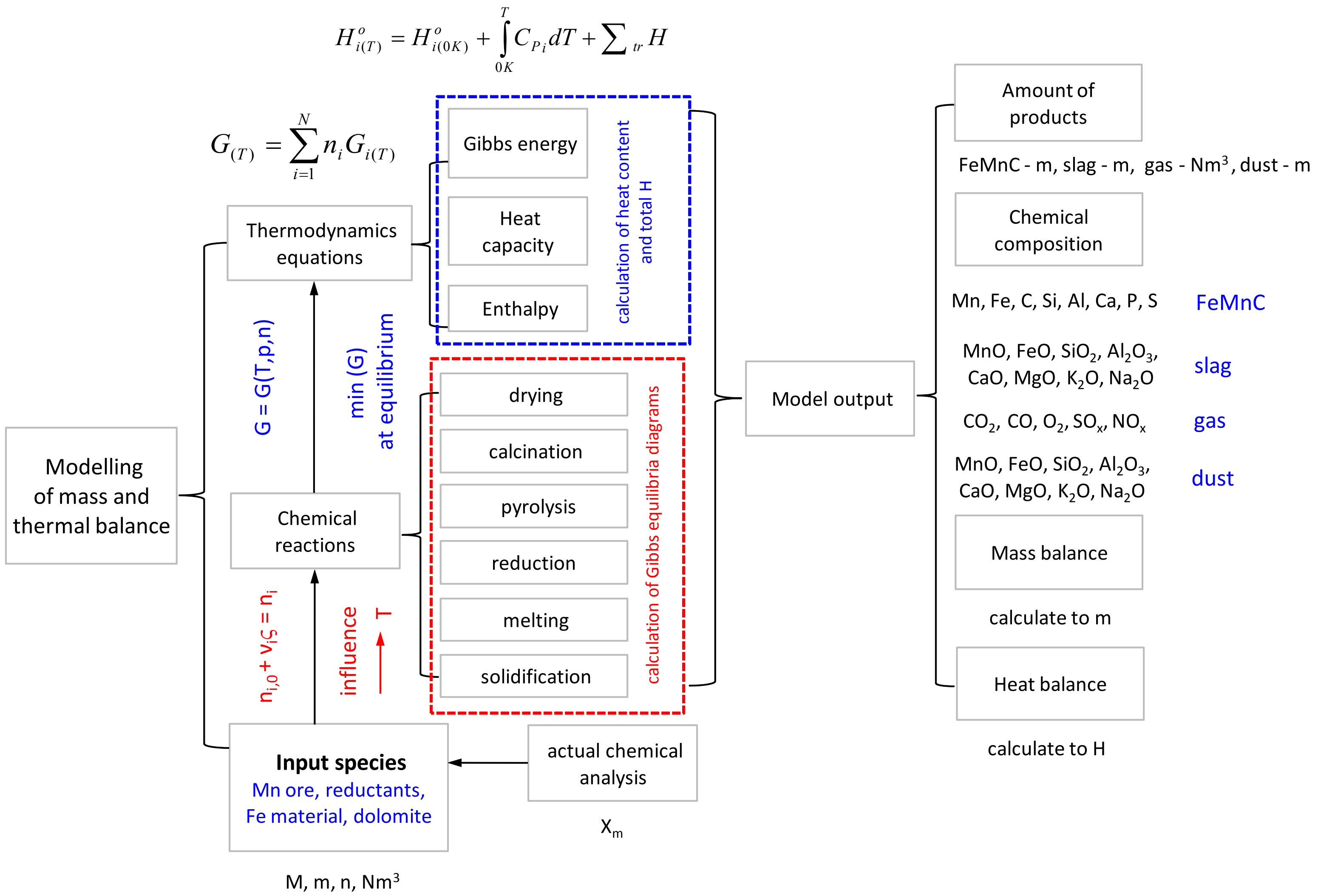
Model of heat - material balance in the production of FeMnC



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Material - heat balance in the production of FeMnC

Heat and Material Balance - F:\Moje dokumenty\Výskum\OFZ-vyrobnosti\HSC výrobnosti\FeMnC_ENG.BAL

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R2

	INPUT SPECIES (1) Formula	Temper. °C	Amount kmol	Amount kg	Amount Nm3	Latent H MJ	Total H MJ
1	**Mn ore 1**	25.000	28.236	2020.000	0.518	0.00	-14961.28
2	MnO2	25.000	19.132	1663.256	0.327	0.00	-9949.08
3	Fe2O3	25.000	0.271	43.254	0.008	0.00	-222.92
4	SiO2	25.000	2.355	141.485	0.054	0.00	-2144.86
5	Al2O3	25.000	0.426	43.456	0.011	0.00	-714.18
6	CaO	25.000	0.360	20.212	0.006	0.00	-228.84
7	MgO	25.000	0.181	7.276	0.002	0.00	-108.61
8	P2O5	25.000	0.014	2.021	0.001	0.00	-21.43
9	H2O	25.000	5.498	99.039	0.108	0.00	-1571.36
10	**Mn ore 2**	25.000	0.000	0.000	0.000	0.00	0.00
11	MnO2	25.000	0.000	0.000	0.000	0.00	0.00
12	Mn2O3	25.000	0.000	0.000	0.000	0.00	0.00
13	Mn3O4	25.000	0.000	0.000	0.000	0.00	0.00
14	Fe2O3	25.000	0.000	0.000	0.000	0.00	0.00
15	SiO2	25.000	0.000	0.000	0.000	0.00	0.00
16	Al2O3	25.000	0.000	0.000	0.000	0.00	0.00
17	CaO	25.000	0.000	0.000	0.000	0.00	0.00
18	MgO	25.000	0.000	0.000	0.000	0.00	0.00
19	P2O5	25.000	0.000	0.000	0.000	0.00	0.00
20	H2O	25.000	0.000	0.000	0.000	0.00	0.00
21	**Mn ore 3**	25.000	0.000	0.000	0.000	0.00	0.00
22	MnCO3	25.000	0.000	0.000	0.000	0.00	0.00
23	Mn(OH)2	25.000	0.000	0.000	0.000	0.00	0.00
24	FeCO3	25.000	0.000	0.000	0.000	0.00	0.00
25	SiO2	25.000	0.000	0.000	0.000	0.00	0.00
26	Al2O3	25.000	0.000	0.000	0.000	0.00	0.00
27	CaO	25.000	0.000	0.000	0.000	0.00	0.00
28	MgO	25.000	0.000	0.000	0.000	0.00	0.00
29	P2O5	25.000	0.000	0.000	0.000	0.00	0.00
30	H2O	25.000	0.000	0.000	0.000	0.00	0.00
31	**Fe material**	25.000	2.142	130.000	0.020	0.00	-30.61
32	Fe	25.000	1.979	110.500	0.014	0.00	0.00
33	Fe2O3*H2O	25.000	0.084	14.950	0.005	0.00	-9.92

BAL IN1 OUT1 Materiály

	kmol	kg	Nm³	MJ	MJ
BALANCE (1)	-1.057	-23.495	826.435	4374.51	8585.71

Exit Stream

Heat and Material Balance - F:\Moje dokumenty\Výskum\OFZ-vyrobnosti\HSC výrobnosti\FeMnC_ENG.BAL

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R2

	OUTPUT SPECIES (1) Formula	Temper. °C	Amount kmol	Amount kg	Amount Nm3	Latent H MJ	Total H MJ
1	**FeMnC**	1500.000	22.766	1005.076	0.153	1404.54	1404.54
2	Fe	1500.000	2.709	151.283	0.019	154.79	154.79
3	Mn	1500.000	14.165	778.171	0.105	1056.98	1056.98
4	C	1500.000	5.595	67.202	0.026	167.20	167.20
5	Si	1500.000	0.281	7.892	0.003	24.89	24.89
6	P	1500.000	0.017	0.529	0.000	0.67	0.67
7	**Slag**	1550.000	7.701	518.264	0.133	745.73	-4262.66
8	MnO	1550.000	3.828	271.566	0.051	316.00	-1158.72
9	FeO	1550.000	0.140	10.032	0.002	16.05	-21.27
10	SiO2	1550.000	2.388	143.506	0.055	255.21	-1920.30
11	Al2O3	1550.000	0.527	53.724	0.014	97.86	-785.08
12	CaO	1550.000	0.463	25.937	0.008	36.08	-257.58
13	MgO	1550.000	0.236	9.521	0.003	18.07	-124.05
14	S	1550.000	0.118	3.774	0.002	6.06	6.06
15	P2O5	1550.000	0.001	0.202	0.000	0.41	-1.73
16	**Gas**	1500.000	39.802	1052.230	903.470	2118.02	-4095.04
17	CO(g)	1500.000	27.975	783.593	637.586	1358.43	-1733.97
18	CO2(g)	1500.000	1.865	82.079	42.506	145.19	-588.70
19	SO2(g)	1500.000	0.118	7.541	2.683	9.35	-25.60
20	O2(g)	1500.000	0.119	3.814	2.716	6.04	6.04
21	H2O(g)	1500.000	9.725	175.204	217.980	599.01	-1752.83
22	**Dust**	1500.000	1.497	83.935	0.018	106.22	-415.11
23	MnO	1500.000	0.957	67.892	0.013	76.18	-292.50
24	Fe2O3	1500.000	0.014	2.230	0.000	2.94	-8.55
25	SiO2	1500.000	0.140	8.442	0.003	14.49	-113.48
26	Al2O3	1500.000	0.005	0.537	0.000	0.94	-7.89
27	CaO	1500.000	0.005	0.259	0.000	0.35	-2.59
28	MgO	1500.000	0.002	0.095	0.000	0.17	-1.25
29	C	1500.000	0.373	4.480	0.002	11.15	11.15

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820561

Comparison of emissions from production of FeMnC

Parameter	SI unit	Min	Max	HSC model (with coke)	HSC model (with charcoal)
SAF gas	Nm^3/t FeMnC	800	1200	903	1024
Dust	kg/t FeMnC	40	120	84	81
NO_x	kg/t FeMnC	0.5	1.5	-	-
SO_2	kg/t FeMnC	0.2	10	7	5
CO_2	kg/t FeMnC	1000	1500	1312	1189
PAH	mg/t FeMnC	2	60	-	-
PCCD	µg/t FeMnC	0.02	4	-	-

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Organizers:

Conclusions to reduce the emission of ferroalloy production

- increasing the amount of biomass in process (mainly waste biomass)
- increasing the use of gas (hydrogen, syngas, biogas, flue gas) in metal production
- pretreatment and pre-reduction of ores
- sintering technology
- plasma technology

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Organizers:

Thanks for attention

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Organizers: